Learning and Analytics in Intelligent Systems 32

Rangan Gupta
Francesco Bartolucci
Vasilios N. Katsikis
Srikanta Patnaik *Editors*

Recent Advancements in Computational Finance and Business Analytics

Proceedings of the International Conference on Computational Finance and Business Analytics

Springer

Learning and Analytics in Intelligent Systems

Volume 32

Series Editors

The main aim of the series is to make available a publication of books in hard copy form and soft copy form on all aspects of learning, analytics and advanced intelligent systems and related technologies. The mentioned disciplines are strongly related and complement one another significantly. Thus, the series encourages cross-fertilization highlighting research and knowledge of common interest. The series allows a unified/integrated approach to themes and topics in these scientific disciplines which will result in significant cross-fertilization and research dissemination. To maximize dissemination of research results and knowledge in these disciplines, the series publishes edited books, monographs, handbooks, textbooks and conference proceedings.

Indexed by EI Compendex.

Rangan Gupta · Francesco Bartolucci ·
Vasilios N. Katsikis · Srikanta Patnaik
Editors

Recent Advancements in Computational Finance and Business Analytics

Proceedings of the International Conference on Computational Finance and Business Analytics

Springer

Editors
Rangan Gupta
Department of Economics
University of Pretoria
Pretoria, South Africa

Francesco Bartolucci
Department of Economics
University of Perugia
Perugia, Italy

Vasilios N. Katsikis
Department of Economics
National and Kapodistrian University of Athens
Athens, Greece

Srikanta Patnaik
Interscience Institute of Management and Technology
Bhubaneswar, Odisha, India

ISSN 2662-3447 ISSN 2662-3455 (electronic)
Learning and Analytics in Intelligent Systems
ISBN 978-3-031-38073-0 ISBN 978-3-031-38074-7 (eBook)
https://doi.org/10.1007/978-3-031-38074-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

CFBA-2023 Conference Committee

Honorary Chair

Prof. (Dr.) Lakhmi C. Jain, Founder, KES International, UK

General Chair

Prof. (Dr.) Soumya Guha Deb, Professor, Finance and Accounting, IIM Sambalpur

Publication and Program Chair

Prof. (Dr.) Srikanta Patnaik, Director, I.I.M.T., Bhubaneswar, Odisha, India

Publication Chair

Prof. (Dr.) Vasilios N. Katsikis, National and Kapodistrian University of Athens, Greece

Program Chair

Prof. (Dr.) Rangan Gupta, Professor, University of Pretoria

Program Co-chair

Prof. (Dr.) Sharada Prasad Sahoo, Berhampur University, India

Finance Chair

Prof. (Dr.) Dhananjaya Sarangi, IT Expert, World Skill Center, Bhubaneswar, India

Finance Co-chair

Eng. Bin Hu, Changsha Normal University

International Advisory Committee

Prof. (Dr.) Francesco Bartolucci, University of Perugia, Italy
Prof. (Dr.) Sonali Das, Professor, Department of Business Management, University of Pretoria

Programme Committee

Dr. David Boohene, West Africa University of Energy and Natural Resources, Ghana, West Africa
Dr. Georgios Mamanis, Greece
Dr. Grzegorz Wilk-Jakubowski, University of Social Sciences in Lodz
Dr. Neelam Rani, IIM Shillong
Dr. Kamran Quddus, IIM Ranchi
Dr. Vandana, Assistant Professor (Decision Sciences), IIM, Sirmaur, Himachal Pradesh
Dr. P. J. Jijo Lukose, IIM Kozhikode
Dr. Swapnarag Swain, IIM Bodhgaya
Dr. Archana Patro, IIM Bodhgaya
Dr. Ramesh Roshan Das Guru, IIM Bodhgaya
Dr. Mukesh Kumar, IIM Amritsar
Dr. Nilesh Gupta, IIM Nagpur
Dr. Arushi Jain, IIM Amritsar
Dr. Prashanth V. Anand, IIM Amritsar

Dr. Aswin Alora, IIM Kozhikode
Dr. Dharani Munusamy, IIM Tiruchirappalli
Dr. Sowmya Subramaniam, IIM Lucknow
Dr. Sobhan Sarkar, IIM Ranchi
Dr. J. Daniel Inbaraj, IIM Raipur
Dr. M. S. Gajanand, IIM Tiruchirappalli
Dr. Deepika Gupta, IIM Visakhapatnam
Dr. Nalin Bharti, IIT Patna
Dr. Rajendra N. Paramanik, IIT Patna
Dr. Chandra Sekhar Bahinipati, IIT Tirupathi
Dr. Mrinalini Pandey, IIT Dhanbad
Dr. Madhusmita Dash, IIT Bhubaneswar
Dr. Shashank Bansal, IIT Dhanbad
Dr. Indrajit Mukherjee, IIT Bombay
Dr. Abhijeet Chandra, IIT Kharagpur
Dr. Rudra Prakash Pradhan, IIT Kharagpur
Dr. P. Murali Prasad, IIT Kanpur
Dr. Shivganesh Bhargava, IIT Bombay
Dr. Usha Ananthakumar, IIT Bombay
Dr. Kalandi Charan Pradhan, IIT Indore
Dr. C. Rajendran, IIT Madras
Dr. Prakash Kotecha, IIT Guwahati
Dr. M. P. Gupta, IIT Delhi
Dr. Sanjay Dhir, IIT Delhi
Dr. Manu Kumar Gupta, IIT Roorkee
Dr. Smruti Ranjan Behera, IIT Ropar
Dr. Naresh Chandra Sahu, IIT Bhubaneswar
Dr. Mithu Rani Kuiti, IIT Jodhpur
Dr. Niladri Das, IIT Dhanbad
Dr. Tanmoy Som, Professor IIT BHU
Dr. Bhargab Chattopadhyay, IIT Jodhpur
Dr. V. J. Sivakumar, NIT Tiruchirappalli
Dr. V. Lavanya, NIT Tiruchirapalli
Dr. Malolan Sundararaman, NIT Tiruchirappalli
Dr. J. Kirubakaran, NIT Tiruchirapalli
Dr. Suvendu Rup, NIT Raipur
Dr. B. Senthil Arasu, NIT Tiruchirappalli
Dr. B. Shameedha Begum, NIT Tiruchirappalli
Dr. Sharada Prasad Sahoo, Berham University, Bhanja Vihar, Berhampur, Odisha
Dr. Manas Kumar Pal, Birla Global University, Bhubaneswar, Odisha
Dr. Rabi Narayan Subudhi, KIIT University Bhubaneswar, Odisha
Dr. Sreekumar, RIMS, Rourkela, Odisha
Dr. Debendra Kumar Mahalik, Sambalpur University
Dr. Manoranjan Parhi, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar, Odisha

Dr. Padmalita Routray, Fakir Mohan University, Baleshwar, Odisha
Dr. Manoranjan Dash, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar, Odisha
Dr. Trina Som, Dr. Akhilesh Das Gupta Institute of Technology and Management, India
Dr. Bharati Mishra, IIIT Bhubaneswar
Dr. Deepak Bansal, Sharda University
Dr. Ajay Kumar, Sharda University
Dr. P. C. Biswal, MDI Gurgaon
Dr. Ashutosh Dash, MDI Gurgaon
Dr. Sandeep Goel, MDI Gurgaon
Dr. Shradhanjali Panda, Ravenshaw University, Cuttack, India
Dr. Somen Dey, Motilal Nehru National Institute of Technology, Allahabad
Dr. Rudra Kalyan Nayak, VIT-Bhopal, India
Dr. Rama Mani Tripathy, Chitkara University, Chandigarh, India
Mrs. Deepti Patnaik, IIMT, Bhubaneswar, India

Organizing Committee

Organizing Chair

Prof. (Dr.) Taosheng Wang, Hunan International Economics University, China

Organizing Co-chair

Prof. (Dr.) Sushanta Kumar Panigrahi, IIMT, Bhubaneswar, India

Organizing Committee

Mrs. Sroojani Mohanty, IIMT, Bhubaneswar
Mr. Debashis Mishra, IIMT, Bhubaneswar
Mrs. Itishree Behera, IIMT, Bhubaneswar
Mr. Alok Arun, IIMT, Bhubaneswar
Mr. Pradeep Kumar Baxla, IIMT, Bhubaneswar
Mr. Kamalakanta Swain, IIMT, Bhubaneswar
Mr. Duryodhan Ping, IIMT, Bhubaneswar
Mr. Rashmiranjan Mishra, IIMT, Bhubaneswar
Mr. Dipak Mishra, IIMT, Bhubaneswar

Mr. Dinesh Chandra Das, IIMT, Bhubaneswar
Mr. Rakesh Patnaik, IIMT, Bhubaneswar

Technical Program Committee

Dr. R. Ramachandran Department of Commerce Annamalai University, Annamalai Nagar, Tamil Nadu India
Dr. Lakshmi Prasad Panda, Department of Humanities, GCE Kalahandi, Bhawanipatna
Prof. B. A. Prajapati; Veer Narmada South Gujarat University Surat, Gujarata
Dr. Sangya Shrivastava Director, RaiBussiness School, Raipur (C.G.)
Dr. P. Malyadri; Government Degree College, Osmania University, Andhra Pradesh, India
Dr. Ravi Sankar, School of Management Asian Institute of Technology, Thailand
Dr. Jayanthi Ranjan, Institute of Management Technology Ghaziabad, India
Dr. Vidya Sekhri, Institute of Management Studies, Ghaziabad, India
Dr. Poonam Garg, Institute of Management Technology Ghaziabad, India
Dr. Tabassum Sultana, Matrusri Institute of Post Graduate Studies (MIPGS), Hyderabad, India
Dr. Susanta Ku. Paikray Department of Mathematics,Ravenshaw University, Cuttack, India
Dr. Kirti Rajhans, National Institute of Construction Management and Research, Pune, India
Mrs. N. M. Leepsa, IIT-Kharagpur, West Bengal, India
Mrs. Pragyan Nanda, IIMT, Bhubaneswar
Mrs. Soma Mitra, IIMT, Bhubaneswar

Preface

As the world becomes more and more data-driven, the importance of computational finance and business analytics is rapidly increasing. With the goal of advancing research in this field, the International Conference on Computational Finance and Business Analytics (CFBA-2023) brought together eminent and budding researchers, academicians, experts, and practical innovators from around the world to share their latest research and practical applications.

CFBA-2023 provided a premier forum for interactions and collaborations among researchers in the areas of financial analytics, human resource analytics, marketing analytics, and business analytics. The conference featured original, unpublished research contributions on a wide range of topics, including computational intelligence for financial modeling, machine learning in finance, talent acquisition analytics, digital marketing, fraud analytics, and much more.

The conference proceedings contain a wealth of knowledge and insights into the latest developments and practical applications in the field of computational finance and business analytics. The papers included in these proceedings represent the cutting-edge research and innovations in the field, showcasing the latest techniques and technologies for solving complex business problems.

We are proud to present these proceedings as a valuable resource for researchers, academicians, and practitioners alike, who seek to deepen their understanding and contribute to the advancement of computational finance and business analytics. We extend our sincerest gratitude to all the authors, presenters, and attendees who made CFBA-2023 a great success and contributed to the growth and development of this important field.

Bhubaneswar, India

Srikanta Patnaik
Publication and Program Chair

Acknowledgements

We would like to express our sincere appreciation and gratitude to all those who have contributed to the success of the International Conference on Computational Finance and Business Analytics (CFBA-2023).

First of all, we would like to express our heartfelt thanks to all the participants, presenters, and attendees of CFBA-2023. Their active involvement, insightful discussions, and valuable contributions made the conference a truly enriching experience.

We would also like to acknowledge EasyChair for their efficient conference management system. Their platform streamlined the submission and review process, making it easier for authors and reviewers to participate in the conference.

Our heartfelt appreciation goes out to our esteemed keynote speakers Dr. Deepika Gupta, Dr. Ashok Mahapatra and Mr. Ananta Charan Swain, whose valuable insights and perspectives greatly enriched our conference. We are grateful for the time and effort they took to prepare and deliver their presentations. We would also like to thank the session chair members, Dr. Brajabandu Padhiary and Dr. Sushanta Kumar Panigrahi, for their invaluable contributions in ensuring that the conference ran smoothly. Their dedication and professionalism in managing the sessions were instrumental in making the conference a success.

Our deepest appreciation goes out to the program and technical committee for their diligent work in reviewing and selecting the papers that were presented at the conference. Their expertise and commitment to academic excellence helped to ensure that the papers presented were of the highest quality. Furthermore, we extend our deepest appreciation to the Organizing Committee for their hard work and dedication in planning and executing CFBA-2023. Their meticulous attention to detail, tireless coordination, and outstanding organizational skills contributed significantly to the smooth running of the conference.

Last but not least, we extend our sincere thanks to the Springer Series Editors of *Learning and Analytics in Intelligent Systems* Prof. George A. Tsihrintzis, Prof. Maria Virvou and Prof. Lakhmi C. Jain for their support and guidance in publishing the conference proceedings *Recent Advancements in Computational Finance and Business Analytics* in their esteemed book series. Their commitment to disseminating scholarly research in the field of computational finance and business analytics is greatly appreciated.

We are grateful to all the individuals and organizations that played a part in making CFBA-2023 a successful and memorable event. Without your support and dedication, this conference would not have been possible. Thank you all for your contributions and commitment to advancing the field of computational finance and business analytics.

Rangan Gupta
Francesco Bartolucci
Vasilios N. Katsikis
Srikanta Patnaik

Editorial

The 1st International Conference on Computational Finance and Business Analytics (CFBA-2023) was a premier forum for researchers, academicians, experts, and practical innovators from around the world. The conference took place at Interscience Institute of Management and Technology, Bhubaneswar, India on 29–30 April, 2023. The conference aimed to facilitate interactions on practical applications and latest developments in the field of management. With its comprehensive program featuring keynote speeches, research paper presentations, and interactive sessions, CFBA-2023 provided a platform for attendees to gain insights, exchange ideas, and forge new partnerships in the exciting realms of computational finance and business analytics.

Computational finance is a field that utilizes mathematical and statistical methods, as well as computer algorithms and models, to analyze and solve complex financial problems. It involves the application of quantitative techniques to understand and predict market behavior, manage risk, and optimize investment strategies. In computational finance, large volumes of financial data are processed and analyzed using sophisticated algorithms and mathematical models. These models can range from simple statistical models to complex quantitative models, such as option pricing models and portfolio optimization algorithms. By leveraging computational power and advanced data analysis techniques, computational finance enables financial professionals to make informed decisions and gain valuable insights into market dynamics. The field of computational finance has revolutionized the financial industry by enhancing trading strategies, risk management practices, and portfolio management techniques. It has enabled the development of algorithmic trading, where computer programs execute trades based on predefined rules and mathematical models. Computational finance has also played a vital role in derivatives pricing, allowing for accurate valuation of complex financial instruments. Moreover, computational finance has facilitated the optimization of investment portfolios by identifying the most efficient asset allocation strategies. It has improved risk assessment and management by incorporating advanced statistical models and simulations.

Similarly, Business analytics is the practice of using data analysis and statistical methods to extract meaningful insights and make informed decisions in a business context. It involves the collection, processing, and analysis of large volumes of data from various sources, such as customer transactions, market trends, and operational metrics. In business analytics, data is transformed into actionable information that can drive strategic planning, improve operational efficiency, and optimize business performance. By applying statistical models, data mining techniques, and predictive analytics, businesses can identify patterns, trends, and correlations within the data to gain valuable insights. Business analytics plays a crucial role in decision-making processes across different functional areas, including marketing, finance, operations, and supply chain management. It helps businesses understand customer behavior, preferences, and needs, enabling targeted marketing campaigns and personalized customer experiences. By analyzing financial data, businesses can identify cost-saving opportunities, optimize pricing strategies, and improve profitability. Additionally, business analytics aids in operational efficiency by identifying bottlenecks, streamlining processes, and improving resource allocation. It enables businesses to forecast demand, manage inventory effectively, and enhance production planning. Furthermore, business analytics supports strategic planning by providing data-driven insights into market trends, competitive intelligence, and future opportunities. It helps businesses evaluate risks, assess market potential, and make informed decisions on expansion, product development, and resource allocation.

Keeping this in view the advancements of CFBA-2023 has focused on both core areas of finance and technological enabled advancements in the area of finance. We didn't limit ourselves to finance we also covered the technological advancements of Human resource, Marketing and Business Analytics as well. The organizing committee has received around 100 papers for the conference which were considered for review and editing. Out of these 100 papers, 62 papers were accepted for presentation and publication whereas 54 papers were registered, which are covered in this proceeding. These papers have been categorized into four major parts which are as follows: (i) *Financial Analytics*, (ii) *Human Resource Analytics*, (iii) *Marketing Analytics*, and (iv) *Business Analytics.*

The Financial Analytics theme covered a range of topics. We received around 30 papers covering the area of financial analytics and core finance covering the area such as computational intelligence for financial modeling, machine learning in finance, and big data finance and economics. It also included discussions on time series analysis, and financial risk management. Participants exchanged ideas on diverse topics like trading strategies, algorithmic trading, and behavioral finance. The theme also addressed the applications of deep learning, Adversarial Network and Prediction model for stock picking in finance.

For Human Resource Analytics we received around 4 paper and the theme discussed issues related to employee relations, green behaviour in workspace environment. The discussions on management decision making and decision making system on ethics of universities were covered.

The Marketing Analytics theme covered various aspects of marketing, such as, customer retention, and digital marketing. Discussions on demand generation, social media marketing, were also held. Participants shared their insights on decision making in social settings, decision making under uncertainty, and ethical decision making. The theme also focused on pricing analytics, retail sales analytics, and customer relationship management. We received around three papers for this particular theme.

The Business Analytics theme covered several topics such as healthcare analytics, machine learning, and optimization. Participants exchanged ideas on supply chain analytics, transportation analytics, and web-based decision making. We have received around 17 papers from this theme which has greatly contributed to our understanding and knowledge of Business Analytics

The CFBA-2023 conference proceedings included papers and presentations on cutting-edge research in the field of management. The conference provided a platform for researchers and practitioners to engage in meaningful discussions and to network with each other. Overall, the conference was a success and provided valuable insights into the latest trends and developments in the field of computational finance and business analytics.

Editors
Rangan Gupta
Francesco Bartolucci
Vasilios N. Katsikis
Srikanta Patnaik

Contents

Part II Human Resource Analytics

Part III Marketing Analytics

Part IV Business Analytics

About the Editors

Prof. (Dr.) Rangan Gupta is a Professor at the Department of Economics, University of Pretoria. He holds a Ph.D. in Economics from the University of Connecticut, USA. He conducts research in the fields of macroeconomics and financial economics. His research has appeared in high impact factor international journals such as *International Journal of Forecasting*, *International Review of Financial Analysis*, *International Review of Economics and Finance*, *Journal of Banking and Finance*, *Journal of International Money and Finance*, *Journal of International Financial Markets, Institutions and Money*, *Journal of Macroeconomics, Economic Modelling, Emerging Markets Review*, *Journal of Forecasting, Energy Economics, Energy Policy, Energy, Macroeconomic Dynamics, Quantitative Finance, Resources Policy.*

Prof. (Dr.) Francesco Bartolucci is a Full Professor of Statistics in the Department of Economics of the University of Perugia (IT), where he also coordinated the Doctorate program in "Mathematical and Statistical Methods for Economic and Social Sciences". Among his research interests, hidden Markov models and discrete latent variable models in general have a special role. On these topics he published papers appeared in prestigious journals of Statistics and Econometrics and he co-authored two books with an international publisher. He collaborated with many young researchers even within graduate programs and acted as Reviewer and Associate Editor for important field journals. He also acted as a reviewer within evaluation programs of the Italian University system. He participated in several research programs, even with the role of coordinator. He was the Principal Investigator of the research project "Mixture and latent variable models for causal inference and analysis of socio-economic data", which was funded by the Italian Government. He is an Editor of *Statistical Modelling*: An International Journal.

Prof. (Dr.) Vasilios N. Katsikis is an Associate Professor of Mathematics and Informatics at the Department of Economics, National and Kapodistrian University of Athens, Greece. He received his Diploma of Mathematics from the National and Kapodistrian University of Athens, his M.Sc. in Applied Mathematics as well as his Ph.D. in Mathematics from the National Technical University of Athens. He has also worked as a post-doctoral researcher in Applied and Computational Mathematics under the financial support of the State Scholarship Foundation (IKY). His research interests lie in the fields of Applied Mathematics, Computational Finance, Artificial Intelligence, Matrix Analysis and Applied Linear Algebra. He has published more than 80 journal papers in high-quality journals, four research books and seven book chapters on the above-mentioned fields, and has a variety of other research activities. He also serves as a reviewer for several journals and congresses.

Prof. (Dr.) Srikanta Patnaik is the Director of IIMT, Bhubaneswar. He has received his Ph.D. (Engineering) on Computational Intelligence from Jadavpur University, India in 1999 and supervised 34 Ph.D. theses and more than 60 M.Tech. theses in the area of Machine Intelligence, Soft Computing Applications and Re-Engineering. Dr. Patnaik has published more than 100 research papers in international journals and conference proceedings. He is author of two textbooks and edited 82 books and few invited book chapters, published by leading international publisher like Springer-Verlag, Kluwer Academic, etc. He is the Editors-in-Chief of *International Journal of Information and Communication Technology* and *International Journal of Computational Vision and Robotics* published from Inderscience Publishing House, England and also Editors-in-chief of Book Series on Modeling and Optimization in Science and Technologies published from Springer, Germany.

Part I
Financial Analytics

Chapter 1
Research on Credit Rating Prediction of International Trade Enterprises Based on Genetic Neural Network

Qingxia Dong

Abstract With the rapid development of the Chinese economy, Chinese enterprises have experienced significant growth in their overall strength. However, this growth has also exposed them to financial risks. The effective identification and warning of financial risks for companies is a topic with both theoretical and practical significance. In this paper, we propose an improved BP neural network model that addresses the adaptive and self-learning characteristics of BP neural networks, resulting in strong robustness and accuracy. Traditional evaluation methods for enterprise credit ratings often overlook the in-depth analysis of large amounts of relevant data beyond factors like enterprise scale, operating region, industry category, and registered capital. To address this, our research group has constructed a targeted investment network, covering over 4 million enterprises and over 260,000 enterprises of different types and categories by collecting, organizing, and processing relevant data. The results indicate that this method has high accuracy in enterprise credit evaluation and practical value.

Keywords Genetic neural network · International trade · Corporate credit investigation

1.1 Introduction

The financial crisis caused by the US subprime mortgage crisis in 2008 spread worldwide, resulting in a large number of business failures and a surge in unemployment. In this sudden crisis, major economies around the world worked together and the global economy quickly recovered. However, in recent years, due to a series of factors such as rising resource prices, escalating international trade protectionism, global inflation, and local conflicts, the recovery speed of the world economy has

Q. Dong (✉)
Shandong Vocational and Technical University of International Studies, Rizhao 276800, Shandong, China
e-mail: junedqx666@outlook.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_1

begun to slow down and gradually shown a slow growth trend. Currently, in China, the credit evaluation of enterprises is still mainly based on the traditional proportional method [1]. The main drawback of this method is that the selection of various indicators and weights in credit evaluation carries a certain degree of subjectivity, which leads to an increase in credit risk. Based on the existing international trade environment, a collaborative environment for international trade business has been formed, which not only enables relevant units and departments in the trade process to standardize data interfaces, but also profoundly affects the implementation mode of international trade business. If enterprises want to achieve better development in the environment of trade cooperation, they must adapt to the characteristics of this new mode of business execution, leverage its advantages, improve its execution efficiency, and enhance its competitiveness [2].

Mu Chen et al. used neural network modeling and combined it with genetic algorithm to solve the problem of reverse classification credit rating. Piramutu et al. utilized feature extraction techniques in neural networks when studying corporate credit in Belgium. The article used credit evaluation research on enterprises and utilized the Garson algorithm to analyze the importance of model variables, fully compensating for the insufficient explanatory power of neural networks. TAM and others study the credit status of the financial industry, using methods such as discriminant analysis, Logit, K-nearest neighbor classification tree, and neural networks to assess their strengths and weaknesses. Reference [3] utilizes self-learning to improve the performance of the network, preventing network searches from falling into local optima, and uses the additional momentum method.

Neural networks began to be applied in the field of credit evaluation in the 1990s. The basic idea of a neural network-based enterprise credit evaluation model is to use the relevant characteristics of customer credit evaluation as the input of the neural network for this type of enterprise customer credit evaluation system, and use the evaluation results as the output value of the credit neural network. Then, a large amount of sample data is used to train this network structure, and different output values can be obtained from different input values [4].

With the development of the Internet, mobile Internet, Internet of Things and various remote sensing detection technologies, a data age in which “everything is recorded and everything is analyzed” has arrived. The technological development and application practice of big data have brought significant contributions to the social economy and people’s daily life. The uncertainty of risk and the incompleteness of objectively existing contract terms provide an opportunity for the uncertainty of bounded rational entrepreneur’s behavior, indicating that the agent’s behavior has the conditions for moral hazard. China’s legal system is not perfect, the credit system is not market-oriented, the entrepreneur’s market-oriented system and credit evaluation mechanism are far from being in place, and the expected credit mechanism for safe economic operation is basically out of date. Due to the lack of long-term incentives, low consumer votes, and imperfect credit mechanisms, limited rational entities pre discount their own “monetary incentives” through contractual or non contractual forms to achieve their own “monetary incentives”. This article believes that there is a prominent credit mechanism in the operation and management of listed companies in China.

The basic evaluation step of a credit evaluation model established on a neural network is to first select and process useful indicators to evaluate a certain behavioral characteristic of the enterprise, and construct a relevant credit evaluation index system for this type of enterprise; Training is the main learning method for neural networks. A neural network system can gradually create a successful neural network by adjusting the connections of neurons according to established rules based on external inputs. The creation process is self-organizing. At the same time, self-organization ability is related to the adaptive ability of neural networks. This article first constructs an indicator system for credit evaluation of corporate environmental behavior, and then elaborates on the learning and training process of BP neural network. Finally, the learning ability of BP neural network is used to evaluate corporate environmental credit behavior, and a BP neural network model for credit evaluation of corporate environmental behavior is constructed. The correctness of the model is verified through experiments.

1.2 Research on Enterprise Credit Rating

1.2.1 Overview of Enterprise Credit Rating

Enterprise credit rating involves two main components: assessing the solvency of the enterprise and classifying its credit rating. The assessment of solvency is a prerequisite for determining the credit rating, which in turn is the outcome of the solvency assessment. Effective collaboration in international trade can help resolve issues related to information transmission and business feedback among trading, production, and logistics enterprises. This enables trading enterprises to plan, manage, and control the entire international trade execution process in a unified manner, facilitating synchronous and coordinated responses to relevant matters. It also allows for the rational allocation and optimization of resources across production and logistics enterprises [5]. The credit rating indicator system serves as the foundation for credit rating agencies and personnel to carry out credit rating work. It also serves as a measure of the objectivity and fairness of the credit rating results. The comprehensive evaluation indicator system of enterprise credit serves as the basis and standard for comprehensive evaluation of enterprise credit. It is a set of indicators that reflect the various attributes of the complex system consisting of the enterprise itself and its environment. These indicators are organized in a structured manner based on membership relationships and hierarchical structures. Refer to Fig. 1.1 for the comprehensive evaluation index system of enterprise credit.

For the first type of quantitative financial indicators, there is a significant difference in the numerical values of financial indicators reflected by enterprises of different sizes, and their values are not directly related to the credit of the enterprise. For

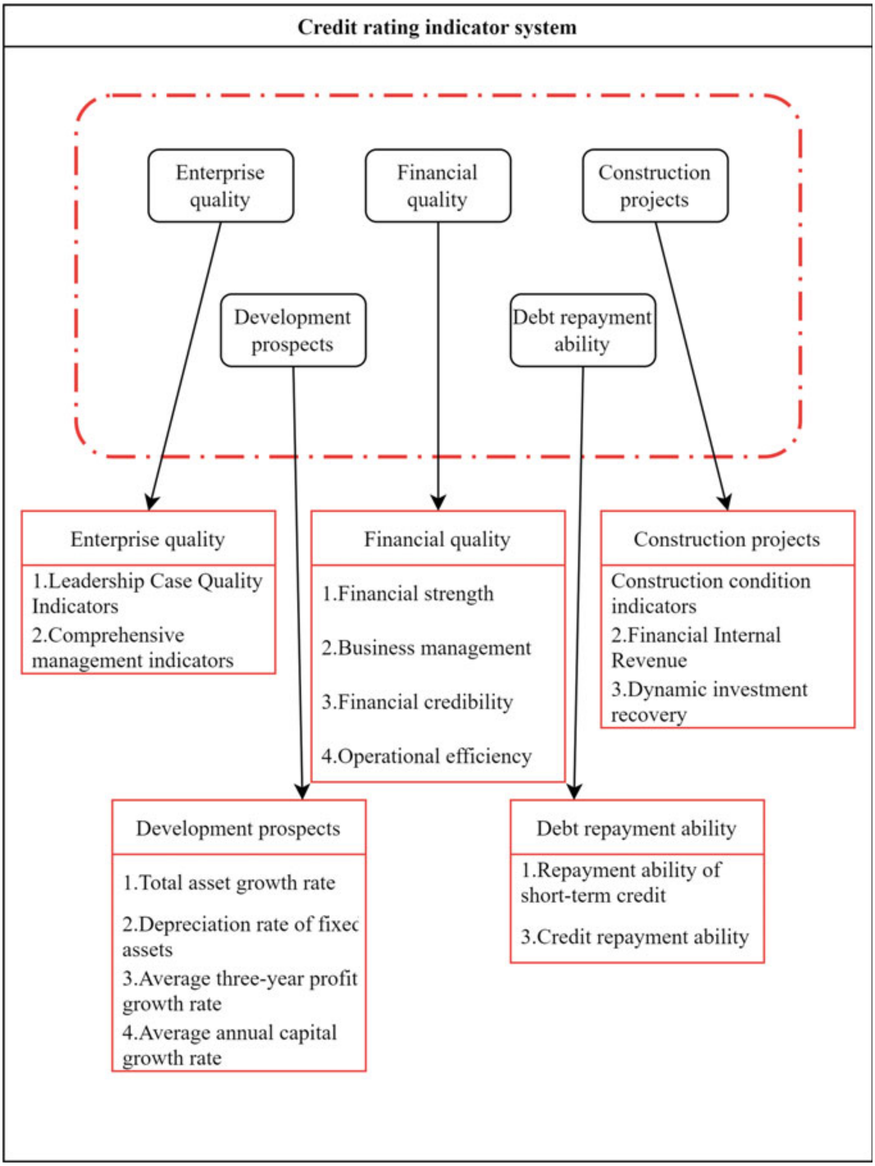


Fig. 1.1 Comprehensive evaluation index system for enterprise credit

the second type of quantitative indicators, by analyzing the sample data provided by banks, it was found that although some financial data is essentially quantitative financial ratio data, the asymmetric distribution of data on the original report results in a change in their attributes. This makes these two financial data equivalents to discrete binary data, rather than slowly changing quantitative data, and their role is more equivalent to the noise signal input from the network, it will cause high intensity interference to the neural network.

According to the four evaluation indexes of enterprise credit, complete the credit rating of enterprises by linear combination. The four evaluation indexes of enterprise credit refer to the basic situation of enterprises, the status of financial indicators, the status of innovation and development ability and public credit supervision information. Firstly, principal component analysis is used to evaluate the current solvency of enterprises, and enterprises are ranked in descending order according to their size. Secondly, cluster analysis is used to automatically divide the ranked enterprises into five credit grades: excellent, good, medium, low and poor. Finally, the enterprises with the lowest credit rating are regarded as financial crisis enterprises, and the rest are regarded as financially normal enterprises.

1.2.2 Selection of Enterprise Credit Rating Indicators

Since the measure of the default risk of an enterprise can be realized by assessing the solvency of the enterprise, eight indicators reflecting the solvency of the enterprise are selected according to the long-term and short-term division criteria [6]. They are: indicators of short-term solvency: current ratio, quick ratio, cash ratio, cash flow ratio. Indicators of long-term solvency: asset-liability ratio, long-term capital-liability ratio, interest coverage ratio, cash flow interest coverage ratio. By means of information collection and expert group opinion consultation, the four domestic dimensions used to evaluate corporate credit information, and the evaluation index system based on these four dimensions were determined. This article takes the credit evaluation of listed companies in China as the research object, and proposes an indicator system for credit evaluation of listed companies in China through the study of credit evaluation of listed companies in China. On this basis, a set of enterprise credit evaluation models based on 26 indicators was established. Considering that this evaluation system is a multi-level and multifactorial process, with both qualitative and quantitative factors influencing the evaluation results, we propose a comprehensive evaluation method using fuzzy mathematics to obtain a concise and intuitive evaluation result. After the index is selected, the corresponding initial variables are determined accordingly [7].

1.2.3 Empirical Study on Enterprise Credit Rating Based on Principal Component and Cluster Analysis

The basic idea of principal component analysis is to extract n uncorrelated principal component variables (m > n) from m original variables with multicollinearity, and use principal component variables to replace and reflect the original Information carried by the variable. To carry out principal component analysis, we must first calculate the principal component. According to the correlation matrix between the normalized original variables, the corresponding eigenvalue is calculated, and then the principal component is judged according to the magnitude of the eigenvalue. Secondly, the number of principal components should be determined [8]. The weight coefficient and evaluation grade of corporate credit index system can be fictitious in the research process, but in the actual evaluation process, these data are determined by specialized agencies and evaluation experts according to the actual situation with specific methods. Cluster analysis is an effective method to study the classification of things. Because it is easy to use and has good classification effect, it is often used for exploratory analysis of data, and it is widely used in many fields such as economy, management, medicine and so on.

1.3 Genetic Algorithm Optimizing BP Neural Network

Artificial neural network method is a method based on mathematical statistics, which processes data based on the working mechanism of the human brain. This method requires continuously adjusting the weights of neurons in the time series, and further improving prediction accuracy by studying the impact of weights on prediction results. When the weight of the neural network is adjusted to a point where it cannot effectively suppress prediction errors, the algorithm will enter a relatively stable state [9]. The artificial neural network method has a wide range of applications, has a strong self-learning function, and can automatically correct and summarize the system. The most important thing is that it can adjust the weight ratio of the internal parameters of the model according to the changes of the internal and external environmental information of the enterprise at any time, thereby improving the credibility of the prediction results. Since the rating model is nonlinear, whether the model can converge and whether it can reach the local minimum depends largely on the initial weights, so whether the initial weights can make the state value of each neuron close to Zero is very important. However, this method also has some defects. The method is too abstract to be applied, and the recognition and learning functions of the network are not mature and stable, which will affect the judgment of the prediction results. The optimization algorithm of the neural network is shown in Fig. 1.2.

According to the distribution of international trade business process in each time period, the international trade business process can be roughly divided into four stages: transaction preparation, transaction negotiation, contract signing and contract performance. In China's securities market, the overall threshold is high, and there are defects in the company's investment system aiming at the start-up period, which makes it difficult for companies to issue creditor's rights, especially for small and medium-sized enterprises to raise funds through stock issuance. In the existing international trade business execution mode, all businesses are carried out in series, and different businesses are carried out in chronological order; Moreover, due to the

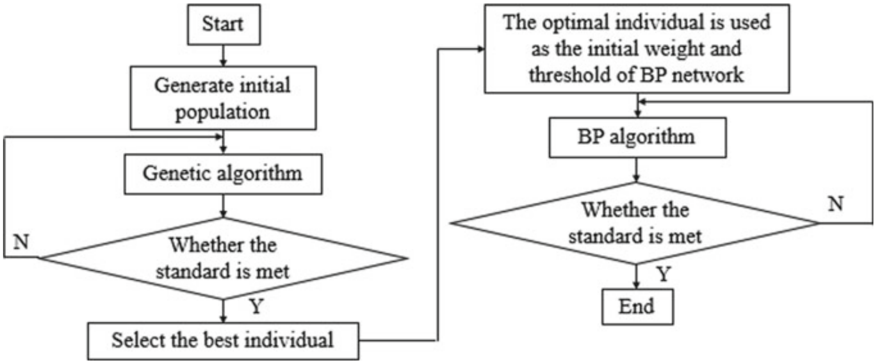


Fig. 1.2 Flow chart of neural network optimization algorithm

limited interactive ability of information, it is impossible to realize real-time monitoring and control in the trade process, and it is also impossible to realize the cooperation between business and process, so there is a certain time interval between two adjacent businesses. Therefore, it can to some extent improve the operational speed and accuracy of feasible solutions of genetic algorithms.

Train the model iteratively, using a weak classifier for each iteration to classify the training samples, and calculate the classification error rate:

$$err_m \frac{\sum \omega_i I(y_i \neq G_m x_i)}{\sum \omega_i} \tag{1.1}$$

where ω_i: The weight of the i-th training sample in this iteration, G_m: the m-th weak classifier.

$$a_m = \log((1 - err_m)/err_m) \tag{1.2}$$

Enterprise reputation index set $\hat{U}$ for comprehensive evaluation:

$$\begin{aligned} \hat{U} &= W \cdot B^T = (\omega_1,\ \omega_2,\ \omega_3,\ \omega_4) \cdot (B_1,\ B_2,\ B_3,\ B_4)^T \\ &= (z_1,\ z_2,\ z_3,\ z_4,\ z_5) \end{aligned} \tag{1.3}$$

In order to calculate the model complexity, $f(x)$ is refined: the regression tree is divided into two parts, one part represents the tree structure itself, which is represented by q, and the other part represents the weight of the leaf node, which is represented by ω, so $f(x)$ is represented as:

$$f_t(x) = \omega_{q(x)},\ \omega \in R^T,\ q : R^T \to \{1, 2, \ldots, T\} \tag{1.4}$$

The input variable feature is mapped to the leaf node index ID by the tree structure, and each leaf node is given a weight ω as the score of the leaf node. Therefore, the XGBoost model complexity is defined as the sum of the squares of the number of nodes in each weak classifier tree and the scores of its corresponding leaf nodes:

$$\Omega(f_t) = \gamma T + \frac{1}{2}\lambda \sum\nolimits_{j=1}^{T} \omega_j^2 \tag{1.5}$$

where γ and T are super parameters.

The hidden layers are:

$$y = f\left(\sum_{i=1}^{26} v_{ij} x_j\right) \tag{1.6}$$

The output layer includes:

$$O = f\left(\sum_{j=1}^{6} \omega_{j1} y_j\right) \tag{1.7}$$

Determine the sigmoid function as a transfer function, and its function expression is:

$$f(x_i) = \frac{1}{1 + e^{-x_i}} \tag{1.8}$$

The function is a non-decreasing continuous function representing the state continuous neuron model in the real number field $[0,\ 1]$.

By adjusting the connection weight value in the BP neural network and the scale of the network (including the number of nodes in the np layer as shown in Fig. 1.2), we can achieve nonlinear classification and other problems, and can access any nonlinear function with any precision. After determining the structure of the BP network, it is trained using a sample set, which means learning and adjusting the weights and thresholds of the network to capture the input–output mapping relationship. The selection of the number of hidden layer units has always been a complex problem in the application of neural networks. In fact, the application of ANN often translates into how to determine the structural parameters of the network and calculate the connection weights between various neurons. The number of hidden layer units is too low.

The fitness function value determines the evaluation result of the genetic algorithm for the viability of chromosomes. The larger the fitness function value of the chromosome is, the easier it is to be selected for genetic operation. The higher the accuracy of the BP neural network. The information interaction in the coordinated international trade business process has been greatly improved, which can realize real-time monitoring and control in the trade process, and realize the coordination of business and process [10]. The development of small and medium-sized enterprises has continuously increased its contribution to the current social economy, and also has obvious advantages in the fields of planning industrial layout and rational allocation of economic resources and has become a strong backing for promoting my country's social economy to keep pace with the times. Table 1.1 indicates the enterprise credit rating indicators proposed in this article.

Some attributes in the database have little to do with predicting the bankruptcy situation of enterprises, while others may have significant correlation with other

Table 1.1 Credit rating indicators for private enterprises

Basic attributes	Ratio	Indicator
Basic attributes	Financial ratio	Total assets
	Total asset liability ratio debt to shareholder equity ratio	Liabilities/total assets
	Equity multiplier	Liabilities/shareholders' equity
	Net return on assets (ROE)	Total assets/shareholder equity
Profitability	Net asset value (ROA)	Net profit/average net assets
	Main business profit margin	Net profit/average total assets
	Main business cost rate	Main business profit/main business income
	EBITDA/main business income	Main business cost/main business income
Operational capability	Accounts receivable turnover rate	Sales revenue/average accounts receivable
	Inventory turnover rate	Cost of sales/average inventory
	Total asset turnover	Sales revenue/average total assets
	Current asset turnover	Sales revenue/current assets
	Fixed asset turnover	Sales revenue/fixed assets
	Net asset turnover	Sales revenue/net assets
Debt paying ability	Current ratio	Current assets/current liabilities
	Quick ratio	(Current assets inventory) current liabilities
	Asset liability ratio	Total liabilities/total assets
	Interest coverage	Profit before interest and tax/financial expenses
	Equity ratio	Total liabilities/shareholders' equity
Cash flow	Cash to current liability ratio	Net operating cash inflow/current liabilities
	Cash to debt ratio	Net operating cash inflow/total debt

attributes. Unrelated and redundant attributes are detrimental to algorithms, increasing model training speed, reducing model prediction accuracy, and weakening model interpretation ability.

Through the high integration and integration of the management information systems of trade enterprises, production enterprises and logistics enterprises, the international trade and business collaborative service system is developed to realize the sharing of information resources, so that all enterprises in the field of national trade can obtain all kinds of information that is very important to them but cannot be fully collected in a conventional way. International trade business collaboration can effectively solve the problems of information transmission and business feedback of trade enterprises, production enterprises and logistics enterprises, enable trade enterprises to carry out unified planning, management and control of the whole international trade business implementation process, and realize the rational allocation and optimization of resources of production enterprises and logistics enterprises.

1.4 Conclusions

With the enhancement of the awareness of economic globalization, China's overall informatization level has made a great leap, and the collaborative environment of international trade and business will gradually take shape. The simulation experimental model shows that the model can achieve the system specified error with fewer training times, and the evaluation accuracy has been improved significantly.

The business execution mode under the collaborative environment has the advantages of parallel business, no time interval between some adjacent businesses, highly integrated and shared business information, seamless connection between businesses in international trade and so on. Small and medium-sized enterprises can use BP neural network to regularly monitor their own credit, so as to keep their own good reputation. To evaluate enterprise credit rating comprehensively, efficiently, objectively, accurately, and conveniently, an enterprise credit rating model based on genetic neural network is established by using genetic algorithm to optimize the weight and threshold of BP neural network model. This paper studies enterprise credit rating and introduces genetic algorithm to optimize BP neural network. The evaluation model makes reasonable judgment through scientific operation, which is conducive to improve the scientific level of scheme decision-making of corporate governance credit investigation evaluation and ensure the effective and orderly progress of governance. Enterprises participating in international trade should grasp the characteristics of business execution mode under information collaboration mode, make full use of its advantages and improve their economic benefits and competitiveness.

References

1. Y. Wang, H. Yang, S. Wang, International trade forecast based on grayscale forecast and neural network model-from ten years of trade data between China and the United States. Bus. Cond. **000**(022), 62 (2019)
2. H. Che, Z. Zhao, Research on credit rating optimization of life insurance industry based on genetic neural network. J. Insur. Vocat. Coll. **33**(5), 8 (2019)
3. S. Wang, L. Zha, Research on credit rating prediction of cross-border e-commerce enterprises based on XGBoost. J. Shaoguan Univ. **39**(6), 4 (2018)
4. J. Liu, L. Zhang, Y. Yin, Prediction model of Chinese enterprises OFDI investment amount based on genetic algorithm-optimized BP neural network. Mod. Comput. **7**, 8 (2021)
5. W. Su, G. Li, Research on safety physical examination model of chemical enterprises based on genetic BP neural network. Softw. Guid. **16**(12), 4 (2017)
6. X. Huang, W. Yang, Early warning analysis of Chinese tea export based on BP neural network model. Jiangsu Agric. Sci. **46**, 310–314 (2018)
7. J. Lu, Thermal error compensation of CNC machine tool combining firefly algorithm and BP neural network. Tianjin Metall. **000**(005), 35–39 (2017)
8. Z. Jiang, D. Yu, Research on positive solutions of Stewart platform based on genetic algorithm and BP neural network. China Water Transp.: Second Half Mon. **19**(7), 3 (2019)
9. H. Zhang, H. Li, The application of BP neural network model in SME financing credit evaluation. Mod. Shopp. Malls **18**, 2 (2017)
10. Z. Tian, G. Ju, Sino-Russian trade forecast based on adaptive neuro-fuzzy inference system. Mod. Bus. **36**, 2 (2019)

Chapter 2
Analytics of Identifying Green Stocks Diversification Opportunities During Pre and Post Outbreak of COVID-19—An Approach of Sharpe Single Index Model and Wavelet Coherence Approach

Neeraj Aswal, Reepu, Sudhi Sharma, and Bijesh Dhyani

Abstract It has been perceived over the last few decades that investments in green stocks or funds have increased sharply. Green stocks are the stocks of those companies that follow the footprints of the Global Green New Deal. The paper initially considers 16 green energy stocks and applied Sharpe Single Index Model, finally 7 stocks were selected. The study gauged the diversification opportunities for passive investors with the seven outperformed green stocks. The study further finds the most resilient diversification opportunity at the onset of COVID-19. The study has further applied Wavelet coherence and has identified that there are portfolio diversification opportunities with Torrent, Websol, Karam Energy, and JSW while investing in the stock market. However, Torrent Power Ltd. is found to be the most resilient stock. The results are useful for passive investors, looking for a green portfolio. The study also provides implications for policymakers.

Keywords Green stocks · Sharpe single index model · Wavelet coherence · Diversification · COVID-19

N. Aswal
Y.S Research Foundation of Policy and Administration, Dehradun, Uttarakhand, India

Reepu (✉)
Department of Management, Chandigarh University, Mohali, Punjab, India
e-mail: reepu.usb@cumail.in

S. Sharma
FIIB, Delhi, India

B. Dhyani
Department of Management Studies, Graphic Era Deemed to be University, Dehradun, India

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_2

2.1 Introduction

Over the past two decades, investors have realized the importance of environmental investing which not only has a profound impact on social, political, or moral issues, it has economic and business issues as well. The climate deterioration and thus, going green has received lots of attention from regulators and policymakers. Post-financial crisis, it is a major agenda at the global forum to get sustainable growth, popularly known as Global Green New Deal (GGND). Investors are inclined toward investment opportunities in companies that are in the business of improving the environment and reducing the effects of climate change [1]. Green investing is perceived as an act of investing in those companies which has a positive impact on the environment and society.

The study is an attempt to gauge the diversification opportunities for passive investors in green stocks. There are very few studies in the literature that focus on the role of green stock as a hedge with other assets (see [2–7]). Interestingly, a handful of studies were done on green stocks or funds in the context of the Indian stock market [8, 9]. It has been found from the strands of literature based on green funds that very scant literature is in the Indian context. The study caters to the gaps and thus provides great insights who are investing in a conventional asset and want to become greener.

Taking into consideration the fascination with green stocks [1] and the current literature gap, the study is identifying diversification opportunities with select green stocks of India while investing in the benchmark index. *The paper further answers the fundamental* **Two** *Questions: Q1. What are the outperformed green stocks and identifying diversification opportunities? Q2. Which green stocks provide resilient diversification during pre- and post-outbreak of the pandemic?*

We attempt to make several contributions to the literature by answering these two fundamental questions. Firstly, we have identified 16 Green Stocks on the basis of their investments/initiatives toward green projects. Later the research study calculates the excess return to beta ratio and identifies the outperforming stocks by the application of the Sharpe Single Index Model. Based on the results, the top 7 stocks which provide an excess return over and above the cut-off rate have to be considered for further analysis. Further, the study also applies the Wavelet coherence during the pre- and post-outbreak of COVID-19, to capture the lead and lag structure, diversification opportunities with Benchmark Index, and finally, identify the resilient opportunities. The study is a novel contribution to the literature on diversification, the impact of an outbreak of COVID-19, and green funds. The implications of the study are important for investors, and policymakers.

2.2 Literature Review

There are studies that found the outperformance of green assets or funds [8, 10–13]. Further, there are studies dedicated to diversification with green assets. Mensi et al. [5] captured dynamic spillover transmissions among green bonds, oil, and G7 countries. Le et al. [4] had examined the behavior of conventional and non-conventional asset classes. The study identified diversification opportunities by capturing time–frequency connectedness and volatility transmissions. They considered Fintech, Bitcoin, and green bonds as nonconventional assets and Equity assets, Gold and Crude oil, and conventional assets. Naqvi et al. [6] analysed 2339 funds from 27 emerging countries and found that traditional energy funds beat the performance of conventional funds. Naeem et al. [14] explored connectedness among green bonds, stocks, conventional bond markets, and commodities. Another study done by Naeem et al. [14] had investigated the time–frequency connectedness among green bonds and financial markets during COVID-19. Pham and Nguyen [15] found green funds as a hedge with other asset classes. Hyunh et al. [1] studied connectedness and gauged diversification opportunities in the era of the 4th industrial revolution. Reboredo and Ugolini [7] tried to capture the connectedness between the green bond and financial markets by the application of the structural VAR model and found low connectivity with the stock market. Broadstock et al. [16] examined green stocks within the context of a balanced income investment portfolio. Jin et al. [17] found green funds a hedge for carbon market risk. In the Indian context, the study done by Tripathi and Bhandari in 2012 and 2015 found the outperformance of green funds. The ESG Index and GREENEX are outperforming the benchmark index. It has been found from the strands of literature based on green funds that very scant literature is in the Indian context. The study caters to the gaps and thus provides great insights who are investing in a conventional asset and want to become greener. The study identified seven outperformed stocks among 16 stocks and finally identified diversification opportunities in the context of the outbreak of the pandemic.

2.3 Research Methodology

2.3.1 Data Profile

The objective of the study is to find outperformed stocks and identify diversification opportunities with Green Stocks. The study has taken 16 green stocks on the basis of their green business model or initiatives toward green or sustainability. The daily closing price data of all these stocks, NIFTY Energy (for the application of the Sharpe Model i.e. identifying stocks that are outperforming) and NIFTY (as a proxy of the stock market and identifying diversification opportunities) have been fetched from the 11th March 2018 to 11 March 2021. The data was retrieved from www.investing.com.

2.4 Methods and Models

2.4.1 Sharpe Single Index Model

The study applied Sharpe Single Index Model (1963), to gauge the stocks that are providing outperformed returns or excess return to beta ratio. The model has applied to 16 select green stocks and identified the seven stocks over and above the cut-off rate. The risk and return have been calculated as follows:

Risk and Return

Step 1. First, we have to calculate the Daily holding period return of the closing price starting from March 2018 to March 2021.

$$\text{DHPR} = (P_t - P_{t-1})/P_{t-1}$$

where, DHPR = daily holding period returns; $\mathrm{P_t}$ = Current price; $\mathrm{P_{t-1}}$ = Previous/ lagged Price.

Step 2 Calculate the average daily return of a considered period.

Step 3 Convert average daily return into an annual return (AR).

$$\text{AR} = ((1 + \text{AR})^{360}) - 1)$$

Step 2. Calculation of Sharpe Single Index Model Returns Based on the Following Equation:

$$R_i = a_0 + \beta R_m + U_t$$

where,

R_i Return of ith stock

R_m Return of the market and here the benchmark index is BSE Energy, $\mathrm{U_t}$ = error term, and a and β are the coefficients of the regression equation.

Step 3. Calculation of Risk

The beta of Sharpe's single-component equation is used to quantify systematic risk. The regression coefficient is known as beta. However, because it is a coefficient of time series data, it should be considered before utilizing it for further research. It is preferable to use a stationary check.

The Variance of the error component (σ_{ei}^2) was used to determine Unsystematic Risk.

Steps for the Application Sharpe Optimized Portfolio

The model has been applied to green energy stocks. The application of the model followed the following steps.

Step 1. Take closing daily price data from March 2018 to March 2021.

Step 2. Calculate daily return.

Step 3. Do the average of all daily returns data.

Step 4. Now convert Average daily return data to annual return data (Ri) by using the formula = ((1 + Average_Returns)^{360}) − 1).

Step 5. Our data is time-series data i.e., it is necessary for stationary check Otherwise the result of the regression coefficient is spurious. We use regression to estimate the residual value.

$$\text{The regression is } R_i = R_f + \beta R_m + U_t \tag{2.1}$$

Step 5. With the help of the regression equation variance of residual ($\boldsymbol{\sigma}^2_{\boldsymbol{ei}}$) is calculated and for the variance of the market take the Risk-free rate of return i.e. (average 10-Year Bond Yield).

Step 6. Now we have to calculate the Excess return Beta ratio by using a formula

$$\text{i.e., } \frac{R_{i\_}R_f}{\beta_i} \tag{2.2}$$

Step 7. After calculating the excess return to beta ratio filter out the security in the descending order.

Step 9. Now we have to calculate the cut-off rate by using. The formula of the cut-off rate (C*) is:

$$C^* = \frac{\sigma_m^2 \sum_i^i = 1\left(R_i - R_f\right)\beta_i/\sigma_{ei}^2}{1 + \sigma_m^2 \sum_i^i = 1\beta_i^2/\sigma_{ei}^2} \tag{2.3}$$

Step 10. The cut-off rate is used to choose securities with an excess return to beta ratio.

By, the application of the Sharpe Single Index model on 16 green stocks, 7 stocks were found to be outperformed over and above the cut-off rate.

2.4.2 Wavelet Coherence

Wavelet coherence shows the correlation between two variables in time frequency space which is based on Pearson correlation. The relationship varies from 0 to 1 signifying low and high correlation. Through this model, the coherence coefficient is calculated by squaring the local correlation coefficient among variables. It decomposes time series considering the various frequency like a short, medium, and long run. The major benefit of this model is that it does not require any pre-treatment of the market data. This model is a form of the cross-wavelet spectrum that is normalized through smoothed wavelet power spectra, for the same, a statistical test is computed.

Therefore, wavelet coherency has been found to be a better method. It is shown mathematically as follows:

$$R_n^2(s) = \frac{\left|S(s^{-1}W_n^{XY}(s)\right|^2}{S\left(s^{-1}\left|W_n^X(s)\right|^2 \cdot S(s^{-1}\left|W_n^Y(s)\right|^2\right)} \tag{2.4}$$

where W_n^{XY} is the CWT, S represents the smoothing operator normalizing time, and $R_n^2(s)$ ε [0, 1] is the wavelet squared coherency.

2.5 Empirical Analysis

2.5.1 Results of the Sharpe Single Index Model

The results of the Sharpe Single Index Model (1963) are encapsulated in Tables 2.1 and 2.2. The top five companies having the maximum excess return to beta ratio captured are Karan Engineering followed by Websol, Indowind, JSW Energy, and Torrent Power (see Table 2.1). In Table 2.2 we calculated the cut-off ratio and we found that Karma Energy, Websol, Indowind, JSW Energy, Torrent Power, BPCL, and Swelect are the seven green companies that are fetching high excess return to beta ratios above the cut-off ratio. We considered all these seven stocks for further analysis for finding diversification opportunities with the benchmark index and finding resilient diversification opportunities.

2.5.2 Results of Wavelet Coherence with an Impact of COVID-19

We examined the connectedness over time with the application of the wavelet coherence approach among the return of Nifty and the returns of seven select green stocks. The stocks that are least connected would be considered for portfolio diversification. Here we are examining the green stocks' connectedness and lead and lag structure with the benchmark index at the onset of the outbreak of COVID-19. The inferences drawn from the results captured the stocks that are resilient and connected throughout, or less connected during pre-crisis, or less connected during post-crisis. Henceforth the inferences drawn from the analysis provide insights to portfolio managers looking for green stocks while investing in the benchmark index. Figure 2.1 represents the wavelet coherence among green stocks and the Benchmark index. The X and Y-axis are representing frequencies or scales and time, respectively. To have a brief encapsulation of the results, we split the scale into five different cycles, i.e., 16–32, 32–64, 64–128, 128–256, and 256–512 days. These cycles are further divided into various

Table 2.1 Results of excess return to beta ratio

Name of stock	R_i (LN return) (%)	R_f (%)	β	Var of residual	Ratio $(R_i - R_f)/\beta$	$(R_i - R_f)\beta$/var of residual	Cumulative of G	Numerator
KARMAENG	56	7	0.0313	0.0094	15.6745	1667.33	1667.33	433.51
WEBELSOLAR	71	7	0.0903	0.0426	7.0841	166.19	166.19	43.21
INDOWIND	57	7	0.0717	0.0180	6.9692	388.00	388.00	100.88
JSW ENERGY	52	7	0.0967	0.0228	4.6534	203.98	203.98	53.04
TORNTPOWER	30	7	0.0637	0.0096	3.6090	376.10	376.10	97.79
BPCL	44	7	0.1262	0.0327	2.9322	89.77	89.77	23.34
SWELECTES	49	7	0.1702	0.0145	2.4671	170.53	170.53	44.34
BFUTILITIE	24	7	0.0723	0.0054	2.3513	435.61	435.61	113.26
TATA POWER	28	7	0.0972	0.0310	2.1612	69.71	69.71	18.12
GIPCL	16	7	0.0438	0.0114	2.0529	180.06	180.06	46.82
INDOSOLOR	32	7	0.1722	0.0070	1.4515	207.12	207.12	53.85
NHPC	21	7	0.1097	0.0076	1.2765	168.60	168.60	43.84
RTNPOWER	18	7	0.1134	0.0264	0.9702	36.71	36.71	9.54
NTPC	10	7	0.0447	0.0348	0.6712	19.29	19.29	5.02
RPOWER	−5	7	0.1910	0.0244	−0.6284	−25.7331	−25.73	−6.69
JINKO SOLAR	110	7	−0.0381	0.0228	−27.0001	−1182.42	−1182.42	−307.43

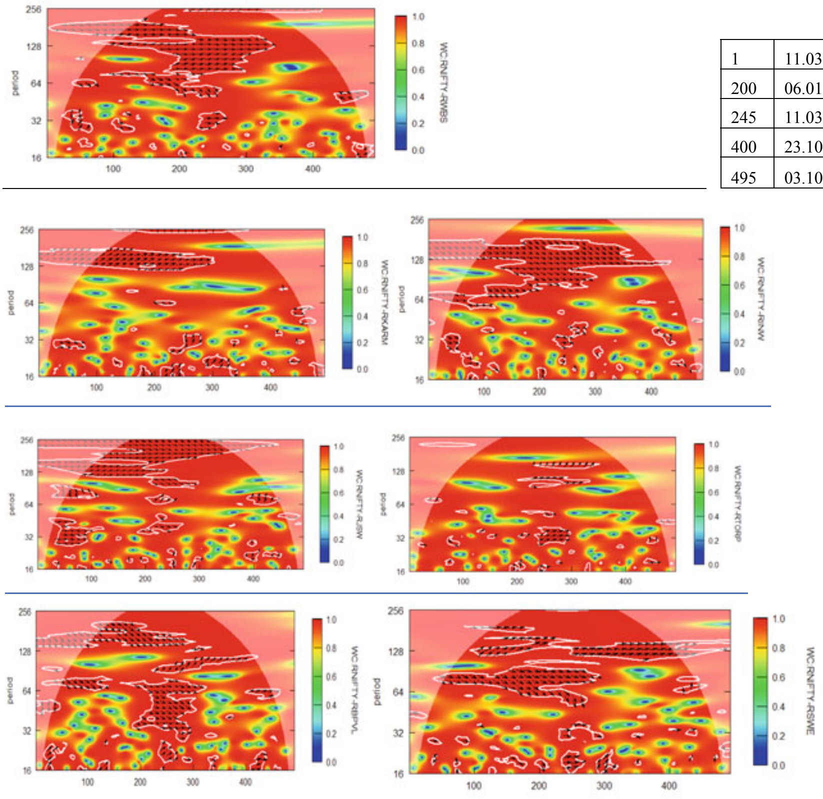
Table 2.2 Results of excess return to beta ratio over cut of rate and selection of the stocks

Name of stock	β^2	β^2/var of residual	Cumulative of K	Denominator	Cut off value	Selection	Z value
KARMAENG	0.0010	0.1040	0.1040	1.0270	0.1012	Included	51.7857
WEBELSOLAR	0.0082	0.1915	0.1915	1.0498	0.1824	Included	14.6275
INDOWIND	0.0051	0.2866	0.2866	1.0745	0.2667	Included	26.7715
JSW ENERGY	0.0094	0.4099	0.4099	1.1066	0.3704	Included	18.1555
TORNTPOWER	0.0041	0.4233	0.4233	1.1100	0.3813	Included	21.4366
BPCL	0.0159	0.4875	0.4875	1.1267	0.4326	Included	9.6564
SWELECTES	0.0290	2.0032	2.0032	1.5208	1.3172	Included	13.5315
BFUTILITIE	0.0052	0.9684	0.9684	1.2518	0.7736	Not included	
TATA POWER	0.0094	0.3046	0.3046	1.0792	0.2822	Not included	
GIPCL	0.0019	0.1686	0.1686	1.0438	0.1615	Not included	
INDOSOLOR	0.0297	4.2330	4.2330	2.1006	2.0152	Not included	
NHPC	0.0120	1.5889	1.5889	1.4131	1.1244	Not included	
RTNPOWER.BO	0.0129	0.4863	0.4863	1.1264	0.4317	Not included	
NTPC	0.0020	0.0574	0.0574	1.0149	0.0566	Not included	
RPOWER	0.0365	1.4932	1.4932	1.3882	1.0756	Not included	
JINKO SOLAR	0.0015	0.0637	0.0637	1.0166	0.0627	Not included	

scales that are 16–32 and 32–64 days as short scale, from 64 to 128 days considered as medium scale, and finally from 128 to 256 days as long scale. The intensity of connectedness could be captured with wavelet power. The colour blue is capturing the high power of connectedness and the red colour shows intense connectedness.

Figure 2.1 captured the connectedness and lead-lag structure, the connectedness intensity captured by the colour, and the lead and lag structure could be captured by arrows. The red island shows intense connectedness and the blue is showing weaker connectedness. The X-axis is showing the time observation, which can be useful to understand the impact of a particular event and for the meticulous understanding of time-varying connectivity. The one-on-one discussion on green stocks with benchmark index has been done hereunder.

The coherence among returns of NIFTY and Websol. It has shown a high-intensity coherence on a long and medium scale during pre-and majorly after the outbreak of



1	11.03.2019
200	06.01.2020
245	11.03.2020
400	23.10.2020
495	03.10.2021

Fig. 2.1 Wavelet coherence among Nifty and green stocks

COVID-19 (from 11.03.2019 to approx. 01.08.2020), as big red Iceland captured. We have seen very small Iceland with high power, it is shown that low coherence during short scale. However, the causality flows from the return of Nifty to Websol. Interestingly, it has been seen that after approximately 1st August 2020 the coherence is almost negligible, this may be because of the subsumed impact of the pandemic over time. By the virtue of the results, we inferred that the outbreak of COVID-19, impacted positively the connectivity, and the volatility transmitted from the benchmark index to the company's volatility. But afterward, there is no connectivity captured.

We have captured again strong coherence among benchmark and Karam Energy Pvt. Ltd. before the outbreak of COVID-19 and persist till the beginning of July 2020. The coherency captured in long and short scales with high power and the benchmark is a leading indicator. It means the volatility transmitted from the benchmark to the stock of Karam Energy Pvt. Ltd. from 11.03.2019 to 04.06.2020 approximately. Afterward, the coherence went to negligible, and thus, no connectivity was perceived.

From the results of coherence and lead and lag structure among return of Nifty and Indowind Pvt. Ltd. It has captured long and medium-scale coherence among both throughout the period. And the benchmark is a leading indicator whereas the return of Indowind is lagged one. However, there is no major short-scale coherence perceived. Similarly, it has been found JSW and benchmark have a high-intensity connectedness. However, on medium and short scales there are few impressions of connectedness.

A very interesting result was perceived through Torrent Power Pvt. Ltd. Only by the advent of the outbreak of COVID-19 only there very few impressions of connectedness. Otherwise, the stock is resilient pre-outbreak of COVID-19 and after 02.07.2020 approximately, there are no signs of connectedness. Henceforth the stocks are providing diversification opportunities with Torrent power.

BPCL was impacted a lot after the outbreak of COVID-19 and the highly intensified vulnerability perceived during this time. But gradually the connectedness lowered and thus, providing diversification in short term. Swelect is again showing high vulnerability during the pre-outbreak of the pandemic, in both medium to long scales. The connectedness increased due to the advent of the outbreak but afterward, the stock was resilient from medium to short scale.

Finally, it can be concluded that the impact has been captured of the outbreak of COVID-19 among all stocks but soon the majority of the stocks have shown recovery after April like Websol, Karam Energy, and JSW. However, stocks like Indowinds, BPCL, and Swelect are providing resilient diversification from medium to short scale. However, Torrent is the most outperformed, and safer resilient stock with the index during the pre- and post-outbreak.

2.5.3 Managerial and Policy Implication

The results show that there are diversification opportunities with Torrent, Websol, Karam Energy, and JSW. The results of diversification with green stocks also provide implications for policymakers. The regulators and policymakers are having sustainable agendas that are going green, using renewable sources, limiting the usage of fossil fuels, and having low carbon emissions. For these large investments are required. Although developing countries are getting funds from developed and international funding institutions. But they need a parallel source of funding and thus the mobilization of domestic funds from the route of capital markets is required and essential. Henceforth diversification opportunities with green funds stimulate capital formation from capital markets and trigger sustainable economic growth.

2.6 Conclusion

The study is a unique attempt in light of diversification in green Indian stocks that provides insights to portfolio investors and policymakers. The study applied Sharpe Single Index Model (1963) to 16 green stocks. The 6 select stocks selected that are having excess returns to beta ratio and are higher than the cut-off rate. It has been observed that the negative mean returns converge to positive from the pre to the post-window period. Moreover, Torrent is showing resilient behavior. The result of the short-term impact of the outbreak of the pandemic is in consonance with the previous studies done by Naeem et al. [18], Arif et al. [2], Hyunh et al. [1], and Reboredo [19]. From the results of wavelet analysis, it has been captured that the overall energy sector was impacted in short term by the outbreak of COVID-19. The results are in consonance with studies done by Mensi et al. [5], Le et al. [4], Naqvi et al. [6], Kuang [3], Arif et al. [20], Reboredo and Ugolini [7]. However, stocks like Indowinds, BPCL, and Swelect are resilient from medium to short scale and Torrent is the most resilient and outperformed. The results show that there are portfolio diversification opportunities with Torrent, Websol, Karam Energy, and JSW while investing in the stock market. The results are useful for passive and retail investors, they can go for long-term diversification with green stocks in the background of outperformance and the short-term impact of a pandemic. The results also provide implications for policymakers to channel funds from capital markets and trigger sustainable growth.

References

1. T.L.D. Huynh, When 'green 'challenges 'prime': empirical evidence from government bond markets. J. Sustain. Financ. Invest. 1–14 (2020)
2. M. Arif, M.A. Naeem, S. Farid, R. Nepal, T. Jamasb, Diversifier or more? Hedge and safe haven properties of green bonds during COVID-19 (2021)
3. W. Kuang, Are clean energy assets a safe haven for international equity markets? J. Clean. Prod. **302**, 127006 (2021)
4. T.L. Le, E.J.A. Abakah, A.K. Tiwari, Time and frequency domain connectedness and spill-over among fintech, green bonds and cryptocurrencies in the age of the fourth industrial revolution. Technol. Forecast. Soc. Chang. **162**, 120382 (2021)
5. W. Mensi, M.A. Naeem, X.V. Vo, S.H. Kang, Dynamic and frequency spill overs between green bonds, oil and G7 stock markets: implications for risk management. Econ. Anal. Policy **73**, 331–344 (2022)
6. B. Naqvi, N. Mirza, S.K.A. Rizvi, M. Porada-Rochoń, R. Itani, Is there a green fund premium? Evidence from twenty-seven emerging markets. Glob. Financ. J. **50**, 100656 (2021)
7. J.C. Reboredo, A. Ugolini, Price connectedness between green bond and financial markets. Econ. Model. **88**, 25–38 (2020)
8. V. Tripathi, V. Bhandari, Green is good in Indian stock market. Colombo Bus. J. **3**(2), 27–45 (2012)
9. V. Tripathi, V. Bhandari, Socially responsible stocks: a boon for investors in India. J. Adv. Manag. Res. (2015)
10. D. Ardia, K. Bluteau, T.D. Tran, How easy is it for investment managers to deploy their talent in green and brown stocks? Financ. Res. Lett. 102992 (2022)

11. M. Briere, S. Ramelli, Green sentiment, stock returns, and corporate behavior (2021). SSRN 3850923
12. T.T.H. Nguyen, M.A. Naeem, F. Balli, H.O. Balli, X.V. Vo, Time-frequency comovement among green bonds, stocks, commodities, clean energy, and conventional bonds. Financ. Res. Lett. **40**, 101739 (2021)
13. L. Pham, T.L.D. Huynh, How does investor attention influence the green bond market? Financ. Res. Lett. **35**, 101533 (2020)
14. M.A. Naeem, I. Mbarki, M. Alharthi, A. Omri, S.J.H. Shahzad, Did COVID-19 impact the connectedness between green bonds and other financial markets? Evidence from time-frequency domain with portfolio implications. Front. Environ. Sci. **9**, 180 (2021)
15. L. Pham, C.P. Nguyen, Asymmetric tail dependence between green bonds and other asset classes. Glob. Financ. J. **50**, 100669 (2021)
16. D.C. Broadstock, I. Chatziantoniou, D. Gabauer, Minimum connectedness portfolios and the market for green bonds: advocating socially responsible investment (SRI) activity (2020). SSRN 3793771
17. J. Jin, L. Han, L. Wu, H. Zeng, The hedging effect of green bonds on carbon market risk. Int. Rev. Financ. Anal. **71**, 101509 (2020)
18. M.A. Naeem, T.T.H. Nguyen, R. Nepal, Q.T. Ngo, F. Taghizadeh-Hesary, Asymmetric relationship between green bonds and commodities: evidence from extreme quantile approach. Financ. Res. Lett. **43**, 101983 (2021)
19. J.C. Reboredo, Green bond and financial markets: co-movement, diversification and price spillover effects. Energy Econ. **74**, 38–50 (2018)
20. M. Arif, M. Hasan, S.M. Alawi, M.A. Naeem, COVID-19 and time-frequency connectedness between green and conventional financial markets. Glob. Financ. J. **49**, 100650 (2021)

Chapter 3
A Study on Growth-Finance Nexus: Evidence From the BRICS Nations

Alok Arun, Bibhutibhusan Mishra, and Srikanta Patnaik

Abstract This article investigates the nexus of *Economic Growth* and the *Financial Development* for BRICS (Brazil, Russia, India, China and South-Africa) nations, within the period 1990–2020. The financial development is segregated into the parts of financial market and institution (Access, Depth and Efficiency). We implemented the Auto-Regressive Distributed Lag test and the results depicts that in BRICS region in long run, overall, it shows financial institution depth and efficiency has positive impact on GDP, while the Financial Institution *access* Financial Market *efficiency*, can have a negative impact on the GDP. It states that the institutions in the BRICS regions contribute more to the economy and the financial market is not that much efficient in the BRICS regions as they are the emerging nations. In short run, financial institution has a negative impact on the economy. In individual case the selected nations have mixed relationship. To investigate the directional causality the *Dumitrescu Hurlin* Panel Causality Test was performed, and the results showed bi-directional causality between financial institution depth and economy and unidirectional causality between financial institution access, financial market depth and efficiency. Thus, it shows that financial development is the major factor in the BRICS nation's economic growth and certain strict policy implications will enhance the economic development of these nations.

Keywords ARDL · Causality test · Economic growth · Financial development · Mixed relationship

A. Arun (✉) · S. Patnaik
Interscience Institute of Management and Technology, Bhubaneswar, India
e-mail: alokarunmpt@gmail.com

B. Mishra
Institute of Business and Computer Studies (IBCS), Siksha 'O' Anusandhan University, Bhubaneswar, India

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_3

3.1 Introduction

The Inter-relations between the *Economic Growth* and *Financial Development* have been extensively researched in the previous literatures. The debate centered on whether growth of the financial markets and the institutions would result in growth of the real sector, resulting in economic progress, or vice versa. Numerous studies have been undertaken in the past, and there is universal agreement that there is a nexus between economic growth and financial development. In the scholarly literature, there are two contrasting ideas explaining the evolution of the relationship between financial development and economic growth. The first point of view, known as *"supply leading hypothesis"*, holds that financial development is required for economic expansion. As it was popularized by the research of Schumpeter [24] and Patrick [19], the other point of view on the nexus between economic growth and financial development holds that genuine economic growth comes before financial development, and this was postulated by Robinson [23] which is known as "*demand following hypothesis*". The research suggests a substantial association between the financial development and the economic growth, which is highly sensitive to these factors used for quantification. A finding of all past researches, whether it is a single nation or a group of nations, invariably differs between these two criteria(s).

Here we try to re-examine the relationship(s) between both the factors of *Economic Growth* and *Financial Development* by using ARDL with the help of Time Series data of the BRICS countries. We have analyzed the results for the individual countries and in the panel form as well. The emerging countries have a huge potential to strengthen their economic and the financial sector that has a huge impact on the world economy as well. For this study we have considered taking the annual GDP as the base to measure of economic growth and for financial development we will be segregating the financial development index into two parts i.e., Financial Institutions (Access, Depth and Efficiency) and Financial Markets (Access, Depth and Efficiency). The study regarding the financial development index has already been made in previous literature but this kind of segregation hasn't been done so far.

The primary goal of this article is to re-establish the link between these components for the BRICS countries from 1990–2020 by implementing auto-regressive distributed lag (ARDL), co-integration and causality as the basic parameters of the study.

The structure of this article is organized into several sections. In Sect. 3.2, we review the relevant literature on the relationship between growth-finance nexus. In Sect. 3.3, we provide a detailed description of the data sources and variables used in our analysis. Section 3.4 presents the methodologies employed to test our hypotheses. In Sect. 3.5, we discuss the empirical results obtained from the tests. Finally, in Sect. 3.6, we summarize our findings and draw conclusions based on our analysis.

3.2 Literature Review

Already there are many articles available that have established the relationship between the Economic Growth and the Financial Development. Theoretically, Schumpeter [24] the pioneer, who started the whole things of finding i.e. the relationship between economic growth and financial development and it, is much more popular among all the economists for many years. Later on, Goldsmith [7], Mckinnon [16] and Shaw [27] extensively researched on this and yielded conclusive evidences that the financial development has a relationship with the economic growth.

There on, in this context many authors have tried and examined about this nexus of the financial development and the economic growth, resulting in development of certain conceptual and practical arguments on it, having the influences on the financial development and economic growth.

(King and Levine [14]; Demetriades and Hussein [4]; Arestis et al. [2]; Masoud and Hardaker [15]; Hsueh et al. [9]; Guha Deb et al. [8]; Nguyen et al. [18]; Pradhan et al. [22]; Sehrawat and Giri [25]; Afonso and Blanco-Arana [1]; Boachie et al. [3]; Wahidin et al. [28]).

All of the authors agreed on a key point that financial development may have an influence on economic growth. King and Levine [14] investigated the impact of financial development on economic growth and discovered a positive association between development and growth, such that financial development has a considerable impact on economic growth, physical capital accumulation and improvement in the efficacy of financial capital usage.

Demetriades and Hussein [4] conducted the causality tests connecting financial development and GDP and the outcomes lend limited credence to the notion that finance is the driving force in the process of economic development. The data clearly showed that causality tests patterns deviate among the nations.

Arestis et al. [2] evaluated the connection between the stock market development and economic growth using the time series techniques and by collecting the data from five developed nations, controlling the impacts of the banking system and the stock market volatility. The findings of the study confirmed that both the banks and the stock market stimulate economic progress, the former has a strong impact.

In addition to these, many modern-day researchers also found out the nexus between financial development and economic growth and discovered many connections between them.

To begin with Masoud and Hardaker [15] investigated the influence of financial development on the developing market's economic growth. The results of the study suggested that share market has a significant impact on economic growth, and the effect remains strong even after accounting for the banking sector and all the other variables. It also supports the notion that the stock market has a stable and long-term equilibrium with economic progress which leads to the evolution of the economy.

Guha Deb et al. [8] examined a causal relationship of financial development and economic growth for 28 countries for different stages of their economic progress. The investigation of the causal flow for the emerging economies followed the "supply leading hypothesis" and for the developed economies there is causal flow followed the "demand following hypothesis". The relationship for both developed and emerging economies predominantly came out to be strong during economic boom phase and it becomes weak during economic downturn phase.

In contrast to that Nguyen et al. [18] studied economic growth and financial development in 22 emerging nations. The results disclosed that there is a positive and linear association between economic progress and financial development. For all the proxies of the financial development it revealed a bi-directional causality between the variables. Contrasting to it Pradhan et al. [22] investigated on G-20 countries and provided practical insights that the bond market sector and stock market sector are co-integrated with economic progress, inflation and interest rate. The Granger causality test validated that Stock market, bond market, inflation and interest rate are the main drivers of the economic progress in a long run.

Sehrawat and Giri [25] examine the relationship between financial development and economic growth for India and the outcomes of the study stated that there is long term association of financial development and economic growth in India in the co-integration test. The ARDL test results demonstrated that both banks based and market-based indicators of financial development have a constructive effect on the economic growth in India. It followed supply leading hypothesis and discovered the significance of both indicators. The same authors [26] also made the same kind of study for the SAARC countries and found the results.

Afonso and Blanco-Arana [1] studied on the variables in OECD and EU nations for the period of 1990–2016, by taking the financial crisis of 2008 into account. They found out certain linear along with non-linear effect of financial development on the growth of the economy.

Boachie et al. [3] in their study has investigated the connection of financial inclusion, banking stability, and economic progress etc. in 18 Sub-Saharan African nations. The findings revealed that economic progress outperforms stability of banking but not vice versa, confirming that there is a unidirectional causality from GDP to banking stability. It validates the demand following hypothesis and also discovering that bank capital regulation has a negative impact on banking stability in the Sub-Saharan area.

In addition to Wahidin et al. [28] they found the impression of bond market development on economic progress prior to the financial crisis which affected globally in the year 2008 and it concluded that bond market had a positive effect on the economic progress before the crisis on both the developed and emerging economies. After the financial crisis the link between the two got weakened in both economies.

Table 3.1 Definition of variables

Variables	Proxy	Definitions	Source
GDP	Economic growth	Annual GDP growth	WDI
FID	Financial institution depth	Private sector to GDP, pension fund assets to GDP, mutual funds assets to GDP, insurance premiums, life and non-life to GDP	IMF
FIA	Financial institution access	Bank branches per 100,000 adults, ATMs per 100,000 adults	IMF
FIE	Financial institution efficiency	Net interest margin, lending deposits spread, non-interest income to total income, overhead costs to total assets, return on assets, return on equity	IMF
FMD	Financial market depth	Stock market capitalization to GDP, stock traded to GDP, international debt securities of government to GDP, total debt securities of financial corporations to GDP, total debt securities of non-financial corporations to GDP	IMF
FMA	Financial market access	Percent of market capitalization outside of top 10 largest companies, total number of issuers of debt (domestic and external, non-financial and financial corporations)	IMF
FME	Financial market efficiency	Stock market turnover ratio (stocks traded to capitalization)	IMF

3.3 Data and Variables

We examined at yearly time series data for the BRICS nations from the 1990–2020 in a balanced panel. We considered annual GDP growth for economic growth, which was obtained from the World Development Indicators (2021) and for financial development it was segregated into major factors of financial markets and institutions which is comprised of Access, Depth and Efficiency which is collected from International Monetary fund. The details of the variables are mentioned in Table 3.1.

3.4 Methodology

The idea behind choosing this set methodology was to find out the long run and short run relationship between the variables and among the countries to find whether they complement to each other or not. The causality tests helped to determine whether a single time series is useful for forecasting the other.

The unit root tests and Co-integration test are performed to check the stationarity and to find out whether two or more variables are correlated for a long period of time.

3.4.1 Checking Stationarity: Unit Root Test

In order to determine if the time series data are co-integrated. It's essential to evaluate the stationarity of the series. One common method used for this purpose is the unit root test, which helps to determine if a sequence is stationary or not. The Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests are used to assess whether or not the sequence is stationary. If $\{y_t\}$ is an AR(p) process, the ADF test is provided by

$$\nabla y_t = \gamma y_{t-1} + \in_1 \nabla y_{t-1} + \in_2 \nabla y_{t-2} + \ldots \in_{p-1} \nabla y_{t-p+1} + \varepsilon_t, \tag{3.1}$$

where 'p' is defined as the process's lag duration, the Akaike Information Criteria (AIC) or Schwarz Criterion (SC) is used to calculate the value of p. The hypothesis is H_0: $\gamma = 0$ as opposed to H_1: $\gamma < 0$. The order has a unit root if H_0 is accepted, suggesting that it is non-stationary. If, on the other hand, H_0 is rejected, the sequence is stationary because it lacks a unit root. The ADF test presumes that the errors are statistically independent and have a constant variance. While minimizing these postulations, we have used another test, the PP test. This test allows for disruptions that are weakly reliant and heterogeneously dispersed.

To explore this method, we consider the following regression equations:

$$y_t = \alpha * + \beta * y_{t-1} + \mu_t, \text{ and} \tag{3.2}$$

$$y_t = \alpha_0 + \beta_0 y_{t-1} + \gamma_0 (t - T/2) + \mu_t \tag{3.3}$$

Phillips-Perron proposed the test for validating hypotheses related to the coefficients $\alpha*$, $\beta*$, α_0, β_0 and γ_0, by defining the distribution and introducing test statistics. The PP test is a modification of the Dickey-Fuller test that accounts for the error process's less constrained nature. When both time series have an order of integration of one, denoted, either the Augmented Dickey-Fuller (ADF) test or the PP test can be used to co-integrate them. These tests are useful for analyzing the relationships between variables and identifying potential cointegration, which can be an important consideration when examining time series data.

3.4.2 Johansen Co-integration Test

Johansen's methodology takes the beginning point in the vector auto-regression (VAR)

$$\Delta y_t = \mu + \pi y_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \varepsilon_t \tag{3.4}$$

Johansen suggests two separate but similar kind of ratio tests for the reduced rank of the π matrix: one of them is the trace test and the other one is the maximum eigen-value test, which is shown in Eqs. respectively.

$$J_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \widehat{\lambda}_{\mathrm{i}}) \tag{3.5}$$

$$J_{max} = -T\ln(1 - \widehat{\lambda}_{\mathrm{r+1}}). \tag{3.6}$$

The size of the sample is denoted by T, and the largest canonical correlating relationship is represented by $\widehat{\lambda}_{\mathrm{I}}$. It is important to note that, in general, none of the test statistics follows a χ^2-distribution. Asymptotic critical values can be found in Johansen and Juselius [10] work, but it should be noted that the critical values for maximum eigen value and trace test statistics are based on the assumption of pure unit-root expropriation. The assumption may not hold true when the system variables are close to unit-root processes.

The main concern with Johansen's processes is their susceptibility to deviating from the pure unit-root expropriation assumption. In other words, the extent to which these processes can accurately identify cointegration may be affected by departures from the assumptions of pure unit-root expropriation. This highlights the importance of carefully considering the underlying assumptions and limitations of statistical tests when analyzing time series data.

3.4.3 Autoregressive Distributed Lag

The broadened version of our study model may be described as follows based on our research variables:

$$\mathrm{GDP} = f(\mathrm{FID} + \mathrm{FIA} + \mathrm{FIE} + \mathrm{FMD} + \mathrm{FMA} + \mathrm{FME}) \tag{3.7}$$

After being converted into a linear form, Eq. (3.7) can be shown as follows:

$$\mathrm{Yt} = \alpha_0 + \beta_1\mathrm{FID} + \beta_2\mathrm{FIA} + \beta_3\mathrm{FIE} + \beta_4\mathrm{FMD} + \beta_5\mathrm{FMA} + \beta_6\mathrm{FME} \tag{3.8}$$

where Y stands for economic growth, FID for financial institution depth, FIA for financial institution access, FIE for financial institution efficiency, FMD for financial market depth, FMA for financial market access, FME for financial market efficiency. Long-run elasticity is represented by the model coefficients of β_1 to β_6, and t is the period for error correction.

Equation (3.8), however, can only depict an explanatory variable's long-term effects on economic growth. We conducted a co-integration test to evaluate the model's short- and long-run elasticities. Over the past few decades, various co-integration tests have been developed and used, including the residual based Engle and Granger [6] and the maximum likelihood-based Johansen tests [11–13] and Johansen and Juselius [10]. However, earlier models were limited in terms of the sequence of integration of variables. To address this issue, Pesaran and Shin [20] introduced a novel cointegration model that allowed for more flexibility in the integration sequence of variables, including those with order of integration I(0) and/or I(1). This model was further refined by Pesaran et al. [21] and Narayan [17]. The development of these models has enhanced our ability to analyze time series data and identify potential cointegration, leading to more accurate and informative economic analyses. Additionally, using a linear transformation, the error correction term may be determined from ARDL. As a result, Eq. (3.8) may be rewritten as follows in ARDL form:

$$\begin{gathered}\Delta Yt = \alpha_0 + \sum_{i=1}^{n} \mu_1 \Delta Y_{t-1} + \sum_{i=0}^{n} \mu_2 \Delta FID_{t-1} + \sum_{i=0}^{n} \mu_3 \Delta FIA_{t-1} + \sum_{i=0}^{n} \mu_4 \Delta FIE + \\ \sum_{i=0}^{n} \mu_5 \Delta FMD_{t-1} + \sum_{i=0}^{n} \mu_6 \Delta FMA_{t-1} + \sum_{i=0}^{n} \mu_7 \Delta FME_{t-1} + \gamma_0 Y_{t-i} + \gamma_1 FID_{t-1} + \gamma_2 FIA_{t-1} + \\ \gamma_3 FIE_{t-1} + \gamma_4 FMD_{t-1} + \gamma_5 FMA_{t-1} + \gamma_6 FME_{t-1} + \omega_t\end{gathered} \tag{3.9}$$

3.4.4 Dumitrescu Hurlin Panel Causality

The approach of Dumitrescu Hurlin panel causality analysis seeks to understand the causal link between variables. It is often regarded as a more advanced variant of Granger causality analysis. It is feasible to assess utilizing panel data in this way. The Dumitrescu Hurlin panel causality analysis equation is illustrated below.

$$Y_{i,t} = a_i + \sum_{k=1}^{K} Y_i^k Y_{i,t-k} + \sum_{k=1}^{k} B_i^k X_{i,t-k} + \varepsilon_{i,t} \tag{3.10}$$

Variables X and Y are represented in this equation. As a result, the purpose of this technique is to evaluate if X is the primary cause of Y. Furthermore, B is the variable's coefficient, and an $\varepsilon_{i,t}$ is the constant term. Furthermore, denotes the error term, while K specifies the appropriate lag interval [5].

Table 3.2 Descriptive statistics

	GDP	FID	FIA	FIE	FMD	FMA	FME
Mean	3.93	0.38	0.34	0.56	0.4	0.29	0.66
Median	4.22	0.34	0.25	0.58	0.39	0.26	0.73
Maximum	14.23	0.88	0.93	0.81	0.79	0.68	1
Minimum	−14.53	0.03	0.03	0.22	0.05	0.07	0.05
Std. Dev	4.85	0.24	0.26	0.14	0.18	0.15	0.3
Skewness	−0.78	0.61	0.59	−0.5	0.11	0.39	−0.38
Kurtosis	4.44	2.43	2.06	2.71	2.11	2.15	1.77
Jarque–Bera	29.37	11.68	14.74	6.91	5.38	8.57	13.49
Probability	0	0	0	0.03	0.07	0.01	0
Observations	155	155	155	155	155	155	155

3.5 Results and Discussion

3.5.1 Descriptive Statistics

Table 3.2 displays the descriptive statistics for the time span 1990–2020. FMA has the lowest mean value (0.29) while GDP has the greatest value (3.93). GDP has the greatest median value (4.22), followed by FME (0.73), FIE (0.58), while FIA has the lowest (0.25). GDP has both the greatest (14.23) and lowest (−14.53) maximum and minimum values. GDP has the biggest standard deviation (4.85), followed by FME (0.3), FIA (0.26), and FIE has the lowest (0.14). The skewness is connected to the variables both positively and negatively. The kurtosis is connected to the variables in a positive way. The Jarque–Bera values are validated and show a normal distribution of the data for the research variables.

3.5.2 Augmented Dickey Fuller and Phillips-Perron Unit Root Tests

The ADF and PP tests are used to determine the stationary of each variable. In contrast to the alternative hypotheses, the null hypotheses says that the variables under examination have a unit root. Table 3.3 depicts the results of the unit root tests. At the level, all the variables appear to be non-stationary, which represents that the variables have a unit root irrespective of the test circumstances. Nonetheless, both test conditions reveal that the first differences of the variables are stationary, as a consequence, all seven factors appear to be listed in order one for a different group of BRICS nations.

Table 3.3 Augmented Dickey Fuller and Phillips-Perron unit root test

Variables	Sample	ADF	Inference	PP	Inference
GDP	Brazil	−4.86	I(1)	−9.41	I(1)
	Russia	−7.39	I(1)	−8.58	I(1)
	India	−5.24	I(1)	−5.24	I(1)
	China	−4.03	I(1)	−4.04	I(1)
	South Africa	−4.45	I(1)	−4.16	I(1)
FID	Brazil	−4.34	I(1)	−4.46	I(1)
	Russia	−4.72	I(1)	−4.71	I(1)
	India	−4.10	I(1)	−4.16	I(1)
	China	−6.41	I(1)	−6.98	I(1)
	South Africa	−6.38	I(1)	−8.52	I(1)
FIA	Brazil	−3.96	I(1)	−3.74	I(1)
	Russia	−2.76	I(1)	−2.76	I(1)
	India	−2.44	I(1)	−2.33	I(1)
	China	−2.08	I(1)	−3.42	I(1)
	South Africa	−2.82	I(1)	−2.82	I(1)
FIE	Brazil	−7.84	I(1)	−7.95	I(1)
	Russia	−6.40	I(1)	−6.41	I(1)
	India	−5.54	I(1)	−6.20	I(1)
	China	−6.16	I(1)	−6.26	I(1)
	South Africa	−8.21	I(1)	−12.46	I(1)
FMD	Brazil	−8.58	I(1)	−8.51	I(1)
	Russia	−4.77	I(1)	−4.28	I(1)
	India	−5.69	I(1)	−5.69	I(1)
	China	−6.14	I(1)	−6.16	I(1)
	South Africa	−5.43	I(1)	−5.47	I(1)
FMA	Brazil	−6.71	I(1)	−9.78	I(1)
	Russia	−4.65	I(1)	−4.61	I(1)
	India	−4.52	I(1)	−4.57	I(1)
	China	−3.95	I(1)	−17.80	I(1)
	South Africa	−6.93	I(1)	−7.18	I(1)
FME	Brazil	−7.33	I(1)	−10.73	I(1)
	Russia	−6.98	I(1)	−6.98	I(1)
	India	−7.01	I(1)	−6.96	I(1)
	China	−5.28	I(1)	−4.33	I(1)
	South Africa	−6.68	I(1)	−6.66	I(1)

Table 3.4 Johansen co-integration test

Country	Null hypothesis	Trace value	0.05 critical value	Max-eigen	0.05 critical value
Brazil	None *	164.70	125.62	48.29	46.23
	At most 1 *	116.41	95.75	40.08	40.08
	At most 2 *	76.33	69.82	–	–
Russia	None *	234.66	125.62	93.26	46.23
	At most 1 *	141.40	95.75	66.83	40.08
	At most 2 *	74.57	69.82	–	–
India	None *	169.13	125.62	64.62	46.23
	At most 1 *	104.51	95.75	–	–
China	None *	215.83	125.62	78.46	46.23
	At most 1 *	137.38	95.75	55.27	40.08
	At most 2 *	82.10	69.82	–	–
South Africa	None *	164.43	125.62	52.29	46.23
	At most 1 *	112.14	95.75	–	–
	At most 2 *	73.74	69.82	36.93	33.88

* represents the significance of the values at the 0.05 level

3.5.3 *Johansen Co-integration Test*

The Johansen co-integration test is shown in Table 3.4. The test findings show that there are three co-integrating vectors for Brazil, Russia, China, and South Africa, and two co-integrating vectors for India. The max-eigen statistics also show two cointegrated equations for Brazil, Russia, and China, as well as one for India and three for South Africa.

The result from the experiments indicates that financial development characteristics are long-run predictors of economic growth for the BRICS countries. Individually, the results of the Johansen Co-integration tests reject the null hypothesis of no co-integration between the variables for the BRICS countries. As a result, it may make long-term projections about economic growth.

3.5.4 *Autoregressive Distributed Lag*

Tables 3.5 and 3.6 represent the results of the Autoregressive Distributed Lag in Panel form of the BRICS countries and also in the individual countries as well. Here we have considered Gross Domestic Product as the dependent variable and established the relationship around it. When we consider individual countries in Table 3.5 the results depict that in Brazil, Financial Institution Depth and Access has positive impact on GDP that means bank credit, pension fund assets, mutual fund assets and insurance premiums are been stored in optimum amount and have positive impact on the economy. Similarly, in case of financial access the citizen of the country has optimum access to ATMs and bank branches. In Russia, financial institution access and financial market access has a positive impact on GDP as a result more people have access to bank branches and ATMs. Citizens do depend on the performance of stock market as second source of income. In case of India and China financial market efficiency and financial market depth has negative impact on GDP as because Indian stock market lacks efficiency in terms of stock turnover and China market lacks depth in their stock market sector.

Table 3.5 Auto regressive distributed lag

Variable	Brazil	Russia	India	China	South Africa
GDP(−1)	−0.06	−0.08	0.37	0.34	0.49
FID	−21.35	14.17	−11.18	−25.02	−58.46
FID(−1)	28.16*	168.07	27.72	30.36	−25.71
FIA	37.58*	74.99*	−16.19	5.72	27.99
FIA(−1)	−34.04	(102.97)*	−22.04	−10.56	−20.18
FIE	−2.95	−25.18	−14.68	20.06	35.75
FIE(−1)	8.21	−9.28	−19.24	−3.59	7.33
FMD	6.96	−17.02	4.78	9.81	27.79
FMD(−1)	12.89	−13.58	−8.76	(13.02)*	20.33
FMA	2.36	60.35*	12.03	−6.89	3.83
FMA(−1)	2.46	−28.58	8.03	9.51	−0.24
FME	−8.51	−1.92	(20.55)*	−1.41	−13.70
FME(−1)	−8.54	−3.15	8.45	−6.21	−16.32
C	−2.34	8.22	31.59	0.42	16.79

* represents the significance of the values at the 0.05 level

Table 3.6 Panel ARDL BRICS nation

Variables	Long run	Variables	Short run
FID	12.11*	COINTEQ01	−0.46
FIA	(8.22)*	D(FID)	(31.89)*
FIE	29.0409*	D(FIA)	−0.44
FMD	−4.41	D(FIE)	−0.75
FMA	2.57	D(FMD)	1.44
FME	(12.43)*	D(FMA)	3.33
		D(FME)	0.56
		C	−1.96

* represents the significance of the values at the 0.05 level

In Table 3.6 we have considered the Panel of the BRICS countries and the results depicts that in long run, overall, it shows financial institution depth and efficiency has positive impact on GDP and financial institution access and financial market efficiency has a negative impact on GDP. It states that the institutions in the BRICS regions contribute more to the economy and the financial market is not that much efficient in the BRICS regions as they are the emerging nations. In short run, financial institution has a negative impact on the economy.

3.5.5 *Dumitrescu Hurlin Panel Causality Test*

In Table 3.7 we performed the Dumitreseu Hurlin Panel Causality Test and the results of tests depicts that there is Bidirectional causality between economic growth and financial institution depth which means the institutions and economic growth go hand-in-hand and they both contribute to each other. There is also a unidirectional causality between economic growth along with financial institution access, financial market depth and efficiency. As a result, it shows that institutional access and financial market depth and efficiency contribute to the economy.

Table 3.7 Dumitrescu Hurlin panel causality test

D-H panel causality test	Causality	W-Stat	Zbar-Stat	Probability
GDP-FID	Bidirectional	5.6	3.2	0
FID-GDP	Bidirectional	5.62	3.22	0
GDP-FIA	No	1.21	−0.91	0.36
FIA-GDP	Unidirectional	5.24	2.86	0
GDP-FIE	No	2.9	0.67	0.5
FIE-GDP	No	1.56	−0.58	0.56
GDP-FMD	No	3.28	1.02	0.31
FMD-GDP	Unidirectional	4.74	2.4	0.02
GDP-FMA	No	1.55	−0.59	0.56
FMA-GDP	No	2.68	0.46	0.64
GDP-FME	No	2.39	0.19	0.85
FME-GDP	Unidirectional	4.32	2	0.05

3.6 Conclusion

The nexus between economic growth and financial development has long been studied. In this study, we looked at the BRICS (Brazil, Russia, India, China, and South Africa) area in a balanced panel from 1990 to 2020. The ARDL results indicate that individual rising nations have positive and negative results between the variables. FID and FIA have a favorable influence on GDP in Brazil. The FIA and FMA have a favorable influence on Russia's GDP. FME and FMD have a negative influence on GDP in India and China. When we analyze it as a panel, we see that financial institution depth and efficiency have a positive influence on GDP in the long run, but financial institution access and financial market efficiency have a negative impact on GDP in the short run. According to the *Dumitreseu Hurlin* Panel Causality Test, there is bidirectional causality between economic growth and financial institution depth, as well as unidirectional causality between economic growth and financial institution access, financial market depth, and efficiency. The findings of the experiments show that economic growth and financial institution depth have bidirectional causality, which means they both contribute to each other. The unidirectional causality results depict that institutional access and financial market depth and efficiency single handedly contributes to the economy.

As a consequence of the study's findings, there are many needed policy adjustments in the country's financial sector, and as these countries emerge, there is a wide range of investment opportunities in this area. The future scope of the study can be extensive as we have only considered the BRICS region. Later on, we can increase the amount of countries and can add up different variables to see the quality of study and can explore the different dimensions.

References

1. A. Afonso, M.C. Blanco-Arana, Financial and economic development in the context of the global 2008–09 financial crisis. Int. Econ. **169**, 30–42 (2022)
2. P. Arestis, P.O. Demetriades, K.B. Luintel, Financial development and economic growth: the role of stock markets. J. Money, Credit. Bank., 16–41 (2001)
3. R. Boachie, G. Aawaar, D. Domeher, Relationship between financial inclusion, banking stability and economic growth: a dynamic panel approach. J. Econ. Adm. Sci. (2021)
4. P.O. Demetriades, K.A. Hussein, Does financial development cause economic growth? Time-series evidence from 16 countries. J. Dev. Econ. **51**(2), 387–411 (1996)
5. E.I. Dumitrescu, C. Hurlin, Testing for Granger non-causality in heterogeneous panels. Econ. Model. **29**(4), 1450–1460 (2012)
6. R.F. Engle, C.W. Granger, Co-integration and error correction: representation, estimation, and testing. Econ.: J. Econ. Soc., 251–276 (1987)
7. R.W. Goldsmith, Financial structure and development. Econ. J. **80**(318), 365–367 (1970)
8. S. Guha Deb, S. Mishra, P. Banerjee, Stock market, banking sector and economic growth: a cross-country analysis over different economic cycles. Stud. Econ. Financ. **36**(3), 348–364 (2019)
9. S.J. Hsueh, Y.H. Hu, C.H. Tu, Economic growth and financial development in Asian countries: A bootstrap panel Granger causality analysis. Econ. Model. **32**, 294–301 (2013)

10. S. Johansen, K. Juselius, Maximum likelihood estimation and inference on cointegration–with applications to the demand for money. Oxford Bull. Econ. Stat. **52**(2), 169–210 (1990)
11. S. Johansen, Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econ.: J. Econ. Soc., 1551–1580 (1991)
12. S. Johansen, *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models* (OUP Oxford, 1995)
13. S. Johansen, Statistical analysis of cointegration vectors. J. Econ. Dyn. Control **12**(2–3), 231–254 (1988)
14. R.G. King, R. Levine, Finance and growth: Schumpeter might be right. Q. J. Econ. **108**(3), 717–737 (1993)
15. N. Masoud, G. Hardaker, The impact of financial development on economic growth: empirical analysis of emerging market countries. Stud. Econ. Financ. (2012)
16. R.I. McKinnon, *Money and Capital in Economic Development* (Brookings Institution, Washington, DC, 1973)
17. P. Narayan, *Reformulating Critical Values for the Bounds F-Statistics Approach to Cointegration: An Application to the Tourism Demand Model for Fiji* (vol. 2, no. 04) (Monash University, Australia, 2004)
18. H.M. Nguyen, Q.T.T. Le, C.M. Ho, T.C. Nguyen, D.H. Vo, Does financial development matter for economic growth in the emerging markets? Borsa Istanbul Rev. **22**(4), 688–698 (2022)
19. H.T. Patrick, Financial development and economic growth in underdeveloped countries. Econ. Dev. Cult. Change **14**(2), 174–189 (1966)
20. H.H. Pesaran, Y. Shin, Generalized impulse response analysis in linear multivariate models. Econ. Lett. **58**, 17–29 (1998)
21. M.H. Pesaran, Y. Shin, R.J. Smith, Bounds testing approaches to the analysis of level relationships. J. Appl. Econ. **16**, 289–326 (2001)
22. R.P. Pradhan, M.B. Arvin, N.R. Norman, S. Bahmani, The dynamics of bond market development, stock market development and economic growth: evidence from the G-20 countries. J. Econ., Financ. Adm. Sci. **25**(49), 119–147 (2020)
23. J. Robinson, *The Generalization of the General Theory, the Rate of Interest and Other Essays* (Macmillan, London, 1952), pp.67–142
24. J.A. Schumpeter, *The Theory of Economic Development* (Harvard University Press, Cambridge, 1911)
25. M. Sehrawat, A.K. Giri, Financial development and economic growth: empirical evidence from India. Stud. Econ. Financ. **32**(3), 340–356 (2015)
26. M. Sehrawat, A.K. Giri, The impact of financial development on economic growth: evidence from SAARC countries. Int. J. Emerg. Mark. (2016)
27. E. Shaw, *Financial Deepening in Economic Development* (Oxford University Press, New York, 1973)
28. D. Wahidin, A. Akimov, E. Roca, The impact of bond market development on economic growth before and after the global financial crisis: evidence from developed and developing countries. Int. Rev. Financ. Anal. **77**, 101865 (2021)

Chapter 4
A Study of Investment Decision Making in Coal Mining Company: A System Dynamic Approach

Akankika Tripathy and Mahalik Debendra Kumar

Abstract Investments decision in mining industry largely depends upon the valuation and comparative study of various available projects. The projects of mining industries are long term and their results are unpredictable in nature involving various uncertainties and risk. In order to minimize these risk and uncertainties these projects and alternative investment opportunities should be studied in terms of various impacting attributes and there casual relationship with each other. Although there are various traditional and strategic investment decision approaches are available those are guiding the industrial investment decision but those existing approach are not considering the volatility involved in the projects and the interrelationship between these mediating factors. So this paper an attempt has been made to discover those influential factors and their impact on the overall investment decision, casual relationship among them as such using system dynamics theory for the long term project investment decisions of mining company and afterward the model has been validated taking the last 25 years of data into consideration.

Keywords Investment decision · Coal mining company · System dynamic

4.1 Introduction

Coal mining industry is one of the largest industrial sectors contributing towards the overall economy of the country. Its operational efficiency and financial competence is largely based upon its long term investment decisions as these decisions have a crucial impact on overall profitability of the company and are associated with risks and uncertainties. Uncertainties relating to the mining ore, fluctuating commodity rates, exchange rates, environmental constrains, political/legal risks bring complexity to the capital investment decision faced by every decision maker involved in the

A. Tripathy (✉) · D. K. Mahalik
Department of Business Administration, Sambalpur University, Sambalpur, Odisha 768019, India
e-mail: akankika@suniv.ac.in

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_4

mining industry [1]. So there must be an efficient project evaluation technique that support the investment decisions and guide towards the optimal investment alternatives. Traditional and strategic investment decision approaches are the most common practice of evaluating investment projects in different mining, manufacturing and construction industries.

The existing approaches to capital budgeting i.e. selection of the best investment opportunity among the various available alternatives can be segregated as simple strategic and advance methods. The traditional approach of investment evaluation, includes payback period, Average Rate of Return, doesn't consider the cash flow and time value of money whereas strategic investment decision approaches such as NPV, IRR, MIRR, Profitability Index etc. where Net Present Value (NPV) represents the expected cashflows from a particular project discounted with risk adjusted discount rate, Internal Rate of Return (IRR) refers to the rate of investment at which the NPV will be zero and MIRR is just like IRR with the underlying assumption that the returns are reinvested at a definite rate. All these strategic approach emphasizes mostly on the cash flow from the investment and also consider the risk, time value of money of such cash inflows. The major drawback of these approaches discovered in various researches is that it doesn't consider the volatility of an investment project and unable to evaluate in cases where there is insufficiency of information for future (Dixit and Pindyck, 1994; Trigeorgis, 1993; Brennan and Schwartz, 1992). The Real Option Approach, Game theory approach overcome the drawback of budgeting with asymmetric information to support overall operational and financial activities [2].

Indian coal mining sector offers a unique eco friendly fuel source to energy market for the present century and future. Coal accounts for 97% of fossil sources of the country (MCL annual report). For effective utilization of this abundant source requires efficient planning of the mining and non mining activities associated with it including the investing function which is crucial as it supply the financing fuel to the other operating functions. In order to strategically operate the investing activities requires application of an appropriate approach as coal mining industry is a capital intensive sector and produce return after a significant period of production. Lilford and Minnitt (2005) explored methods for mineral deposit project valuation. The study's conclusion was that choose of an estimation methodology depends on one's capacity to accurately predict all of the existing information and on basic contributing variables (such as commodity prices, exchange rates, technical data, economic data, comparative transactions, and uncertainty risk) that are necessary for each valuation methodology to have an informed the decision-making process.

With an effort to propose an approach of investment decision making of coal mining sector overcoming the drawbacks of existing capital budgeting techniques we have undertaken a case study of Mahanadi Coal Field Ltd., the major coal producing subsidiary of Coal India Ltd. having the second largest coal reserve of India. This paper identifies the basic attributes contributing towards the Investment process of coal mining firm and the casual relationships among them. Lastly it proposes a model using system dynamic for the alternative evaluation in investing decision based on influential factors.

4.1.1 System Dynamics

Simulation models propose solution to a specific problem in a virtual spreadsheet run as a blueprint to the implication of the solution. Similarly system dynamic simulation technique pioneered by Forrester in 1967 is based upon the information feedback system. It applied in order to study and analyze the mechanism of a problem and its dynamic complexity by establishing interaction between the sub system and attributes both qualitative and quantitative with the basic principle of system thinking and using computer simulation. System dynamics is the combination of four shadow principles involving the structure of information feedback systems, sufficient supporting information regarding the actual system and decision-making processes, computer-based simulation models that represents arithmetically backed realistic systems, and interactive experimental modeling approach towards understanding the complex systems [3].

System dynamic has been a significant tool for decision making process in various industries. It has been used in different micro sectors ranging from planning and policy formulation [3, 4] studying the economic behavior [5], in public management system [6], model development for biological and medical problems [7], energy and the environment [8], in the natural and social science theory development [9], dynamic decision making [10], complex non-linear dynamics [11], software engineering [12], and supply chain management [13, 14], Barlas and Aksogan [15] and many more.

System dynamic in recent days has been evolved to be an alternative method for capital budgeting practice to different sectors. Liang et al. [16] has suggested that the production, operational efficiency of power supply enterprises can be enhanced by implementing the optimization model for the investment decisions in terms of system dynamics by optimizing the economical, financial and managerial research. It will facilitate systematic arrangements of inputs in accordance to the basic objective of the enterprise, and they emphasizes on the dynamic approach as it is essential to improve the production and resource segregation capability. Srijariya et al. [17] have used the system dynamic model in the capital budgeting of National Health Security office and illustrated that the system dynamic model as an significant tool to financial management practice that predict accurately by analyzing large and complex real life problems.

4.2 Research Design

After analyzing the existing system of investment decision making framework and the literature suggesting the implication of dynamic optimization model for the capital budgeting practice, we used system dynamic model for the systematic consideration of mediating variables, interrelationship between them providing attention toward the time constraints. The influencing variables have been identified and model has been constructed based upon existing decision making framework of Mahanadi Coal Field Ltd. using the VensimPLE 9.3.5. The model than simulated and the simulated data has been compared with the expected figures of variables pertaining to a particular mining project, considered by MCL for investment decision in order to validate the model.

4.2.1 System Definition

The selection of an appropriate investment alternative in MCL is based on evaluation of available opportunities or projects based upon the influential attributes like Production capacity, Expected cost of production including both fixed and operating, Net cash flow and NPV etc. We have identified these basic attributes contributing to MCL's capital budgeting practices.

4.2.2 Conceptual Analysis

The Fig. 4.1; has shown the basic casual loop diagram of operational and financial aspect of a mining project which is developed after considering the criterion in terms of sales, production and cost that has an effect on overall cash inflow from the particular project and the feedback loops between them, where the positive sign represents a reinforcing effect and negative sign shows balancing effect.

The casual loop diagram identifies the loops between group of variables and based on these loops the stock flow diagram is designed which is nothing but the algebraic representation of the model. The stocks define the system status, retaining a memory of it. Flow describes the change in stock in terms of inflow and outflow for a definite period and the variables determine the flow value as it shown as rates. So here the developed stock flow diagram has been algebraically strengthen by the already established equations between these variables as described in Table 4.1.

4.2.3 Model Validation

Model validation signifies to what extent the model can reflect the real situation as such it constitutes an important step for the SD modeling as it ensures the model utility in the real life scenario. Barles [18] has emphasized on behavioral test of a system dynamic model is enough for its validation. So after producing the casual loop diagram, stock flow diagram, attributes associated and the equation the model can be stimulated for a rational period. The stimulated data than compared with the actual past data to ensure that the model reflects the actual system.

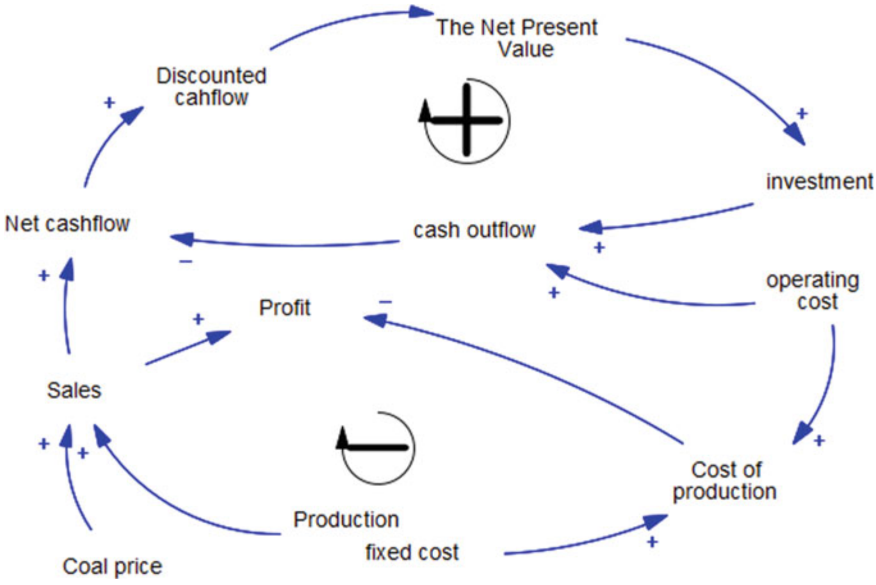


Fig. 4.1 Casual loop diagram of investment decision making system of coal mining company

Table 4.1 Variables and equations presented in SD model

Variables	Equations
Cash outflow	Investment + operating cost
Sales	Production * coal price
Cost of production	Operating cost + fixed cost
Profit	Sales − cost of production
Net cashflow	Sales − cash outflow
Discounted cashflow	Net cashflow/(1 + discounted rate)^time
The net present value	INTG(discounted cashflow, 0)

In this paper as we have considered the capital investment decision system of Mahanadi Coalfield Ltd to develop the model and the stimulated data resulted from the model has been compared with the 25 years expected data of a particular project undertaken by MCL to validate the model. After considering the formal aspect of validation proposed by Barles [18] we have chosen (Root Mean Square Error) RMSE as a statistical tool to test the model validity as they are suitable statistical indicator of reliability and sensibility that derive the absolute deviation between the actual and simulated data and indicates the actual magnitude to which they divert from each other. RMSE has been a standard tool used for model validation over the years (e.g., McKeen et al. 2005; [1, 19–21]). As we have identified from these literatures the value of RMSE ranging between 0 and 0.75 as a good performance indicator of the

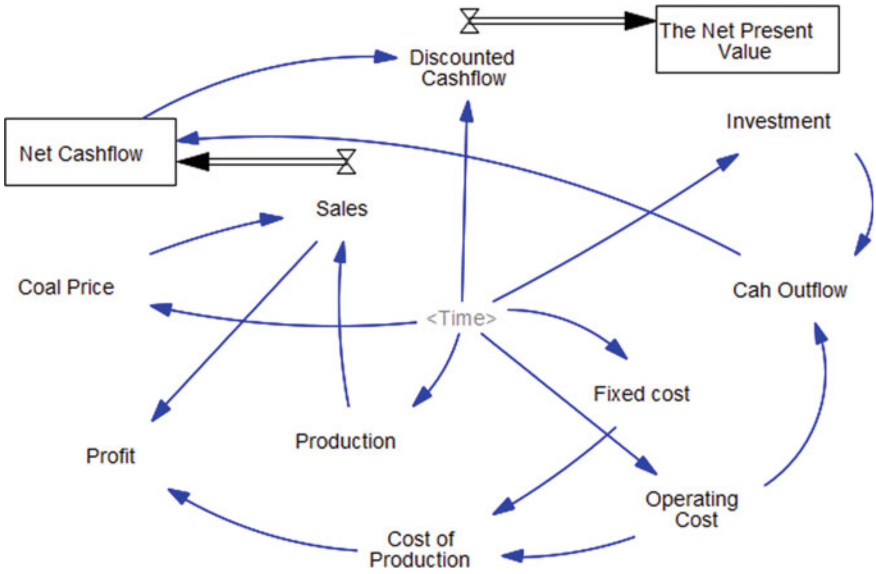


Fig. 4.2 Stock flow diagram of investment decision making system of coal mining company

model and here the value of RMSE for Net cash flow is 0.63 and for Net Present value is 0.629. So we can conclude that there is a remarkable coincidence between the stimulated and actual data. The agreement between the actual and stimulated data can be seen through the graph contained in Fig. 4.3.

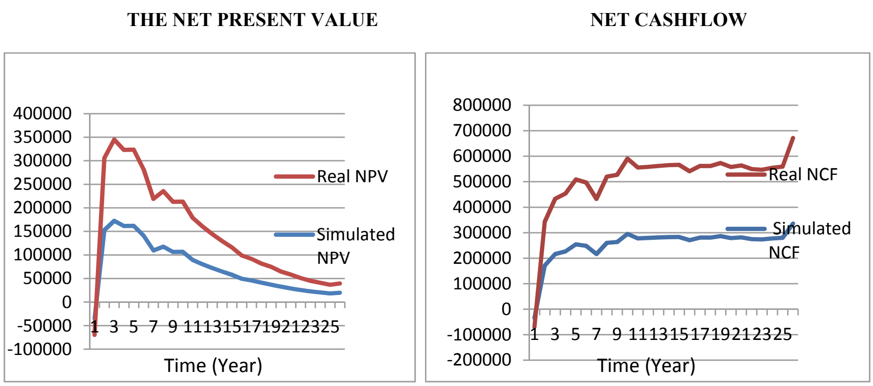


Fig. 4.3 Comparison of model's simulated output and real data

4.3 Conclusion

Investments decision in mining industry largely depends upon the valuation and comparative study of various available projects. The projects of mining industries are long term and their results are unpredictable in nature involving various uncertainties and risk. The drawback associated to existing strategic and advance approach of capital budgeting has motivated the research for an alternating suitable approach and based upon the literature we have considered the system dynamic approach for developing a more systematize decision making framework taking a case study of Mahanadi Coalfield Ltd a coal producing subsidiary of CIL. The variables has been identified their interrelationship has been studied based on feedback loop and a model has been proposed that replicate the system to a certain extent. The validity of the model also been tested in order to ensure its utility in real life. The system dynamic approach helped us to simplify the complex investment decision making system by giving due consideration to the time constrain and interrelationship between variables, uncertainties and risk like coal price changes, interest rate changes etc.

4.4 Future Scope of the Study

Although the paper presents a dynamic approach to investment decision but it has some limitations as variables to different projects may differ from those considered here. Moreover the best overall value of project and geological uncertainty involved to a mining project has been ignored which requires more advanced and appropriate optimization model which can be considered in future researches. Moreover the study framed the system dynamic model based upon the investment decision making framework of Mahanadi Coalfield Ltd and is generalized for the whole industry which generate the future scope to study the dynamic behavior of investment decision in other coal mining companies based on the suggested factors or any such influencing factor identified through further research.

References

1. D. Liu, G. Li, N. Hu, Z. Ma, Application of real options on the decision-making of mining investment projects using the system dynamics method. IEEE Access **7**, 46785–46795 (2019). https://doi.org/10.1109/ACCESS.2019.2909128
2. H.T.J. Smit, L.A. Ankum, A real options and game-theoretic approach to corporate investment strategy under, in *Source: Financial Management* (Vol. 22, Issue 3) (1993)
3. J.W. Forrester, Industrial Dynamics (Pegasus Communications, Waltham, MA, 1961)
4. J.M. Lyneis, *Corporate Planning and Policy Design: A System Dynamics Approach* (Mit Press, 1980)
5. J.C. Collins, D.E. Soper, G. Sterman, Factorization for one-loop corrections in the Drell-Yan process. Nuclear Physics B, **223**(2), 381–421 (1983)

6. J.B. Homer, C.L. St. Clair, A model of HIV transmission through needle sharing. Interfaces, **21**(3), 26–49 (1991)
7. J.E. Hansen, P. Bie, Distribution of body fluids, plasma protein, and sodium in dogs: a system dynamics model. Syst. Dyn. Rev. **3**(2), 116–135 (1987)
8. A. Ford, H.W. Lorber, Methodology for the analysis of the impacts of electric power production in the West. NASA STI/Recon Tech. Rep. N **77**, 31428 (1977)
9. M. Dill, Capital investment cycles: A system dynamics modelling approach to social theory development, 15th International system dynamics conference: systems approach to learning and education into the 21st Century, Google Scholar, (1997)
10. J.D. Sterman, Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment. Manage. Sci. **35**(3), 321–339 (1989)
11. E. Mosekilde, E. Larsen, S. John, Coping with complexity: deterministic chaos in human decision making behavior, in *Beyond Belief: Randomness, Prediction and Explanation in Science* (pp. 199–299) (CRC Press, 2018)
12. T.K. Abdel-Hamid, The dynamics of software development project management: An integrative system dynamics perspective, Google Scholar, (1984)
13. D.R. Towill, Time compression and supply chain management—a guided tour. Logist. Inf. Manage. (1996)
14. H. Akkermans, P. Bogerd, B. Vos, Virtuous and vicious cycles on the road towards international supply chain management. Int. J. Oper. Prod. Manage. **19**(5/6), 565–582 (1999)
15. Y. Barlas, A. Aksogan, Product diversification and quick response order strategies in supply chain management, August 1999, [online] Available: https://ieiris.cc.boun.edu.tr/faculuty/barlas/
16. Y. Liang, J. Zheng, J. Ye, W. Liu, X. Wang, Study on optimal strategy of investment decision of power supply company based on system dynamics, in *2018 International Symposium on Social Science and Management Innovation (SSMI 2018)* (pp. 589–599) (Atlantis Press, 2019)
17. Srijariya, A. Riewpaiboon, U. Chaikledkaew, System dynamic modeling: an alternative method for budgeting. Value Health **11**, S115–S123 (2008)
18. Y. Barlas, 'Formal aspects of model validity and validation in system dynamics.' Syst. Dyn. Rev. **12**(3), 183–210 (1996)
19. T. Chai, H.C. Kim, P. Lee, D. Tong, L. Pan, Y. Tang, I. Stajner, Evaluation of the United States national air quality forecast capability experimental real-time predictions in 2010 using air quality system ozone and NO_2 measurements. Geosci. Model Dev. **6**(5), 1831–1850 (2013)
20. N.H. Savage, P. Agnew, L.S. Davis, C. Ordóñez, R. Thorpe, C.E. Johnson, M. Dalvi, Air quality modelling using the met office unified model (AQUM OS24-26): model description and initial evaluation. Geosci. Model Dev. **6**(2), 353–372 (2013)
21. Y. Fan, R.G. Yang, Y.M. Wei, A system dynamics based model for coal investment. Energy **32**(6), 898–905 (2007). https://doi.org/10.1016/j.energy.2006.09.015

Chapter 5
Accounting Intelligent System Modeling of Financial Performance Evaluation Based on Software-Defined Network

Lijuan Du

Abstract The development of computers has entered a stage of growth in the application of computers in corporate finance. In this process, corporate finance becomes a reference tool for enterprise decision-making, an essential tool for enterprise management decision-making, and an indispensable component of enterprise management. This article comprehensively utilizes data mining technology, expert knowledge based fault diagnosis theory, and interdisciplinary financial audit theory to develop an intelligent financial audit system that can handle multiple data types and automatically discover audit clues. This article directly extracts and completes the visualization of log files attached to the underlying database, transforming information into knowledge and insight. Determine whether the user's behavior is abnormal based on information such as operation time, operation type, and operation frequency, and identify clues of suspected violations or violations. The model designed in this paper (WTL-BiLSTM), but the loss function value obtained from the final training is the smallest compared with the other two models, indicating that the classification effect is the best.

Keywords Software definition network · Financial performance evaluation · Accounting intelligence system

5.1 Introduction

From the commercialization of computers to the present, the development process of enterprise information systems can be divided into transaction oriented stages, system oriented stages, and decision oriented stages [1]. In today's rapidly developing internet information technology, traditional computerized accounting cannot fully reflect the impact and importance of internet information technology on corporate

L. Du (✉)
Jiangxi Vocational Technical College of Industry and Trade, Nanchang 330038, China
e-mail: dlj080220@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_5

accounting, let alone encompass its essence. In accounting informatization, attention should be paid to both the application of information technology and its impact on accounting work. It is different from traditional manual accounting that only focuses on accounting content, and it is also different from computer accounting, which only uses technological means for accounting and only simulates manual accounting [2]. Any economic theory or economist has its own unique or branded axiology, which is regarded as the most solid cornerstone of all its theories [3]. From the perspective of axiology, the orientation of historical value is the most basic manifestation of the historical view of economics. The fundamental contradiction between the two schools of thought is not only due to the differences in research tools and methods used, but also due to the different values on which they are based. A certain economic analysis and the proof is only an economic explanation of certain historical values [4]. From a technical point of view, business intelligence is mainly manifested in the following two levels: first, the performance indicator platform and related technologies are used [5]. Usually, the performance indicator platform generates corresponding performance indicators based on the business data in the ERP system, summarizes and analyzes a large amount of data information in the system, and realizes the solution of key indicators (KPI) with the help of a variety of different graphs and tables, including radar balls, speedometers, volume columns, etc., so as to comprehensively and systematically show the real marketing situation of enterprises; Secondly, the related technology of business analysis is introduced [6].

The enterprise fund settlement (financial management department) is also responsible for managing various funds related to the production and operation of the enterprise, and recording changes and balances of funds. By managing and supervising the increase or decrease of funds, effective supervision of corporate funds can be achieved. This enables banks and other investors to better understand and grasp the status of funds, thus enabling them to better handle the approval and disbursement of large amounts of funds. It also allows for the registration and production of large amounts of economic vouchers and accounting books, and the preparation of a large number of reports. The accounting work in the finance department is very complex. At the same time, financial data is also confidential to the company, and there are very high requirements for its security [7].

This paper uses the idea of "intelligent accounting expert decision-making system" to study this topic, and explores the establishment of an accounting intelligent system model for the financial performance evaluation of transnational corporations, so as to realize the overall system modeling of the financial performance evaluation of transnational corporations, and proposes a new method for the financial performance evaluation of transnational corporations. The intelligent accounting expert decision-making system is a new type of accounting intelligent system that integrates traditional accounting decision support systems based on data and models with knowledge-based accounting expert modules, and further integrates and develops them. Its biggest feature is the organic integration of management principles of decision-making models and expert databases, forming an intelligent and unified management system. From the perspective of financial management, analyze the financial software of enterprises, rationally analyze the functions of financial software in practical applications, provide corresponding solutions for major contradictions and problems, and compare current financial software based on the future development trend of the software, draw lessons from it, and correct shortcomings.

5.2 Accounting Intelligent System Modeling for Financial Performance Evaluation

5.2.1 The Composition of Accounting Intelligence System for Financial Performance Evaluation

Financial intelligence is to model the financial management theory, import the data into the data warehouse through intelligent matching, or take a certain data source as the analysis object. According to the financial management model, the data in the data warehouse can be processed by using the high-speed and accurate computing power of the computer to quickly get the business diagnosis report, monitor the financial information in real time, form business decision suggestions and provide financial early warning information [8]. Financial intelligence system not only emphasizes traditional bookkeeping, accounting, production management and cost management, but also emphasizes management contents such as control, planning, forecasting, analysis and decision-making [9]. Compared with the traditional financial model, the financial intelligence system model has the characteristics of universality, interactivity and visualization, and is more suitable for financial personnel and managers [10]. As shown in Fig. 5.1.

Finally, this article believes that the focus of value chain accounting research is to expand the internal and external relationships of enterprises to external relationships of enterprises, thereby breaking through the limitations of enterprises on enterprise entities in the enterprise accounting system. The scope of value chain accounting extends with the extension of the value chain, which includes three types of value integration: vertical value chain extension mainly refers to the industrial chain in which enterprises are located, especially the integration between upstream and downstream enterprises; The extension of the horizontal value chain is mainly reflected in competition and cooperation between companies, and the externalization of company behavior is manifested in the diversification of relationships between companies; The extension of the value chain related to the environment mainly refers to the integration of enterprises and their living environment. Due to the impact of enterprise behavior on the living environment, changes in the living environment can have an impact on the survival of enterprises. The above-mentioned enterprise data mainly include business orders, bills, inventory, industry opponent data and industry information data, as well as various data of the external environment of the enterprise. Business intelligence is an assistant to the correct decision-making of enterprise business operation, which is applicable to every decision-making level, that is, tactical

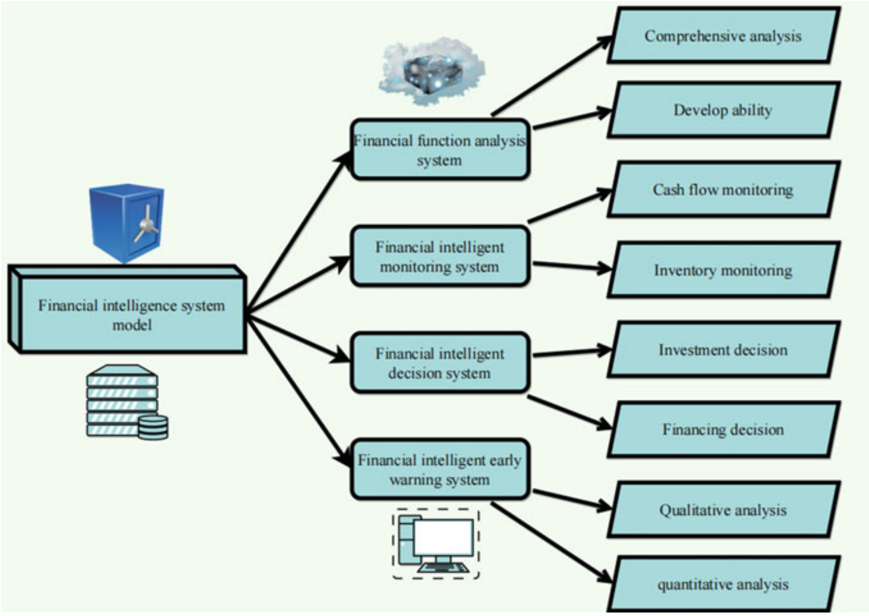


Fig. 5.1 Functional structure of financial intelligence system

level, operational level and strategic level. To convert enterprise data into knowledge, other technologies must be used for processing, such as data mining, data warehouse, online analytical processing, etc. The data of the enterprises mentioned above mainly includes commercial orders, bills, inventory, data of industry competitors, industry information data, and various data of the external environment of the enterprise. Business intelligence can help companies make the right decisions in business operations, and it can be applied at every decision-making level, including tactical, operational, and strategic levels. In order to turn company data into knowledge, other technologies such as data mining, data warehousing, online analysis, etc. need to be applied. This article aims to help managers at all levels of the company better understand the current business situation, so that the company can make correct decisions in its future development. Among them, data mining technology, data backup technology, and data warehouse technology are key technologies for enterprises to achieve business intelligence. It is also related to the application of software and hardware. The basic architecture is composed of three parts, namely data mining, data warehouse and online analytical processing. The bottom-up relationship of this H part is shown in Fig. 5.2.

The informatization construction of enterprise financial system includes the application of enterprise financial software and its accounting subsystem. From the perspective of financial accounting, the completion of enterprise financial management is the service goal of enterprise management, so that first of all, the financial

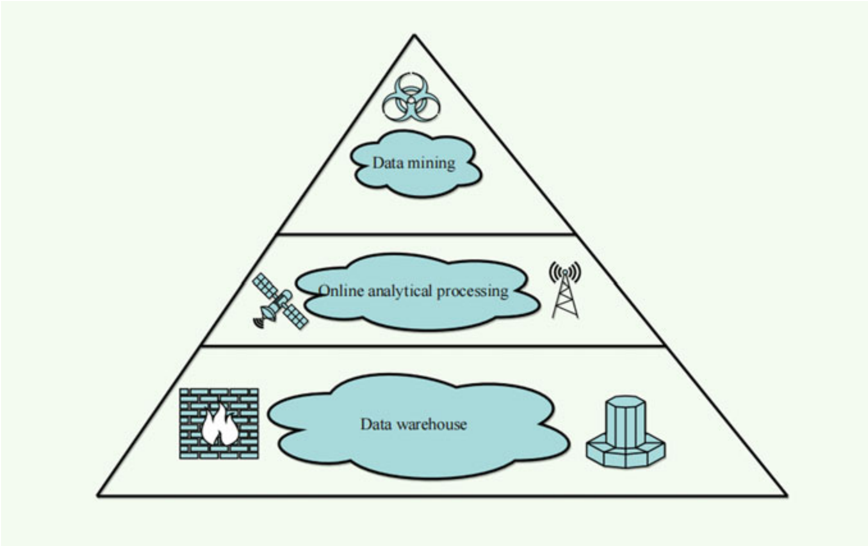


Fig. 5.2 System architecture

accounting function, information processing function, accounting supervision function, etc., enterprise production and management provide auxiliary services, which is consistent with the development of enterprise management informatization. At the data level, the use of data manipulation components at the data level provides a unified and standardized data manipulation object to the business collection layer of the system, making the business logic layer a rooted tree that is a living stream; And detailed information about the data. When processing data, the business layer cannot obtain data from the system database. There are various types of business data, including both shared data for various types of users and private data that only users with relevant operational permissions can use. On this basis, various data components in the data layer are combined to form a component library that can perform multiple operations on system data.

5.2.2 Financial Intelligent Decision System

The most important function of financial management is to make decisions on major investment and financing projects of enterprises and manage daily working capital. However, the current performance evaluation method based on financial indicators makes enterprises pay too much attention to obtaining and maintaining short-term financial results, and enterprises are unwilling to make capital investment that may cause the current profit level to decline in pursuit of long-term strategic goals, so they invest too much in short-term performance and too little in long-term value creation, which inhibits the ability of enterprises to create future value. At present, many enterprises have invested a lot of time and money to build online analytical processing business systems and office automation systems to record the relevant data of various transactions.

According to statistics, in the past two H years, a massive amount of data has been continuously increasing at a geometric progression rate, containing a large amount of commercial value. However, this is only the result of insufficient utilization of existing data resources. In theory, corporate financial early warning is a special regulatory approach. Firstly, it is the cross integration of multiple disciplines such as finance, accounting, and statistics; Secondly, this article employs various analytical methods such as comparative analysis, factor analysis, and proportional analysis; Thirdly, an analysis and comparison were made of the information and resources available to each company; Finally, through the research of this project, we can identify potential risks that may arise in the operation of the company, so as to promptly remind policy makers and help them develop corresponding strategies to reduce potential risks. For shareholders, if in the period of inflation, financing can significantly reduce the investment risk of enterprises; if in the period of economic activity, financing can help enterprises improve the rate of return; if in the period of economic downturn, reducing financing can well avoid financial risks and reduce capital expenditure.

5.3 Accounting Intelligence System for Financial Performance Evaluation Based on Software Definition Network

5.3.1 Financial Statement Audit Analysis Model

For example, enterprises and administrative institutions differ greatly in their account data due to their different nature and accounting systems. Therefore, the audit analysis model is not universal and unchangeable. The specific model should be built by auditors according to the nature of different units.

Above, the per capita expenditure and total per capita expenditure of 34 colleges and universities are calculated respectively for the subject i. In order to find out the colleges and universities with the most abnormal expenditure under the subject i, this paper designs a formula (5.1) to measure the degree of difference in the subject n, and comprehensively consider the differences between colleges and universities themselves and other colleges and universities m, and find out. It mainly includes two parts, $E^*_{m,n,i,j}$ is to calculate the degree of difference of its own changes over the years, and formula (5.1) is the degree of difference with other universities.

$$\frac{f_{m,n,i,j} - F_{n,i,j}}{F_{n,i,j}} \tag{5.1}$$

$$E_{m,n,i,j} = E^*_{m,n,i,j} * \frac{f_{m,n.i.j} - F_{n,i,j}}{F_{n,i,j}} \tag{5.2}$$

$$E^*_{m,n,i,j} = \frac{f_{m,n,i,j} - M_{n,i,j}}{M_{m,i,j}} \tag{5.3}$$

$$M_{m,i,j} = \frac{\sum_{n=1}^{3} f_{m,n,i,j}}{3} \tag{5.4}$$

Among them, $E^*_{m,n,i,j}$ is the difference of the subject itself; formula (5.1) indicates the degree of difference from the population; $M_{m,i,j}$ is the average of the subjects for 13 years.

After getting the difference value, the top 20% universities with large difference are selected as the key audit objects by default.

On this basis, corresponding audit rules and audit analysis models were established. On this basis, an audit expert knowledge base was established and its content was analyzed. After the entire audit mode generates an important audit target, it will be found whether there are corresponding rules in the knowledge base. If there are corresponding rules, they will be directly called and used for reasoning and analysis together with the model. Only on the basis of the value chain can a company gradually shift towards a value chain based business model and a value chain based business model. When a company wants to operate its value chain, its foundation has shifted from a single business activity to an economic activity based on the entire industry. Of course, this requires a highly mature market and more coordinated products and sales services. Under the current market conditions, enterprises are not yet able to complete the entire process of the value chain well. However, the construction of a new performance evaluation system based on value chain accounting can provide some basis for the entire process of enterprises.

5.3.2 Research on Simulation Results

Accounting voucher is a type of voucher used to record economic activities, which includes: voucher summary, debit and credit account code, debit and credit account name, debit and credit amount, etc. In these aspects, traditional audit methods do not pay attention to the summary of vouchers. Usually, after discovering some suspicious clues, auditors will verify the voucher summary table to determine whether it is a financial illegal act, which is called "finding evidence with clues". However, few people directly discover audit clues based on the voucher summary table. Credential summary is a summary description of business activities. As for an accounting account, due to the similarity of its economic transactions, accountants often use certain financial professional terms related to the account when preparing voucher summaries. Therefore, voucher summary is related to accounting subjects, and the accounting subjects corresponding to similar voucher summaries are generally the same. The traditional financial intelligence implementation strategy has a long battle line, and it is difficult to establish a data warehouse. The fundamental reason for this phenomenon is that data warehouses should be theme oriented, while managers do not fully understand the requirements. In addition, due to the rapid changes in the social environment, the content of the project is constantly changing, increasing the difficulty of project execution. Without the support of senior leaders, the execution of the project will be difficult, and in severe cases, it will also lead to the failure of the project. By utilizing low-risk financial intelligence strategies, managers can easily see visual data display and analysis through certain simplified programs, providing decision-making support, and continuously communicating and understanding their needs with managers during this process.

Because there is no certain amount of correlation between the test sample data and the training sample data, this paper uses the test sample data as the test data to study, which can directly reflect the survival of the fittest of the network. In addition, the researchers also used 80 sets of test data to simulate the output of the sample data of the network, and compared the calculated error. The prediction error is expressed in error, and the prediction error rate is expressed in error rate. Therefore, when researchers use sim () function to study the analog output of the network, the error value between the output value and the actual value is small, which can represent the credit rating model to a certain extent. This paper also studies the predicted and actual values of some test samples, as shown in Table 5.1.

This paper can directly see from the table that the error rate between the predicted value and the actual value of the sample data is getting smaller and smaller. It can be seen that the simulation ability of the evaluation indicators of asset management is very good. As shown in Figs. 5.3 and 5.4.

By comparing the loss function change charts of the three models, it can be seen that the bidirectional LSTM model based on word vector (W-BiLSTM) drops to the stable value at the fastest speed, and our WTL-BiLSTM model (WTL-BiLSTM) obtains the minimum loss function value in the final training, which shows that the classification effect of this model is the best. The results indicate that among the three models, the WTL-BiLSTM model, W-BiLSTM model, W-LSTM model, and W-LSTM model have higher classification accuracy. Divide the operation records of financial software into two parts: software record files and basic database record files. On this basis, a dataset design method based on datasets was proposed. However, in practical applications, some users with specific permissions may enter the underlying database and change the form of their recorded actions, which poses a threat to the

Table 5.1 Predicted and actual values of test samples

Serial number	Expected value	Actual value	Prediction error value	Prediction error value
1	1.34575	3.12453	−1.33452	−0.2833
2	4.26124	4.2154	0.02123	0.04634
3	1.12456	1.24310	−0.44342	−0.0164
4	2.35162	2.26424	−0.01422	−0.0046

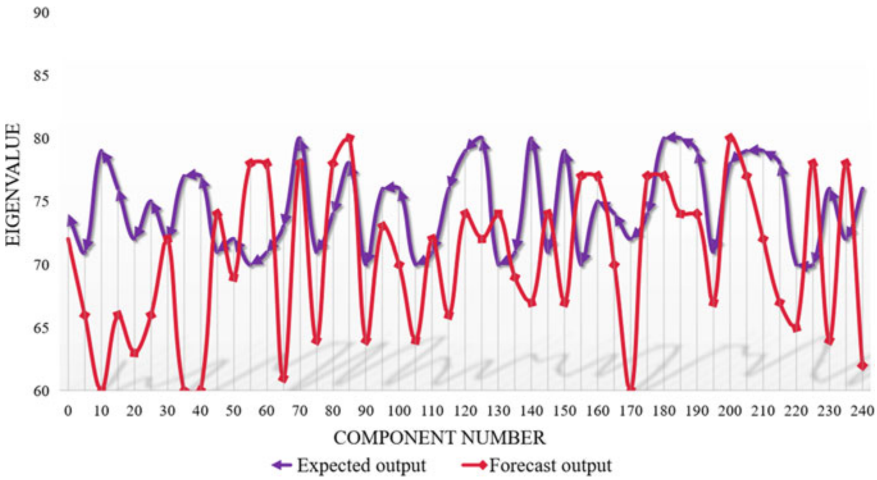


Fig. 5.3 Predicted input value and expected output value of detection data

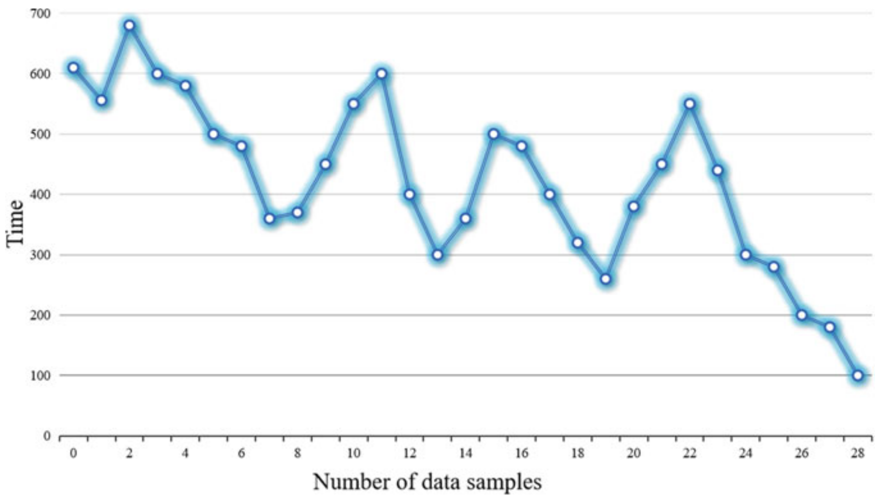


Fig. 5.4 Prediction error value of test data

security of the software. The log files, along with the base database, will also provide details of the actions taken by the user on the database and will not be changed. In this way, we can directly extract log files associated with low-level databases and convert this information into knowledge and insights. By using information such as the time, type, and frequency of operations to assess user behavior, potential issues such as exceeding authority and violating the law can be identified.

5.4 Conclusion

Financial intelligence is a product that adapts to the development and changes of economic forms. From the perspective of enterprise management, it combines advanced international financial management concepts with sound financial management systems, and utilizes multi-dimensional and in-depth analysis of financial data to improve the timeliness of financial data organization. On this basis, a fuzzy control method based on fuzzy logic is proposed. This article starts with requirement analysis, goes through many twists and turns, and ultimately draws on mature software from other companies to complete the design of the entire system. This company has many financial systems. For a long time, the data in databases has been very complex, which has brought many difficulties to the design and operation of databases. Thanks to the help of my supervisor and colleagues, many problems were successfully solved. During this process, I feel that my abilities have greatly improved. During the testing process of this system, we found that there were still certain issues with its audit of new users, and made corrections to it. A group has been added to the system waiting to confirm if the user ID is correct, and new users are managed by it. After the user registration is completed, the system will issue an audit request to the system administrator to verify the identity of the new user. I will focus my future work on optimizing the software definition architecture to better adapt to the RPL routing protocol and respond quickly to malicious attacks from both external and internal sources, detecting and isolating malicious nodes with minimal cost.

References

1. O. Yurekten, M. Demirci, Citadel: cyber threat intelligence assisted defense system for software-defined networks. Comput. Netw. **191**, 108013 (2021)
2. L. Yao, Financial accounting intelligence management of internet of things enterprises based on data mining algorithm. J. Intell. Fuzzy Syst. **37**, 5915–5923 (2019)
3. B. Hussain, Q. Du, B. Sun, Z. Han, Deep learning-based DDoS-attack detection for cyber–physical system over 5G network. IEEE Trans. Ind. Inf. **17**, 860–870 (2020)
4. B. Gao, Research and implementation of intelligent evaluation system of teaching quality in universities based on artificial intelligence neural network model. Math. Probl. Eng. **2022**, 1–10 (2022)
5. Y. Luo, D. Ren, Influence of the enterprise's intelligent performance evaluation model using neural network and genetic algorithm on the performance compensation of the merger and acquisition parties in the commitment period. PLoS ONE **16**, e0248727 (2021)
6. E. Pay. Bosch, L. Bori, A. Beltran, V. Naranjo, M. Meseguer, P–141 artificial intelligence system for the automation of the blastocyst morphology evaluation in GERI Time-lapse Incubator. Hum. Reprod. **36**, deab130 140 (2021)
7. B. Hashemi, S. Taheri, A.-M. Cretu, E. Pouresmaeil, Systematic photovoltaic system power losses calculation and modeling using computational intelligence techniques. Appl. Energy **284**, 116396 (2021)
8. H. Seibt, A. Beyer, M. Häfner, C. Eggert, H. Huber, T. Rath, Sa2027 Evaluation of a real-time artificial intelligence system using a deep neural network for polyp detection and localization in the lower gastrointestinal tract. Gastrointest. Endosc. **91**, AB249 (2020)

9. J. Tang, L. Hai, Construction and exploration of an intelligent evaluation system for educational APP through artificial intelligence technology. Int. J. Emerg. Technol. Learn. **15** (2021)
10. S. Hamal, Ö. Senvar, Comparing performances and effectiveness of machine learning classifiers in detecting financial accounting fraud for Turkish SMEs. Int. J. Comput. Intell. Syst. **14**, 769–782 (2021)

Chapter 6
Application Design of RPA Financial Robot Integrating Financial Big Data and Financial Sharing Services

Lu Wang, Yan Shen, Shaochun Liang, Nan Zhou, Changping Jia, and Ping Shang

Abstract Driven by big data, a new financial management model, which effectively integrates financial business, reengineers processes, optimizes organizational structure and standardizes processes, has gradually become the goal of enterprise financial sharing center to improve management efficiency, reduce financial accounting costs and improve service quality. The application of RPA, namely financial robot, can effectively make up for the shortcomings of financial sharing center. This paper proposes an intelligent analysis and processing technology of financial big data based on deep belief network (DBN), and applies artificial intelligence and data mining technology to financial data analysis and risk early warning. The simulation results show that after many iterations, the MAE of this method is obviously superior to the traditional back propagation neural network (BPNN) model, and the error is reduced by 32.78%. The results show that the improved DBN enhances the robustness of the model and the rationality of the initial weight threshold setting on the basis of maintaining the prediction advantage of DNN, and effectively improves the prediction performance of the prediction model. With the improvement of algorithm supported by data mining and artificial intelligence technology, the application of RPA financial robot in financial sharing service center can greatly improve work efficiency and accuracy, and promote the intelligent transformation of enterprise finance.

Keywords RPA robot · Financial big data · Artificial intelligence · Data mining

L. Wang (✉) · Y. Shen · S. Liang · N. Zhou · C. Jia · P. Shang
Shandong Vocational and Technical University of International Studies, Rizhao 276800, China
e-mail: 346465193@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_6

6.1 Introduction

Modern information technologies, such as big data, cloud computing, AI and network management, have promoted the coming of the era of financial management in smart enterprises, especially in the fields of charge processing, purchase and payment, corporate account accounting and tax management [1]. Faced with massive data and tedious daily work, financial personnel have been unable to meet the needs of traditional information technology, and it is urgent to solve it through digital intelligent tools [2]. DM is a new technology with the development of AI and database technology in recent years. It is an advanced processing process to screen out implicit, credible, novel and effective information from a large amount of data. Nowadays, financial transformation has officially entered the intelligent stage, which is the new direction of financial informatization development after the financial integration software stage and the financial business integration stage [3]. Financial intelligence is based on big data, cloud technology, Internet of Things, blockchain, AI and other information technologies, and uses technology engines and big data and other information technology means to empower the financial digital transformation of group enterprises [4]. The application of RPA robot can effectively improve the organization mode, resource utilization, workflow and value output of enterprise finance, effectively promote the improvement of enterprise financial management ability, and become a solid foundation for enterprise financial transformation and development. Man–machine cooperation has become a consensus [5].

The continuous emergence of emerging technologies and the rapid development of AI empower the financial management reform and promote its gradual transformation from informationization to intelligence and digitalization. Enterprises want to grow and develop without the participation of financial management, and the specific contents of financial management work by management mainly include analyzing enterprise financial indicators, monitoring and reducing enterprise financial risks, and making financial decisions [6]. Therefore, perfecting and optimizing the financial decision support system is of great significance for enterprises to improve the level and quality of financial management, comprehensive market competition and profitability [7]. By collecting information technology, the business process of financial management can be reconstructed and combined with more professional financial management to provide financial sharing services, which not only improves the scientific nature of financial information, but also ensures the quality. RPA is an intelligent software, which can perform complex tasks through the operation interface [8]. RPA robot is also an important application of RPA in the field of financial services, which mainly adopts RPA software technology and integrates all kinds of knowledge and skills, thus replacing traditional manual financial applications and digital information technology [9].

6.2 Related Works

With the development of AI technology, in order to improve the accuracy and efficiency of asset management, the integration of AI technology and accounting theory has become a research hotspot. Jain et al. pointed out that the future development of the accounting industry will inevitably require the combination of AI, and put forward a smart accounting scheme that integrates AI application, accounting theory and practice [13]. Vanneschi et al. put forward a dynamic financial early warning system based on AI technology to solve the problem of accurate supervision and prediction of wealth in the stock market [14]. Letaief et al. put forward an improved idea of incremental updating algorithm from the perspective of sensitivity and time efficiency in order to solve the problem that incremental updating algorithm cannot find new patterns in new data [15]. Chen et al. studied the distributed reinforcement learning algorithm, and realized the identification of abnormal financial data by establishing a reasonable financial data analysis index system [16]. Li et al. used deep learning and network to build an internal intelligent audit system based on financial sharing mode [17].

Most of these studies focus on the theoretical analysis of accounting, and only give the financial model analysis but not the specific implementation plan, which leads to poor realization. Based on this, this paper puts forward an intelligent analysis and processing technology of financial big data based on DBN, and applies AI and data mining technology to financial data analysis and risk early warning, thus providing algorithm support for the technological innovation of RPA financial robot.

6.3 Methodology

6.3.1 Technical Characteristics of RPA Financial Robot

RPA financial robot is a kind of computer intelligent programming software that automatically executes financial workflow or tasks according to the designed rules and instructions. Its working principle is to use robots as virtual labor force through software automation, and complete financial business work with high repeatability and clear rules according to preset procedures. As the most widely used and mature skill technology in the field of intelligent finance, RPA financial robot can help enterprises collect big data and mine related financial data, and realize data visualization and operational recycling. RPA financial robot technology itself is based on information financial management software, follows certain rules, and relies on computer interface to meet intelligent financial management services. On the basis of actual financial management, its main function is to simulate manual management and prevent repeated transactions [10]. The work form of financial sharing service center is mainly to effectively integrate the financial work content of enterprises, and realize the financial cost control of enterprises by integrating and optimizing the financial workflow. This standardized and unified management model has reduced the demand for financial personnel of branches and subsidiaries, and reduced the expenditure of hiring a large number of accounting personnel, thus reducing costs and improving efficiency.

Independent RPA user interface is a financial robot that will not destroy or destroy the existing financial system structure, and can meet the requirements of system-wide data flow. It has great application potential in the fields of finance, procurement, supply chain and customer service [11]. Therefore, RPA process robot greatly improves the efficiency of financial work, liberates financial personnel from tedious daily business, and shifts the focus of financial work to forecasting, cost management, financial analysis and business decision. RPA has the advantages of cross-application and multi-function. It can simulate people to perform repetitive and intensive operations with lower cost, faster speed and higher precision, and interact with existing user systems through preset programs to improve production efficiency and create smarter and more optimized financial management mode for enterprises [12]. RPA financial robot can automatically process data in batches, with high speed and accuracy, which generally helps the financial sharing service center to achieve a qualitative leap in efficiency and quality in financial management. Compared with traditional financial management, financial robots have changed the working methods of financial personnel, significantly improved the overall work efficiency and service quality of financial personnel, and at the same time improved the production efficiency of products, thus achieving the goal of sustainable development.

6.3.2 Financial Data Analysis and Risk Pre-alarm

The RPA financial robot is applied to the financial sharing center, which replaces the manual operation with high repeatability and regularity, automates the financial workflow, liberates part of the labor force, and can create more value in financial work [13]. Compared with manual financial management, the automated workflow reduces the operating cost of personnel. The intelligent financial risk pre-alarm model based on DBN is shown in Fig. 6.1.

The application of financial robots in the financial sharing service center replaces simple and repetitive manual operations with an all-day automatic working mode, which liberates part of the labor force, improves financial work efficiency and reduces operating costs. The financial sharing center can solve the problem of data flow in financial accounting with the help of RPA technology, break through the space limitation between systems, link the two independent links of system operation and data collection, and reduce the problems in data entry [14]. RPA computer imitates human behavior and helps enterprises to realize process automation, thus processing data in a standardized and high-quality way. The financial robot has complex logical judgment ability, completely simulates human behavior for information input, data reading, application system operation, report making and other operations, and provides an

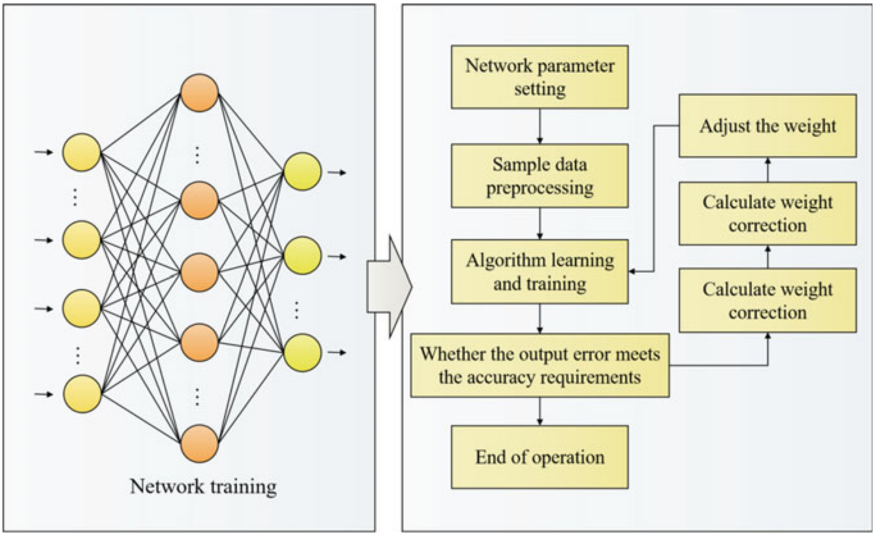


Fig. 6.1 Intelligent financial risk pre-alarm model based on DBN

image-based process automation designer without writing code, so that both general business personnel and IT developers can easily control the process automation.

Assume that the relevant financial indicators are set as X , and assume that there are N financial indicators. Let $X_1, X_2 \ldots, X_n$ independent variable, financial risk be set to Z, the value of Z is between 0 and 1. Predict the probability of financial risk occurring.

$$\sum(Z_i) = f\left(\beta_1 x_1 + \beta_2 x2 + \ldots + \beta_p x_{ip}\right) \tag{6.1}$$

When $Z = 0$ and $Z = 1$, Z is not sensitive to changes in X , and X needs a large change to cause a weak change in Z. Small changes in Z will have large changes in $\partial(p)$, which will change the function.

$$\frac{\partial\theta(Z)}{\partial Z} = \frac{1}{Z} + \frac{1}{1-Z} \tag{6.2}$$

Available:

$$\theta Z = 1n\left(\frac{Z}{1-Z}\right) = X'\beta \tag{6.3}$$

Due to:

$$1n\left(\frac{Z}{1-Z}\right) = X^T\beta \Rightarrow \frac{Z}{1-Z} = e^{XT\beta} \Rightarrow Z = \frac{e^{XT\beta}}{1+e^{XT\beta}} \tag{6.4}$$

Obtain:

$$Z = \frac{e^{X'\beta}}{1+e^{X'\beta}} \tag{6.5}$$

With the support of cloud technology, enterprise management can make reasonable decisions in the shortest time to avoid financial risks, form targeted and reasonable problem solutions and improvement plans for financial sharing centers, and improve the financial management level and efficiency of financial decision-making. Through several rounds of training of noisy data samples, the system can extract various weight matrices between input layer, hidden layer and output layer.

6.4 Result Analysis and Discussion

At present, many enterprises have begun to implement financial sharing centers. By using financial software, the workload of financial staff is reduced, and the efficiency of business processing is significantly improved, freeing financial staff from heavy financial work [15]. Financial robots are most suitable for repetitive and deterministic processes with clear definitions and few exceptions, that is, they are suitable for a large number of transactions with established rules, interact with multiple applications by using specific software algorithms, automatically complete various management tasks, and execute transaction processes in the user interface. By using RPA, the financial robot replaces the financial staff, and the quality and efficiency of the work will be improved, effectively reducing a lot of repetitive work. If we can't change the financial work mode, it will have a serious impact on the development of enterprises. Therefore, RPA technology should be applied to the financial sharing center in time to promote the transformation of enterprise financial work, realize financial sharing and improve the quality and efficiency of development.

In order to prevent the leakage and loss of important information data in the financial sharing service center, enterprises should back up the original data before business processing, save the storage files in time when executing the process, and encrypt the sensitive information data. For financial robots that contact with important information, they should be deployed in the intranet or set up an external network robot separately for the process business that needs to be connected to the external network, and then carry out data conversion. By training the designed DBN with discrete financial data, a better network weight can be obtained. Then, substituting the obtained network weights into the neural network can become the basic model of financial risk pre-alarm. Compare the DBN output data with the real financial data, as shown in Fig. 6.2.

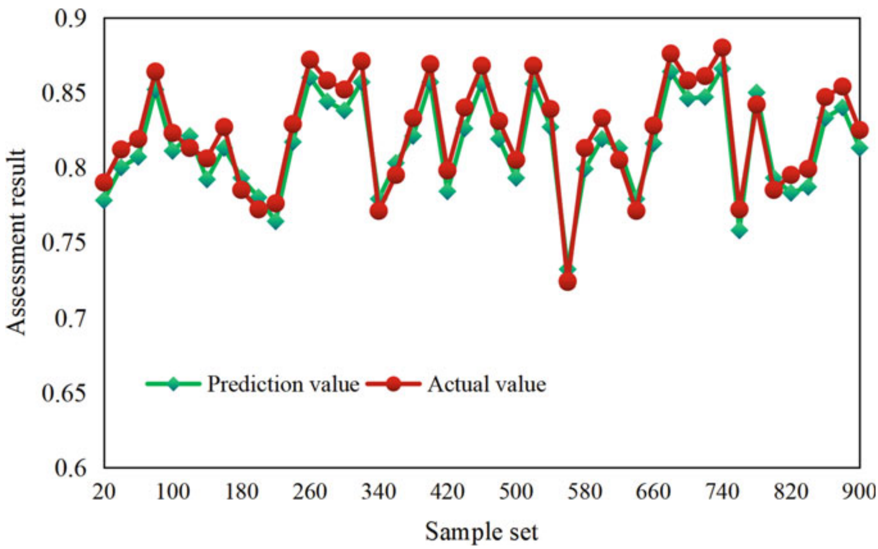


Fig. 6.2 DBN learning results

It is not difficult to see that the result of DBN learning is convergent and can approximate the original data well. Filter the rules according to the time sequence constraints satisfied by the front and back attributes of the rules, and get the time sequence rules. The prediction accuracy of different algorithms in financial data analysis of RPA financial robot is shown in Fig. 6.3.

The model in this paper predicts that the fitting degree between the output value and the expected output is better than that of the traditional BPNN, mainly because the model in this paper adds noise reduction characteristics to the input data on the basis of self-coding neural network, optimizes the original input data, increases the robustness of the extracted features, and improves the data generalization ability of DNN.

There are two main factors that affect the output of the pre-alarm model, namely, whether the learning ability of the model is efficient and whether it has excellent generalization ability, and the input and output variables in the model will also affect the implementation effect of the model. Comparing the MAE of this model with that of the traditional BPNN model, the result is shown in Fig. 6.4.

As can be seen from Fig. 6.4, after many iterations, the MAE of this method is obviously superior to the traditional BPNN model, and the error is reduced by 32.78%. The results show that the improved DBN enhances the robustness of the model and the rationality of the initial weight threshold setting, and effectively improves the prediction performance of the prediction model, which can provide algorithm support for the technological innovation of RPA financial robots. With the algorithm improvement supported by DM and AI technology, the application of RPA financial robot in financial shared service center can greatly improve work efficiency and

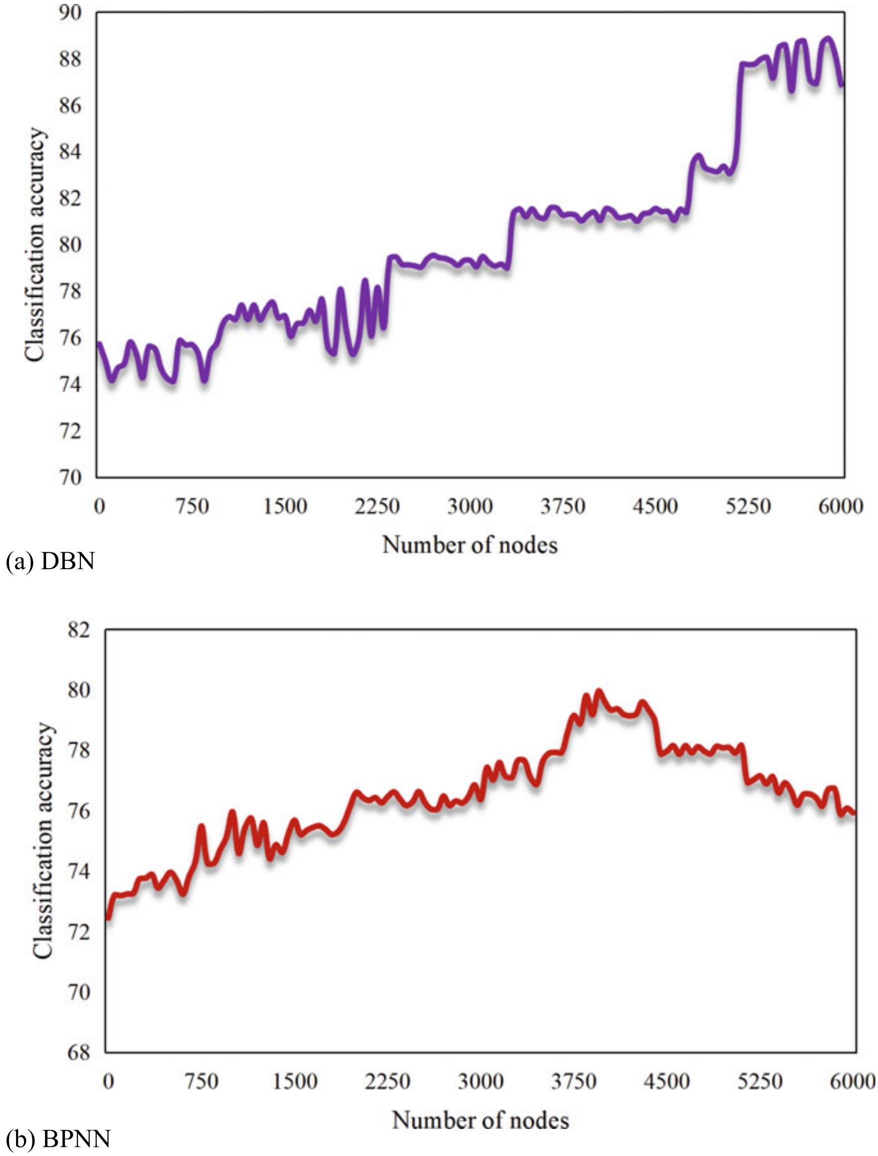


Fig. 6.3 Prediction accuracy of different algorithms in financial risk management

accuracy, save financial operating costs, strengthen risk management and control, free accountants from repetitive work with low added value and turn to management consulting, data analysis and value-added services, thus promoting the intelligent transformation of enterprise finance.

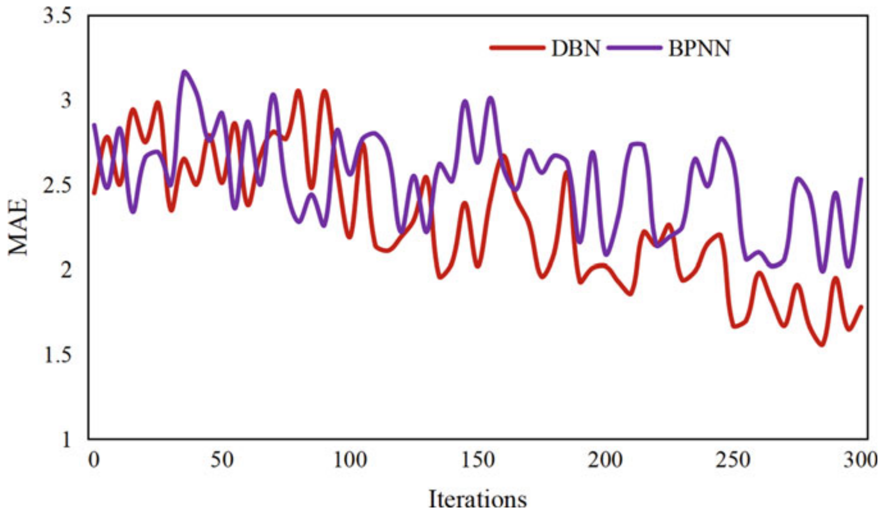


Fig. 6.4 Comparison of MAE

6.5 Conclusions

In the digital era, the application of intelligent automation and emerging technologies in the field of accounting can further reduce costs and increase efficiency, give full play to the flexibility of financial management functions, and continuously inject new vitality into economic development. Different from traditional ERP software, RPA financial robots tend to repeat operations quickly and automatically. This paper presents an intelligent analysis and processing technology of financial big data based on DBN, which applies artificial intelligence and data mining technology to financial data analysis and risk early warning, thus providing algorithm support for the technological innovation of RPA financial robot. The results show that after many iterations, the MAE of this method is obviously better than the traditional BPNN model, and the error is reduced by 32.78%. On the basis of maintaining the advantages of DNN prediction, the improved DBN enhances the robustness of the model and the rationality of the initial weight threshold setting, effectively improves the prediction performance of the prediction model, and can provide algorithm support for the technological innovation of RPA financial robots.

Based on computerization and automation, the financial robot integrates the financial sharing service center into RPA technology, which accelerates the financial management process of the whole company. It is precisely because of these characteristics that it provides a huge development space for financial robots based on RPA technology. There are still some shortcomings in this system, such as: the training time of neural network is long, and the initial value of the network is not given guidance. The optimization of the initial network value and the adaptation of network parameters in the system will be the further research direction.

Acknowledgements The Ministry of Education of the People's Republic of China's industry-university collaborative education project: "RPA Financial Robot Development and Application Course Construction" (No.: 220500353312616).

References

1. X. Wang, Research on the analysis of internet financial risk based on data mining. Revista De La Facultad De Ingenieria **32**, 720–729 (2017)
2. J.Q. Trelewicz, Big data and big money: The role of data in the financial sector. IT Prof. **19**, 8–10 (2017)
3. A.S. Edu, Positioning big data analytics capabilities towards financial service agility. Aslib J. Inf. Manag. **74**, 569–588 (2022)
4. J. Tang, C. Li, Y. Fu, C. Li, The Borderless Integration of Financial Management Innovation Using Big Data Analysis of Social Media. Wireless Communications and Mobile Computing 2022 (2022)
5. F. Ying, Study on the early warning system construction of financial affairs for innovative enterprises. Revista de la Facultad de Ingenieria **32**, 290–298 (2017)
6. Y. Liu, Z. Yu, Y. Yang, Diabetes risk data mining method based on electronic medical record analysis. J. Healthc. Eng. 2021 (2021)
7. L. Mao, Analysis on the enterprise financial risk based on interactive data association rule mining technology. Boletin Tecnico/Technical Bulletin **55**, 772–781 (2017)
8. T. Zheng, T. Wang, Application of data mining technology in internet financial risk analysis. Revista de la Facultad de Ingenieria **32**, 124–133 (2017)
9. L. Bonnafous, U. Lall, J. Siegel, An index for drought induced financial risk in the mining industry. Water Resour. Res. **53**, 1509–1524 (2017)
10. X. Gong, Z. Wang, L. Wang, Research on financial early warning model for papermaking enterprise based on particle swarm K-means algorithm. Paper Asia **34**, 41–45 (2018)
11. M. Qu, Y. Li, Financial risk early-warning model based on kernel principal component analysis in public hospitals. Math. Probl. Eng. **2021**, 1–7 (2021)
12. S. Tian, H. Yue, Construction and research on enterprise financial crisis early warning based on artificial intelligence neural network. Boletin Tecnico/Technical Bulletin **55**, 19–27 (2017)
13. A. Jain, Y. Sharma, K. Kishor, Financial supervision and management system using Ml algorithm. Solid State Technol. **63**, 18974–18982 (2020)
14. L. Vanneschi, D.M. Horn, M. Castelli, A. Popovič, An artificial intelligence system for predicting customer default in e-commerce. Expert Syst. Appl. **104**, 1–21 (2018)
15. K.B. Letaief, F. Takawira, B. Worthman, A partnership in the financial management of ComSoc. IEEE Commun. Mag. **56**, 4–5 (2018)
16. W. Chen, J. Wang, H. Wu, The application of ASP. NET to realize the integration of personal financial management and financial awareness in college students under the background of shared economy. Revista de la Facultad de Ingenieria 32, 486–494 (2017)
17. Z. Li, J. Wang, An optimization application of artificial intelligence technology in enterprise financial management. Boletin Tecnico/technical Bulletin **55**, 83–89 (2017)

Chapter 7
Digital Inclusive Finance, Advanced Industrial Structure and Quality of Economic Growth—Empirical Evidence Based on Provincial Panel Regressions with Threshold Effect Models

Zitong Wang

Abstract In this paper, we use the panel data of 30 Chinese provinces from 2011–2020 to investigate the influence of digital inclusive finance on the economic development quality and the threshold effect of advanced industry structure. The conclusion is as follows: The growth of DFI has an clear positive effect on improving the quality of economy; the advanced industrial structure shows a double threshold effect in the improvement of economic development quality by DFI. Furthermore, it is found that the digital inclusive finance in East, Middle and West has a positive effect on the quality of economic growth. In the east and west areas, there is a single threshold effect, while in the middle there is no threshold effect.

Keywords Component · Digital inclusive finance · Panel regression · Threshold effect model · Industrial structural transformation · High-quality economic development

7.1 Introduction

7.1.1 Research Background

Improving Economic Development Quality is a Key Point of Economic Transition in China since the 14th Five-Year Plan. Under the background of the transition from high speed to high quality, the development of DFI and the improvement of the availability of finance for all sectors will not only contribute to the overall structure

Z. Wang (✉)
Wuhan University of Technology, Wuhan, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_7

of the financial supply [1] but also to the quality of the financial sector [2], but also promote the deep integration of digital finance and the real economy by increasing the supply of high-quality products and stimulating the vitality of domestic demand [3], and help China's economy develop in a high-quality and healthy manner.

Digital Finance Inclusive is a kind of new approach to finance integration by means of digital finance. It is also one of the most important strategies for Chinese nation. The Nineteenth Party Congress Report makes it clear that "deepen the reform of the financial system, improve the capacity of financial services to the real economy." The 14th Five-Year Plan also stresses "accelerating digital development, building a digital China, and promoting the deep integration of digital technology and the real economy", and it is stated that "a highly adaptable, competitive and inclusive modern finance system will be enhanced." It also is stated that "we need to develop a high level of adaptability, competitiveness, and acceptance of modern finance, as well as to establish a system to effectively provide finance to the real economy."

7.1.2 Digital Inclusive Finance Development in China

The overall level of development of DFI. From 2011 to 2021, China's digital inclusive finance has been developing rapidly. Based on Peking University DFI Index (2011–2021) [4], as illustrated in Fig. 7.1, the mean finance index of all Chinese provinces increased from 40.004 in 2011 to 372,719 in 2022 digital inclusive finance developed very rapidly in 2016.

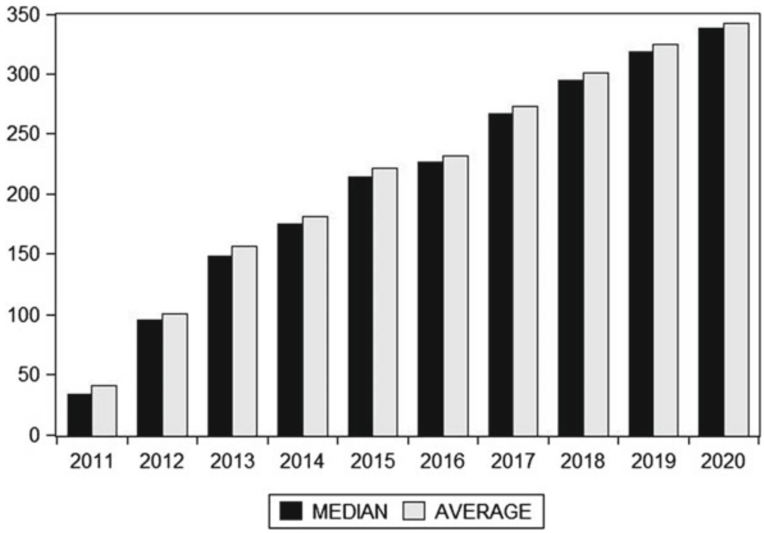


Fig. 7.1 Mean and median values of provincial digital inclusion indices, 2011–2021

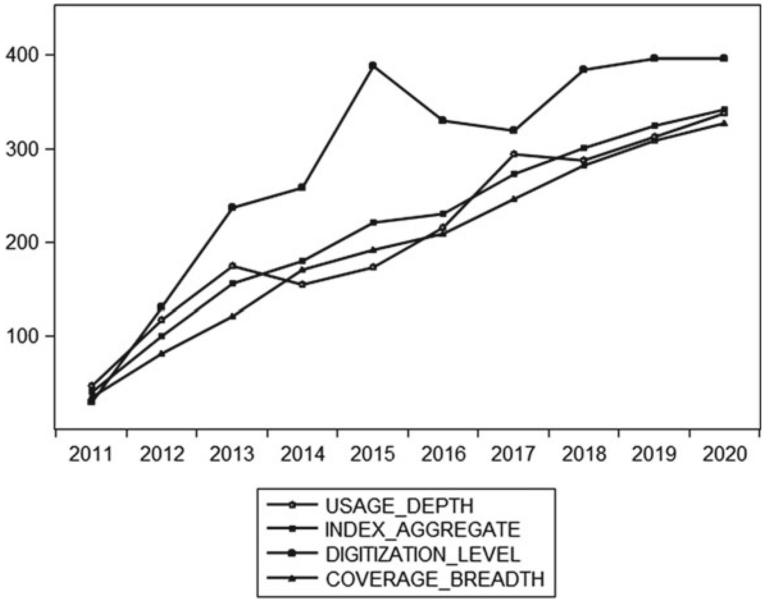


Fig. 7.2 Trends in the index of digital inclusive finance, breadth of coverage of digital finance, depth of usage of digital finance, and index of digitalization of inclusive finance in China

Development depth of digital inclusive finance in China. As shown in Fig. 7.2, in the period 2011–2021, besides the larger scale, wider scope, deeper use and digitalization of inclusive finance, Chinese Digital Inclusive Financial Indicators have made significant progress. This shows that DFI has played a significant role in reducing funding thresholds, extending funding sources and facilitating funding.

The level of development of digital inclusive finance in different regions of China. As shown in Fig. 7.3, The total number of Chinese digital finance inclusive has been greatly improved, but the regional growth rate of East Chinese East is much higher than that of Middle and West. From the supply side, this is because of the maturity of the East's finance system compared with the rest of the area, and the related finance reformation and operation mode were implemented in the east, followed by the middle and west. The financial environment, financial system and talent base in the eastern area are also more prominent than those in the western and central area, so they can better build the relevant product system and business specifications; from the demand side, the industrial structure transformation process in the eastern area is faster than that in the central and west area, with hi-tech industries and service industries dominatin, and the number of small and medium-sized micro enterprises is greater, so the demand for financing and financing channels is greater. Digital inclusive finance is developing rapidly in the eastern region. As digital inclusive finance continues to develop in the eastern, western and central areas, the overall level of DFI in the three major regions continues to narrow, which also shows that the

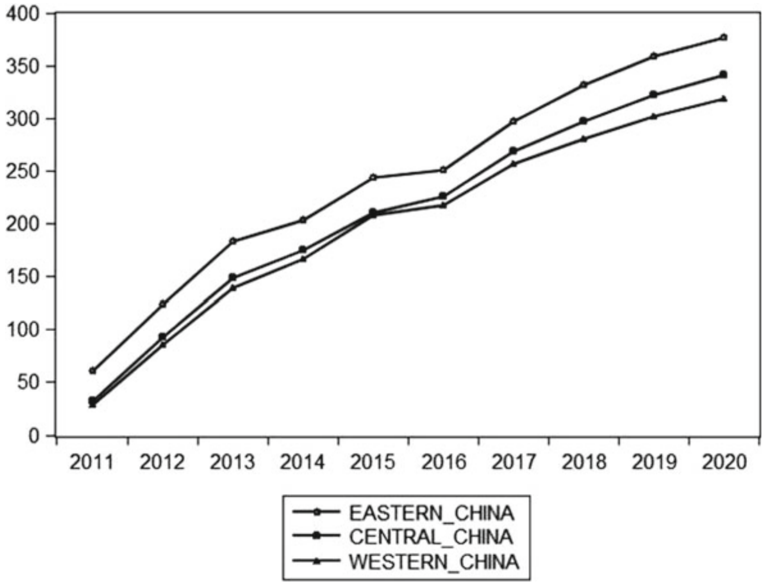


Fig. 7.3 Regional development level of digital financial inclusion

whole finance development level is getting better, and the circulating and circulating system of the capital elements are getting better.

7.1.3 Research Significance and Innovation Points

Digital inclusive finance has formed with banks, non-bank financial institutions, Internet giants, and fintech enterprises as service subjects, supply chain finance, consumer finance, intelligent investment and advisory, insurance technology, and digital banking as service channels, rural revitalization [5], green development [6], small and micro enterprise financing [7], and livelihood areas [8] as service targets, payment system, credit system, capital market, etc. It is an ongoing development of inclusive finance, which can effectively balance the dual objectives of commercial and social [9]. Based on reducing the cost of funding and expanding the scope of funding, it has solved the issues such as asymmetric information, expensive funding, inadequate support for innovative and entrepreneurial activities, and uneven development of traditional financial systems. It has been effective in fostering SMEs [10], facilitating the restructuring of industry and helping to enhance the quality of economy [11]. However, does Digital Finance Inclusive have any distinction on improving the Economy Quality in Various Phases of Industry Restructuring? Is there heterogeneity in the betterment of the quality of economic development by DFI in different regions with differences in industrial structure?

In view of this, using the Panel Data of Thirty Provincial Districts of Chinese Continental Provinces, 2011–2020 (Due to incomplete data, Tibet is excluded from the statistics), this paper examines the effect of DFI development on economic growth quality by using panel regression and threshold effect model, and examines the nonlinear effect of DFI development on economic growth. The innovations and marginal contributions of this paper include: first, unlike the existing literature that explores the relationship between DFI and economic quality growth through the mediating effect model, this paper adopts the threshold effect model to seek whether there is a non-linear relationship between development of DFI and quality of economic development in various phases of industrial restructuring. Second, on the basis of analyzing the relationship between DFI development and economic growth quality, this paper divides the sample into eastern, central and western regions to clarify the heterogeneity of digital inclusive finance and economic development quality.

7.2 Literature Review and Research Hypothesis

7.2.1 Impact of Digital Inclusive Finance

Economic growth should not only focus on economic growth, but also on the quality of development [12]. Its development goal at the macro level needs to improve the overall quality of the national economy and achieve synergistic development between industries [13]. Unlike traditional institutions represented by banks, which tend to lend differently to high-net-worth customers leading to poorer availability of financial services for disadvantaged regions and disadvantaged groups [14], DFI has lower financing threshold than traditional finance and wider coverage, helping to optimize the distribution of resources and enhance the quality of economic growth in terms of supply and demand.

On the one hand, from the supply side, DFI can rectify the unbalanced allocation of elements and increase productivity through increasing the transparent and fast information transmission rate. In particular, the inclusion and fairness of DFI will help to improve the matching of financial capital with real industry capital, advance technological innovation and optimize industrial structure [15]. At the same time, the digital development of finance reduces information costs and improves the allocation efficiency of production factors, which will promote the fairness of employment and entrepreneurship opportunities [16]. Finally, the trend of optimizing and upgrading industrial structure can motivate enterprises to carry out technological innovation, upgrade industrial chain, and improve product quality and the speed of new product development [17].

On the other hand, on the demand side, it is possible to reduce the revenue gap through developing DFI [18]. DFI is able to lower the cost of providing and utilizing financial services, ease the financial exclusion and funding restrictions in the countryside [19] and exert poverty reduction effects. The narrowing of the urban–rural income gap will lead to the expansion of the overall consumption scale of the society and tap the consumption potential of rural areas [20], forcing the further transformation of the supply-side structure [21]. Therefore, this article puts forward the following assumption.

H1: There is an impact of DFI on the quality improvement of economic development.

7.2.2 The Threshold Effect of Industrial Structure

Transforming the industry structure is the necessary demand of high-quality economy. In the short-term, the advanced industrial structure has a significant restraining effect on the economic growth, and the advanced industrial structure has a positive effect on the long-term economic growth [22]. Advanced industry structure mainly manifests in the transfer to the third industry [23]. In the first and middle stages of industrial transformation, the total factor productivity of the tertiary sector is small, which leads to "negative structural benefits". There will be some cost impact when the industry structure is upgraded, which leads to the co-occurrence of production and cost. Therefore, the following assumptions are put forward in this article.

H2: There is a threshold effect of advanced industrial structure in the impact of DFI on the quality of economic growth.

7.3 Study Design

7.3.1 Variable Measurement

Explained variables. The explanatory variable is economic growth (ECO), as opposed to earlier studies that used a single indicator evaluation method to assess the quality of economic development [24], today's studies on economic growth are based on economic aggregates and cover the results of the synergy of all aspects of economic activity [21]. Therefore, the measurement of economic growth should adopt a comprehensive multi-level indicator measurement system. In this paper, we refer to the comprehensive indicator system approach on economic growth measurement by Li et al. [25], and improve it based on the need of this paper to measure the quality of economic growth in three dimensions: overall level, quality of development, and residents' well-being. See Table 7.1 for details.

In order to measure the impact of each indicator on economic growth (ECO), In this article, we use the Entropy-Value Approach to compute the importance of

Table 7.1 Basic indicators of economic growth quality

Classification indicators	Basic indicators	Calculation	Nature of indicator
Overall level	Output level	Disposable income per inhabitant	Positive indicators
	Local finance	Local fiscal general budget revenue	Positive indicators
Development quality	Innovation capability	Number of valid invention patents for industrial enterprises above the scale	Positive indicators
	Industry structure	Tertiary industry value added index	Positive indicators
	Technology support	Local financial science and technology expenditure	Positive indicators
	Environmental protection	Sulfur dioxide emissions	Negative indicators
Residents' well-being	Resident consumption	Per capita consumption expenditure of all residents	Positive indicators

every index in economy growth (ECO). The specific process of entropy method is as follows.

First, each metric was standardized.

To make positive indicators.

$$Y_{ij} = \frac{\max(X_{it}) - X_{it}}{\max(X_{it}) - \min(X_{it})} \tag{7.1}$$

To make negative indicators.

$$Y_{ij} = \frac{X_{it} - \min(X_{it})}{\max(X_{it}) - \min(X_{it})} \tag{7.2}$$

where denotes the observed value of an indicator in year t for the i region. denotes the standardized value. indicates the maximum value of an indicator in the i region; And the minimum value of an indicator in the region i.

Next, the information entropy value of each indicator is calculated E_i:

$$E_i = -\ln(n)^{-1} \sum_{j=1}^{n} p_{ij} \ln p_{ij} \tag{7.3}$$

Among them

$$p_{ij} = Y_{ij} \Bigg/ \sum_{j=1}^{n} Y_{ij} \tag{7.4}$$

Finally, the weights of each indicator are determined.

$$W_i = \frac{1 - E_i}{n - \sum_{i=1}^{n} E_i} \tag{7.5}$$

where, W_i is the weight of an indicator for the i region.

By multiplying each weight by the standardized value of the indicator, a composite index of economic growth (ECO) is obtained. The weights of each economic growth quality index after calculation by the entropy method are shown in Table 7.2.

Because of the emphasis of this article on the development of regional economy, the quality of development occupies a greater role in the three first level indexes. After deriving the weight values of each individual indicator, the combined economic growth (ECO) index can be calculated.

$$\begin{aligned} \text{ECO} = &0.09\text{X1} + 0.132\text{X2} + 0.428\text{X3} + 0.014\text{X4} \\ &+ 0.245\text{X5} - 0.019\text{X6} + 0.072\text{X7} \end{aligned} \tag{7.6}$$

The raw economic growth (ECO) is logarithmized in this paper, considering the gap between the various data measures.

Explanatory variables. The explanatory variable is digital inclusive finance (DIF). Referring to Chu et al. [26] and based on Guo et al. [27], The DFI Aggregate Index

Table 7.2 Weighting of comprehensive indicators of economic growth quality

Classification indicators	Weighting (%)	Indicators	Symbols	Information entropy	Effect Value	Weights
Overall level	0.222	Output level	X1	0.962	0.038	0.090
		Local finance	X2	0.945	0.055	0.132
Development quality	0.706	Innovation capability	X3	0.821	0.179	0.428
		Industry structure	X4	0.994	0.006	0.014
		Technology support	X5	0.897	0.103	0.245
		Environmental protection	X6	0.992	0.008	0.019
Residents' well-being	0.072	Resident consumption	X7	0.97	0.03	0.072

of DFI Index of Peking University (2011–2020) developed by DFI Research Center of Peking University. Considering the gaps between the data measures, the original Digital Inclusive Finance (DIF) is logarithmized in this paper.

Threshold variables. The threshold variable is the industrial structural transformation variable (ISC). In this paper, we refer to Ren and Zhu [28] to construct

$$\mathrm{ISC} = \mathrm{PI}_{\mathrm{it}} + 2\mathrm{SI}_{\mathrm{it}} + 3\mathrm{TL}_{\mathrm{it}} \tag{7.7}$$

$\mathrm{PI}_{\mathrm{it}}$, $\mathrm{SI}_{\mathrm{it}}$ and $\mathrm{TL}_{\mathrm{it}}$ respectively represent the proportions of value added from the primary, secondary, and tertiary industries in the total regional output.

Control variables. (1) Government spending (GE). The government expenditure plays an important part in boosting the economy [29]. The government expenditure can effectively direct the resources to the more productive industries, optimize and upgrade the industry structure, and improve the quality of the economy. So, this article chooses the proportion of GDP and the proportion of the total amount of government spending.

(2) Level of education (EDU). The accumulation of educational human capital can promote growth [30] and the higher the level of education in a region, the higher the quality and quantity of the labor force in that region is reflected. In this paper, we refer to XueGui and He Liancheng and use the number of students enrolled in colleges and universities per 100,000 people to express the educational level (EDU), considering that this variable is not in the same order of magnitude as other variables, so it is logarithmicized [31].

(3) Level of infrastructure (IF). The improvement of infrastructure construction level can link the factors such as science and technology innovation activities and financial resources in each province organically, thus reducing the cost of factor flow [32]. The construction of infrastructure can also stimulate the development of a series of upstream and downstream industries and promote the improvement of economic development level. Therefore, in this paper, we refer to the study of Hua et al. [33] and improve it by measuring the level of infrastructure construction in each province in terms of road mileage.

(4) Openness of the economy (OPEN). The degree of trade openness also affects innovation, competition from foreign trade will stimulate local enterprises to invest more in innovation [34], and the increase of trade openness will also lead to the increase of total economic development, foreign investment will also allow new technologies to be introduced in order to increase economic efficiency. Based on Hui-Ping Wang's research [35], in this article, we measure the extent to which every province is open in terms of its share of its total volume of imports and exports. (converted into RMB at the current year's exchange rate) to GDP.

(5) Level of traditional financial development (TFN). Traditional finance is dominated by the banking sector. Since traditional financial institutions represented by banks favor high net worth customers, the development of conventional financial services has a positive impact as well as a negative impact on the economy. In this paper, we refer to the studies of Yin et al. [36], Zhang and Yang [37] and others

selected the proportion of lending to GDP as a benchmark for the conventional finance development.

7.3.2 Data Source

In this article, we focus on the economical developing quality of different provinces, and examines the overall level of economic development, development quality and residents' well-being of each province. 30 provinces in mainland China (Tibet is not included in the statistics due to incomplete data) are selected as the research sample, with 2011–2020 as the investigation interval. Figures for DFI index are derived from Beijing University DFI Index (2011–2020). The information on lending is from PBOC, while the other figures are from China Statistical Yearbook (2012–2020). In order to make up for the lack of data, we apply SPSS software and Neighborhood Line Trend Approach.

7.3.3 Model Setting

Panel regression model. The development of DFI can have an impact on the quality of economic growth. In view of this, the following panel regression model is constructed.

$$\mathrm{ECO_{it}} = \beta_0 + \beta_1 \mathrm{DIF_{it}} + \beta_2 \mathrm{X_{it}} + \varepsilon_{it} \tag{7.8}$$

where $i = 1, 2, 3, \ldots, N$, represents cross-sectional individuals;$t = 1, 2, 3, \ldots, T$, represents years;X represents the set of control variables;ε_{it} represents the residual term.

Threshold regression model. The threshold effect regression model of ISC constructed in this paper is as follows:

$$\begin{aligned} \mathrm{ECO}_{it} &= \alpha_0 + \alpha_1 \,\mathrm{DIF} \times I(\mathrm{ISC} \leq \theta_1) + \alpha_2 \\ &\mathrm{DIF} \times I(\theta_1 < \mathrm{ISC} \leq \theta_2) + \ldots + \alpha_{n+1} \,\mathrm{DIF} \times I \\ &(\mathrm{ISC} > \theta_n) + \alpha_{n+2} \, X_{it} + \varepsilon_{it} \end{aligned} \tag{7.9}$$

where is the indicator function, and if the equation in parentheses holds, then takes 1, otherwise takes 0, and is the threshold value of ISC to be estimated; the remaining variables have the same meaning as above.

7.4 Empirical Analysis

7.4.1 Descriptive Statistical Analysis

Table 7.3 shows the results of descriptive statistics for the variables ECO, DIF, GE, EDU, IF, OPEN, and TFN. From the data in Table 7.3, it can be seen that the maximum value of ECO is 12.178 and the minimum value is 7.063, which indicates that there is a big gap between the different areas in terms of economic growth, but there is an improvement in the general quality. DFI has a maximal value of 6.068 and a lowest of 2.786, which shows that there is great disparity between different areas, and their developing level remains middle.

In addition, to avoid the problem of multicollinearity due to the possible high correlation of independent variables in the model, a multicollinearity test was performed in this paper. The test of variance expansion factor (VIF) was passed. The overall VIF value of the model in Table 7.4 is less than 5, and the VIF value of each variable is less than 5, indicating that there is no multicollinearity among the variables.

Table 7.3 Descriptive statistics of variables

Variables	Number of observations	Average value	Standard deviation	Minimum value	Maximum value
ECO	300	8.998	0.949	7.063	12.178
DIF	300	5.212	0.677	2.786	6.068
ISC	300	1.324	0.729	0.527	5.244
GE	300	0.297	0.210	0.120	1.353
EDU	300	7.823	0.292	6.987	8.633
IF	300	14.925	7.984	1.21	39.44
OPEN	300	0.788	0.096	0.471	1.003
TFN	300	1.488	0.473	0.669	2.998

Table 7.4 Multicollinearity test

Variable Name	VIF	1/VIF
DIF	1.78	0.561
GE	2.32	0.431
EDU	2.17	0.460
IF	2.38	0.419
OPEN	1.87	0.534
TFN	2.88	0.347

7.4.2 Panel Regression Analysis and Heterogeneity Test

As shown in Table 7.5, based on the panel data, F, Breusch-Pagan and Hausman tests were carried out, and the F and Hausman tests indicated that FE model was selected, therefore, the fixed effect model was selected to be analyzed.

Table 7.6 shows the results of the national sample and sub-regional estimation. On a national scale as a whole, the development of DFI contributes significantly to improving the quality of economy. It has an obvious positive relationship with a significance of 1%, and hypothesis 1 is verified. According to the heterogeneity test, the regional analysis finds that DFI also has an important positive effect on the improvement of economic development quality in the eastern, western and central areas, and the positive effect of DFI on the improvement of economic development quality is ranked in the central, eastern and western regions, respectively. This is mainly due to the long-term marginalization of the financing environment in the central region compared with the eastern region. In this context, capital accumulation in the central region can only rely on state-owned financial institutions, so the savings and loans of state-owned banks become the main channel of savings-investment transformation. Since state-owned financial institutions mainly serve the state-owned economy, financial institutions in central China are bound to be subject to more administrative intervention in investment choices, which ultimately leads to the exclusion of a large number of SMEs and private enterprises from this organized financial market [38]. In such a context, digital inclusive finance can normally make up for such shortcomings. In the eastern region, the relatively low role of digital inclusive finance in improving the quality of economic development is due to the diversified financial landscape that has already formed in the region, including state-owned commercial banks, joint-stock banks, non-bank financial institutions, and foreign financial institutions. Moreover, due to the higher level of industrial structure, consumer spending, innovation capabilities, and pollution control in the eastern region overall, the impact of digital inclusive finance on improving the quality of economic development is relatively weaker than in the central region [39].

The weakest effect of DFI on the improvement of economic growth quality in the western region is due to the fact that the western region is in the process of transformation of advanced industrial structure, and the negative impact of "negative structural profit" reduces its contribution to the improvement of economic growth quality. Due to the influence of the western development strategy, the credit decisions

Table 7.5 Model selection tests

Inspection type	Statistical quantities	P	Model should be selected
F-test	94.532	0.000***	FE Model
Breusch-Pagan test	731.845	0.000***	RE Model
Hausman test	104.724	0.000***	FE Model

Note ***, **, *represent 1%, 5%, 10% significance levels, respectively

Table 7.6 National panel regression and heterogeneity analysis results

Variable name	National	Eastern region	Central region	Western region
DIF	0.109*** (8.284)	0.463*** (7.456)	0.737*** (6.666)	0.398*** (9.731)
GE	0.114** (2.118)	0.129** (2.068)	−0.329* (−1.795)	−0.17** (2.229)
EDU	0.022 (0.906)	0.9** (2.522)	−0.149* (−1.688)	0.244*** (4.062)
IF	0.02 (0.865)	0.299*** (4.69)	−0.008 (−0.067)	0.461*** (8.058)
OPEN	0.112*** (3.147)	0.415*** (5.911)	0.062 (0.679)	0.145** (2.215)
TFN	0.038* (1.818)	0.058 (0.586)	−0.092 (−0.523)	0.064 (1.093)
Constant	0.004 (0.269)	0.051 (0.822)	0.29*** (2.896)	0.142** (2.453)
R-Squared	0.520	0.714	0.644	0.841

Note ***, **, *represent 1%, 5%, 10% significance levels, respectively

of financial institutions in the western region are subject to the will of the government, which makes small, medium, and micro enterprises (SMEs) obtain effective financing from traditional financial institutions unlike those in the central region, thus reducing the impact of digital inclusion.

7.4.3 Threshold Effect Analysis

Threshold effect test. This paper analyzes the non-linear relationship between the digital finance inclusive and the region economic by means of regression analysis. The transformation of industrial structure is an important factor affecting the quality development of the economy. Based on this, this paper uses the level of advanced industrial structure (ISC) as the threshold regression variable to explain the influence pattern and threshold characteristics of DFI development on the quality of economic development.

Before conducting the threshold regression analysis, this article examines the threshold effect of the Advanced Industry Structure, which is presented in Table 7.7.

From Table 7.7 it can be found that the industry has passed both single-threshold and double-threshold in a significant degree of 1% and 5%, and has failed three threshold. Therefore, this paper combines theoretical and practical situations and uses the double threshold model to test the threshold effect of industrial structure, and the results show that the threshold values are 0.921 and 1.440.

Table 7.7 Results of the threshold effect test

Variables	Threshold setting	F-value	P-value	10%	5%	1%
ISC	Single threshold	63.69	0.000	27.578	29.695	35.969
	Double threshold	41.36	0.003	22.942	26.048	34.992
	Three-fold threshold	17.41	0.410	31.127	42.229	61.950

Threshold effect regression results. Using Eq. (7.4), a regression analysis was carried out to determine the threshold effect for an advanced industry structure, as illustrated in Table 7.8.

As can be seen from Table 7.8, there are differences in the role of digital inclusive finance in improving the quality of economic development at different levels of advanced industrial structure. When the advanced industrial structure is not greater than the first threshold value ($\theta_1 = 0.921$), the regression coefficient of digital inclusive finance is 0.0028, which is significant at the 1% level; when the advanced industrial structure is greater than the first threshold ($\theta_1 = 0.921$) and not greater than the second threshold ($= 1.440$), the regression coefficient of digital inclusive finance is 0.0037, which is significant at the 1% level, indicating that when the advanced industrial structure crosses the threshold, the digital inclusive finance is more significant for improving the quality of economic development; when the advanced industrial structure is greater than the second threshold ($\theta_2 = 1.440$) When the advanced

Table 7.8 Regression results of threshold effects

Variables	ECO
ISC $\leq \theta_1$	0.0028*** (8.81)
$\theta_1 <$ ISC $\leq \theta_2$	0.0037*** (15.12)
ISC $> \theta_3$	0.0031*** (11.74)
GE	0.8160 (1.58)
EDU	0.4351*** (3.10)
IF	0.0510*** (4.34)
OPEN	−0.0032*** (−3.07)
TFN	−0.0677 (−0.88)
F	305.71***
R2	0.1453

Note ***, **, *represent 1%, 5%, 10% significance levels, respectively industrial structure is greater than the second threshold ($\theta_2 = 1.440$), the regression coefficient of DFI is 0.0031, which is significant at 1%, which shows that the effect of digital inclusive finance on improving the quality of economic development is weakened after the second threshold., but it is still stronger than the initial stage of industrial structure transformation, as verified by H2.

7.5 Regional Heterogeneity Analysis

Further test is made on the threshold effect of East, West and Central Industrial Structure. Table 7.9 shows the results. In the east, as can be seen in Table 7.9, the East Regional Advanced Industry Structure has a single-threshold effect, which is 0.757. There is no threshold effect in the advanced industry structure of middle area, and there is no obvious difference between single-threshold, double-threshold and triple-threshold. The West Developed Industry Structure is characterized by single-threshold effect, which is 0.881.

The results of the regression of regional heterogeneity of threshold effects are shown in Table 7.10.

For the eastern region, when the advanced industrial structure is less than the first threshold ($\beta_1 = 0.757$), the regression coefficient is 0.0042, which is significant at 1%; when the advanced industrial structure is greater than the first threshold

Table 7.9 Results of the test for regional heterogeneity of the threshold effect

Region	Threshold setting	F-value	P-value	10%	5%	1%
Eastern region	Single threshold	67.95	0.000	21.898	24.905	34.939
	Double threshold	17.83	0.113	18.596	20.629	25.637
	Three-fold threshold	12.07	0.807	34.534	40.404	52.308
Central region	Single threshold	4.56	0.683	14.047	16.965	22.293
	Double threshold	8.43	0.187	11.570	14.189	18.391
	Three-fold threshold	6.14	0.760	23.989	27.824	39.072
Western region	Single threshold	32.12	0.007	17.815	22.464	28.429
	Double threshold	12.78	0.190	15.705	18.485	27.236
	Three-fold threshold	5.93	0.820	22.814	27.594	39.742

Table 7.10 Regression results of regional heterogeneity of threshold effects

Variables	ECO	
	Eastern region	Western region
ISC $\leq \beta_1$	0.0042*** (9.95)	
ISC $> \beta_1$	0.0025*** (5.68)	
ISC $\leq \gamma_1$		0.0023*** (3.86)
ISC $> \gamma_1$		0.0037*** (9.07)
GE	−2.2932** (−2.43)	0.4986 (0.83)
EDU	−0.1608 (−0.57)	0.1862 (0.97)
IF	0.0726** (2.85)	0.0378*** (4.01)
OPEN	−0.0044*** (−3.51)	−0.0014 (−0.63)
TFN	0.3575** (2.55)	−0.1300 (−1.37)
F	7318.02	206.37
R2	0.2837	0.7913

Note ***, **, *represent 1%, 5%, 10% significance levels, respectively

($\beta_1 = 0.757$), the regression coefficient is 0.0025, which is significant at 1%. It indicates that the contribution of the development of digital inclusive finance to the improvement of economic development quality decreases when the advanced industrial structure crosses the threshold value. Regarding the central region, as there is no threshold effect, the development of digital inclusive finance can only be found to have a significant promoting effect on the quality of economic development through panel regression models, but there is no non-linear relationship. In the west area, the regression factor is 0.0023 with a significance of 1% when the developed industry structure is below the 1st threshold value ($\gamma_1 = 0.881$), and the regression factor is 0.0037 with a significance of 1%; The regression factor is 0.0037 when the developed industry structure exceeds a first threshold value ($\gamma_1 = 0.881$), which is significant at 1%. The results show that, when the developed industry structure exceeds the threshold, the contribution of the digital inclusive financial system to improving the economy is enhanced.

For the eastern region, as state-owned commercial banks, joint-stock banks, non-bank financial institutions have long been formed the diversified financial landscape with the coexistence of institutional and foreign financial institutions, coupled with the gradual transformation of industrial structure to a later stage, the digital inclusive finance for the quality of economic development will also be weakened. For the central region, this article holds that the main cause of the lack of threshold effect of DFI is that it is highly compatible with the middle area industry structure. Since the financing environment in the central region is more marginal compared with the eastern region, when digital inclusive finance is developed, the lower financing threshold and wider coverage greatly promote the transformation and upgrading of the supply side and demand side, which makes the stage of improving the quality of economic development in the central region show a high growth rate. As the advanced industrial structure of the central region is in the process of transformation, the overall industrial structure of the eastern region has not yet reached the advanced level, and the inflection point of digital inclusive finance for the improvement of economic development quality has not yet appeared. For the western region, due to the influence of the western development strategy, the credit decision of financial institutions in the western region is subject to the will of the government, which makes the small and medium-sized enterprises different from the central region to obtain effective financing from traditional financial institutions, so the inflection point of digital inclusive finance for the quality growth of economic development will come earlier than that of the central region.

7.6 Robustness Tests

In the robustness test, this paper draws on the approach in the study by Cheng and Ren [40] and uses the method of adding the control variable urbanization level (UR) to conduct robustness tests on the regression results in Table 7.11. The data is taken from the China Statistical Yearbook. The results show that: Nationally, DFI has a significant positive effect on economic growth quality, while DFI has a significant positive effect on economic growth quality. The robust test results are in agreement with those in Table 7.11, which shows the robustness of this paper.

7.7 Conclusions and Recommendations

7.7.1 Conclusion

This article analyzes the influence of DFI on Economy Development Quality and Threshold Effect of Advanced Industry Structure Using Panel Data of Thirty Chinese Provinces During 2011–2020, and further conducts regional heterogeneity analysis to draw the following research conclusions.

At the national level, DFI has a significant effect on improving the quality of economic development. In the east, middle, and west areas, the enhancement of

Table 7.11 Panel regression robustness test results

Variables	ECO			
	National	Eastern region	Central region	Western region
DIF	0.406*** (13.123)	0.421*** (6.897)	0.651*** (4.819)	0.333*** (8.228)
GE	−0.324*** (−6.346)	−0.089* (−1.9)	−0.509*** (−4.279)	−0.013 (−0.159)
EDU	−0.229***(−5.363)	−0.125* (−1.927)	−0.562*** (−4.28)	0.229*** (3.773)
IF	0.347*** (10.421)	0.463*** (9.492)	0.049 (0.374)	0.557*** (11.947)
OPEN	0.345*** (7.375)	0.215** (2.365)	0.145* (1.819)	0.106** (2.41)
TFN	−0.01 (−0.21)	−0.081 (−1.023)	−0.048 (−0.37)	0.011 (0.189)
UR	0.311*** (5.699)	0.477*** (3.567)	0.658*** (3.081)	0.207*** (5.157)
Constant	0.016 (0.515)	−0.143*** (−3.363)	0.158 (1.457)	−0.243*** (−4.454)
R-Squared	0.860	0.876	0.892	0.918

Note ***, **, *represent 1%, 5%, 10% significance levels, respectively

digital inclusive finance has a significant impact on the quality of economic development, but this enhancement is strongest in the middle area and the weakest in the west.

In the influence of DFI Development to Enhance Economy Developing Economy, there exists dual threshold effect of Advanced Industry Structure. Regardless of whether the advanced industrial structure crosses the threshold value or not, there is a significant positive effect of DFI on the improvement of economic development quality. In the eastern area, there is a single threshold effect in the advanced industrial structure, and DFI has a significant positive impact on the improvement of economic development quality regardless of whether the threshold value is crossed or not, and the development of DFI decreases on the improvement of economic development quality when the advanced industrial structure crosses the threshold value. In the central region, there is no threshold effect for the advanced industrial structure, so we can only conclude that the development of DFI has a important contribution to the improvement of economic growth quality based on the panel regression model, but there is no non-linear relationship. In the western region, it shows a single threshold effect, and the impact coefficient increases with the cross-country threshold value of the advanced industrial structure.

7.7.2 Recommendation

On the basis of the research results, the following suggestions are put forward.

Vigorously develop DFI to promote the improvement of economic development quality. We should take advantage of the low threshold and wide coverage of DFI to vigorously develop DFI across the country, especially in the western and central areas, to further promote the transformation of industrial structure, the improvement of residents' well-being, the improvement of environmental quality and the improvement of economic development nationwide.

In addition, We should seize the chance to transform the industry structure and enhance the influence of the digital inclusive finance on the economic development.

References

1. C. Dong, D. Si, Has digital financial inclusion improved the "low-end lock-in" dilemma of urban technology innovation? J. Shanghai Univ. Financ. Econ. **4**, 62–77 (2022)
2. K.-C. Liao, Y. Zhang, G. Peng, Study on the impact mechanism of digital inclusive finance on total factor productivity of urban financial industry. Contemp. Financ. Econ. **12**, 65–76 (2021)
3. F. Lu, Q. Wang, Digital inclusive finance and the improvement of efficiency of financial services in the real economy. Nankai J. (Philosophy and Social Science Edition) **3**, 34–47 (2022)
4. F. Guo, J.Y. Wang, F. Wang, T. Kong, X.U.N. Zhang, Z.Y. Cheng, Measuring the development of digital inclusive finance in China: index compilation and spatial characteristics. Q. J. Econ. **19**(4), 1401–1418 (2020)
5. L. Tong, H. Tian, Y. Li, Y. Yuan, Inner mechanism, realistic dilemma and path choice of digital inclusive finance empowering rural revitalization. Agric. Econ. **10**, 113–114 (2022)
6. Z. Zhang, J. He, Digital inclusive finance and urban green economic growth: a spatial spillover perspective. J. Stat. **5**, 10–19 (2022)
7. S. Sun, Digital inclusive finance to help the development of micro, small and medium enterprises. Banker **10**, 32–35 (2022)
8. Z. Jin, Y. Liu, The impact of digital inclusive finance on the urban-rural income gap in China. Coop. Econ. Technol. **16**, 53–55
9. Y.F. Dong, X.M. Zhao, Responsible digital inclusive finance: origin, connotation and construction. Nanfang Financ. **1**, 50–56 (2018)
10. S. Zhao, M. Li, K. She, Digital finance and the availability of financing for small and medium-sized enterprises—micro evidence from bank loans. Econ. Dyn. **8**, 98–116 (2022)
11. J. Fan, B. Wang, L. Yan, J. Qu, The impact of digital inclusive finance on innovation resilience of high-tech manufacturing industry—A test based on systematic GMM and threshold effect. Sci. Technol. Progress Countermeas. **17**, 51–61 (2022). R.J. Barro, Quantity and quality of economic growth. Chilean Econ. **5**(2), 17–26 (2002)
12. J. Ma, X. Tang, Industrial cluster network, structural evolution and synergistic development: the case of Yeji wood and bamboo industry. J. Anhui Normal Univ. (Humanities and Social Sciences Edition) **47**(4), 111–121 (2019)
13. Beidoguang, The order of financial development-from macro finance, capital market to inclusive finance. China Urban Financ. **6**, 80 (2018)
14. Productive service industry agglomeration, industrial structure upgrading and regional eco-efficiency improvement—panel data from 30 Chinese provinces from 2003–2016
15. Q.J. Zhang, L. Huang, Digital inclusive finance, industrial structure and high-quality economic development. Jianghan Forum **10**, 41–51 (2021)

16. M. Ji, X. Zeng, Research on the role of digital inclusive finance in promoting residents' consumption under the goal of common prosperity. Price Theory Pract. **5**, 66–69+193 (2022)
17. X. Song, An empirical test of digital inclusive finance to narrow the urban-rural income gap. Financ. Econ. Sci. **6**, 14–25 (2017)
18. L. Zhou, A review of research on the development of digital inclusive finance. Financ. Account. Mon. **1**, 147–153 (2022)
19. H. Yang, Q.R. Wang, K. Zhang, Exploration of digital inclusive finance, education level and rural poverty in China. Jianghan Acad. **3**, 41–52 (2021)
20. Z. Wang, J. Yao, H. Sun, Urban-rural income gap, consumption propensity and consumption structure upgrading. Stat. Decis. Making **15**, 51–54 (2022)
21. C. He, J.S. Qi, Internet finance, consumption and economic growth. Financ. Account. Mon. **6**, 126–132 (2022)
22. Y. Huang, Y. Liu, The avoidance of "negative structural profit" and high-quality economic development in industrial restructuring. Southeast Acad. **5** (2020)
23. G. Li, X. Li, Environmental regulation, industrial structure upgrading and high quality economic development: the case of Beijing, Tianjin and Hebei. Stat. Decis. Making **18**, 26–31 (2022)
24. X. Cao, B. Ren, China's economic transformation and the quality of economic growth: an examination based on the contribution of TFP. Contemp. Econ. Sci. **4**, 23~29+124~125 (2008)
25. L. Li, Y. Zhang, Construction and preliminary assessment of the index system for measuring the transformation of China's economic development. China Ind. Econ. **4**, 54–63 (2011).
26. C.-C. Chu, M.-H. Tong, Y. Li, et al.: Digital inclusive finance and provincial economic growth in China: an empirical study based on spatial econometric model. Explor. Econ. Issues **42**(6), 179–190
27. F. Guo, J.Y. Wang, F. Wang et al., Measuring the development of digital inclusive finance in China: indexing and spatial characteristics. Econometrics (Quarterly) **19**(4), 1401–1418 (2020)
28. L. Ren, D. Zhu, Is China's financial development green—and on the Chinese environmental Kuznets curve hypothesis. Dyn. Econ. **11**, 58–73 (2017)
29. J. Lu, J. Liu, Aging, government spending and economic growth—An empirical study based on the perspective of Chinese provinces. Chongqing Soc. Sci. **2**, 54–74 (2021)
30. J. Pan, T. Xu, Y. Xuan, Aging, human capital and economic growth. Explor. Econ. Issues **7**, 74–89 (2022)
31. G. Xue, R.C. He, Market competition, financial exclusion and urban-rural income gap. Financ. Trade Res. **27**(1), 1–8 (2016)
32. R.C. Wang, M. Yang, Institutional environment, infrastructure and efficiency improvement of "science and technology-finance" system. Scientol. Res. **35**(9), 1313–1319 (2017)
33. X. Hua, X. Jin, H. Lu, et al., Evolution of spatio-temporal pattern of coupled coordination of high quality development and influencing factors—The case of Zhejiang counties. Geoscience **41**(2), 223–231 (2021)
34. W. Yu, Q. Chen, H. Chen, Analysis of the impact of different environmental policy instruments on technological innovation—An empirical study based on provincial panel data in China from 2004–2011. Manag. Rev. **28**(1), 53–61 (2016)
35. H. Wang, Z. Wang, M. Wang, Intellectual capital, spatial spillover and total factor productivity in Chinese industry. J. Shanxi Univ. Financ. Econ. **38**(5), 1–10 (2016)
36. X. Yin, G. Chen, S.R. Cheng, Re-examination of the relationship between financial development and urban-rural income gap in China—Estimation based on panel unit root and VAR models. Contemp. Econ. Sci. Contemp. Econ. Sci. **1**, 15–24+124 (2007)
37. Y. Zhang, Z. Yang, The mechanism and dynamic analysis of financial development and urbanization on urban-rural income gap. Stat. Decis. Making **5**, 84–88 (2018)
38. F. Huang, The status and role of finance in the rise of central China. Econ. Perspect. **11**, 65–67 (2006)
39. Z. Zhu, H. Liu, Financial development and economic growth in the western region. Contemp. Econ. **4**, 42–43 (2006)
40. S.J. Cheng, X.C. Ren, Green investment, foreign investment and carbon dioxide emissions: a dynamic panel system based on GMM and threshold effect analysis. Technol. Econ. Manag. Res. **8**, 27–32 (2022)

Chapter 8
Application of Fake News Detection in Stock Market Analyzer and Predictor Using Sentiment Analysis

Yuan Yao, Xinyu Wu, and Peng Zhang

Abstract In the field of quantitative investment, it has always been a problem to obtain more accurate forecasts of stock price. Analyzing investor sentiment from online emotional text to find out the stock price trend has become a hot issue. However the large amount of fake information used for misguiding investor sentiment on the network may influence the performance of the stock price forecasting model. So we try to use fake news detection to remove these information, which may increase the accuracy of the model. And we successfully improve the performance of the stock price forecasting model with the help of fake news detection, and the improvements of accuracy are from 0.29% to 4.37%.

Keywords Stock trend prediction · Sentiment analysis · CNN · Fake news detection · Quantitative investment

8.1 Introduction

With the continuous development of Internet finance and stock market, massive stock data with rich information has been generated. Because people lack effective methods and practical technologies to extract valuable information in such complex situation, it is hard to understand and draw information from the massive stock data. So, it becomes a hot issue how to use a certain algorithm or data processing technology to effectively mine the rules hidden in stock data and find out the stock price trend.

Y. Yao
School of Mathematical Sciences, Peking University, Beijing, China

X. Wu
School of Cyberspace Security, Nanjing University of Science and Technology, Nanjing, China

P. Zhang (✉)
Institute of Information Engineering, Chinese Academy of Sciences, Beijing 100093, China
e-mail: pengzhang@iie.ac.cn

School of Cyber Security, University of Chinese Academy of Sciences, Beijing 100049, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_8

The use of artificial intelligence algorithm combined with big data platform has a strong approximation ability to the nonlinear relationship of massive stock market data. Therefore, people gradually begin to use computer algorithms to invest in the stock market. In the whole trading process, the prediction of stock prices movement is an extremely important link.

In today's constantly growing economy, predicting and analyzing the stock market is crucial because it reflects the economic situation, but it is also a challenging task. This is because of the nonlinear characteristics of stock data. Other factors that make stock prices difficult to predict include society, economy, public opinion, media, trading behavior, politics, etc. Professional traders have created a series of analytical methods, including techniques, fundamentals, quantification, etc., in order to make predictions. The availability of massive data has prompted researchers to apply machine learning technology to the stock market, and some of these studies have produced quite promising results [8].

However, it is undeniable that although the financial market has become one of the earliest applications to adopt machine learning (ML). Since the 1980s, people have been using ML to discover patterns in the market. Although ML has made significant progress in predicting market outcomes, recent deep learning has not significantly improved the prediction of financial markets. Although deep learning and other ML technologies have finally made Alexa, Google Assistant, and Google Photos possible, there seems to be little progress in the stock market [2, 3].

As stated in the Efficient Market Hypothesis, markets cannot be fully predicted, making it extremely difficult to apply these research results to real-world investment trading techniques and make price predictions. The exploration in this field has a complete development history, from support vector machine to time series analysis, from random forest to memory neural network. Until now, technical analysis methods have developed completely and maturely, but the fact that financial markets are inherently unpredictable makes it difficult for pure technical analysis to further develop [5]. Compared to datasets for image classification, this obvious requirement is difficult to meet for most financial datasets. Another issue is equally important, in fact, dealing with the difference between future and history is a common challenge in machine learning. In addition to ensuring that the test and training datasets have similar distributions, it is also necessary to ensure that only when future data follows the training/validation distribution is suitable for application [6]. The final problem is also the fundamental one. High frequency trading and algorithmic trading dominate the short-term price, while news and public opinion dominate the price trend for many days. Different factors work together in the financial system, making it difficult to deal with simple single factor machine learning.

Among all these factors that affects the stock price like stock transaction price, trading volume, etc., investor sentiment is the most intuitive and important factor [1]. The earliest quantitative indicators of sentiment were measure during market transaction data, such as the discount number and turnover rate of closed-end funds. However, these data are indirect to reflect the investor's sentiment, but under the past technologies and data conditions, the quantification of indirect indicators has been the best means. Since then, many researchers have also made improvements, hoping to use more direct means to learn the views of investors. With the progress of Internet and computer technology, it has become a common used method to analyze stock market sentiment through text data in recent years. The existence of the Internet can provide enough text big data (such as news, we media, twitter, etc.) for such methods. The artificial intelligence algorithm analyze the investor's emotional text with natural language processing, so as to find out the stock price law [4, 15]. Compared with traditional methods, such text data contain more emotional information and cover a wider range, but the credibility of these data is not sufficient. Removing those fake news so as to improve the quality of the data set can be a feasible way to improve the model performance [7].

At the same time, the machine learning model of fake information detection has been fully developed, both simple models based on LIAR package and complex models have good performance [16, 19]. Therefore, we can use the fake information detection model to screen the emotional texts collected to make the stock price prediction model better.

8.2 Experiment

8.2.1 Methods

We reprint a stock price forecasting model based on emotional text analysis. Price data of several stocks of NASDAQ and relevant news information from news media like Reuters are collected and then pretreated. Uppercase letters are replaced by lowercase letters, punctuation is removed, we unify tense, singular, plural, and remove those stop words [9, 10].

First the words of these new pretreated are passed through a learn a bleem bedding matrix (randomly initialized initially) to map into a vector $f = \binom{n}{p} \in R^{m+q}$, in which n represent the feature extracted from the news and p represent the price data of the ticker related to the news. A convolutional neural network is trained using all these vectors [11]. In this problem, cross entropy is used as the loss function, and a normal noise proportional to the learning rate is added in the process of gradient descent so as to use Stochastic Gradient Langevin Dynamics to obtain more robustness. Because of the randomness of model training, we use the same group of training data to train the model multiple times, select the model that performs best in the validation set and test the performance of the model in the test data set.

After that, we selected an open source fake news detection model [14], and then copied and modified it. The model is based on LIAR dataset [12, 13], which mainly extracts features from the content of the news and also employs an attention mechanism to use the side information of the subject, author, title and other side information. We use a learnable embedding matrix to map words to vectors. A context query vector $q \in R^{1\times d}$ is set to record the summarized side information. A convolution neural network (CNN) is applied over this new word representation matrix $E \in R^{n\times d}$ where n is the number of words in the statement, and extracts features $f_c \in R^{F \times n \times 1}$ from E. And features are also learnt by a CNN model so as to give out the authenticity rating as well as the fakeness rating.

We collate the collected news data of different stocks and use the fake news detection model to score the authenticity of them, reorganize the news with higher authenticity score and train another the stock price prediction model again. And we compare and analyze the accuracy of the models selected for different authenticity.

8.2.2 *Data Analysis*

For baseline, we train the models for 500 epochs with no early stopping. The learning rate was chosen $0.001 \times epoch^{-1}$. And we train other 4 models with dataset processed under different Authenticity Standard (compute the ratio of the authenticity score to fake score, if the ratio is higher than the standard, the news will be accepted) [17, 18].

We apply cross entropy as loss and collect the accuracy of different models, and we also collect the accuracy when the prediction (a variable between 0 and 1, in which 1 represents an increase and 0 represents a decrease) >0.7 or <0.3 and when the prediction >0.9 or <0.1. Because of the randomness in the model generation process, we repeat training 5 times for each model and selected the ones with better performance.

From Table 8.1 we can see the loss is improved by 10.74% in maximum and accuracy has an improvement of 4.37% in maximum. Although the improvement is not significant, compared with baseline, different models trained by new data obtained under different standard all have steadily improved in terms of loss function and accuracy (except accuracy when prediction >0.9 or <0.1). The least improvement of loss is 7.33% attributed by dataset with standard 0.5, and the least improvement of accuracy is 0.29% attributed by dataset with standard 0.6. This shows that using fake news detection helps in improving the quality of dataset and the performance of the stock price movement prediction model (Fig. 8.1).

Table 8.1 Performance of different models

Data type	Authenticity rate	Data scale	Loss	Accuracy (%)	Accuracy (prediction > 0.7 or < 0.3) (%)	Accuracy (prediction > 0.9 or < 0.1) (%)
Baseline	0	51,087	0.8664	54.42	54.74	34.06
Fake news detection processed	0.5	48,608	0.8029	58.79	57.98	44.20
	0.6	40,099	0.802	54.71	58.38	68.67
	0.65	35,868	0.7986	53.51	57.20	56.04
	0.7	29,953	0.7733	56.25	58.67	63.64

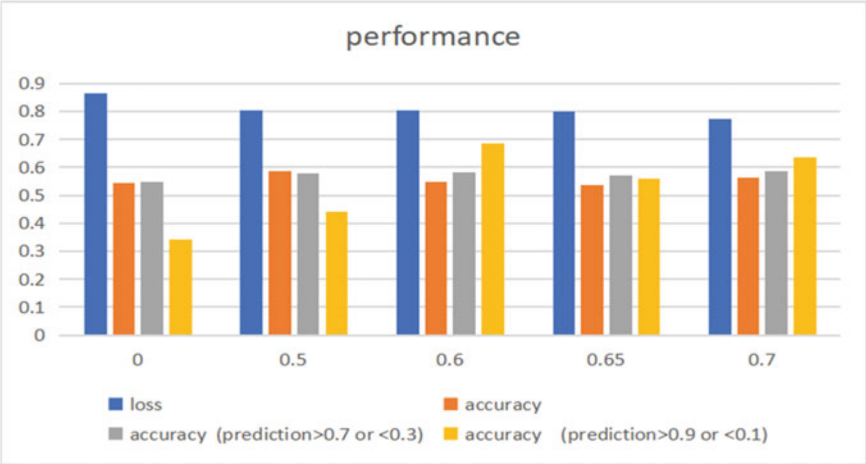


Fig. 8.1 Training 5 times for each model and selected the ones with better performance

8.3 Areas of Improvement and Future Work

Using machine learning technology to analyze emotional texts to predict stock prices is an emerging research method, as we can see, with the continuous development of the Internet and mobile communication technology, the way people access and disseminate information is constantly changing. Now, a series of digital media such as social media and news media has become an important way for people to obtain information. These media contain a large amount of emotional text, and the emotional signals contained therein are closely related to market conditions. Therefore, obtaining predictive information about stock prices from emotional texts has gradually become a hot research topic [21].

Using machine learning techniques to analyze emotional text to predict stock prices is currently one of the most widely used methods. This technique uses natural language processing technology and machine learning algorithms to analyze a large number of emotional texts such as social media and news reports, extracts emotional signals from them, and predicts the ups and downs of stock prices based on them [20]. In recent years, with the rapid development of artificial intelligence technology, the application scope of machine learning technology in analyzing emotional text has become more and more extensive, and its development prospects have attracted much attention [22].

Firstly, using machine learning techniques to analyze emotional text to predict stock prices has obvious advantages as a reference for investors. Traditionally, investors mainly rely on company financial reports, market research reports, and other information to make decisions. However, these pieces of information are often affected by various factors such as market environment, political factors, etc., and may not accurately reflect the true trend of stock price changes. Using machine learning technology to analyze emotional text can obtain more comprehensive and sensitive information better understand market conditions, and assist investors in making wiser investment decisions.

Secondly, using machine learning techniques to analyze emotional text to predict stock prices can improve the regulatory capabilities of financial regulatory agencies. Financial regulatory agencies need to better understand and regulate market conditions to ensure market stability and fair competition. Using machine learning technology to analyze emotional text can obtain more comprehensive market information, better monitor market risks, and better protect the interests of investors.

Of course, using machine learning techniques to analyze emotional text to predict stock prices also faces some challenges and limitations. The biggest challenge is how to accurately identify and quantify emotional signals and relate them to actual fluctuations in stock prices. In addition, it is necessary to consider multiple factors that affect stock prices, such as the company's financial situation, market environment, etc., to ensure the stability and accuracy of the prediction results.

Overall, using machine learning techniques to analyze emotional text to predict stock prices has broad application prospects in the future. With the continuous improvement of artificial intelligence technology and data processing capabilities, this technology is expected to become an important reference for financial market investment decisions and have a positive promoting effect on financial regulation.

Of course, any technology has its drawbacks, and for predicting stock prices through emotional text analysis, the following points should be noted:

Firstly, there is uncertainty in the analysis results of emotional texts. The emotional analysis of emotional texts is influenced by many factors, such as the context of the text, cultural background, personal emotions, etc. Therefore, using it as the main basis for predicting stock prices may have errors and biases.

Secondly, the stock market is very complex. In addition to emotional factors, the stock market is also influenced by numerous economic, political, and social factors. The changes in these factors may have a greater impact on stock prices, while the impact of emotional texts is relatively small.

Finally, the reliability of the data needs to be ensured. When using machine learning technology to analyze emotional texts, it is necessary to ensure the reliability of data sources and the accuracy of data annotation. If there are issues with the data, it may affect the results of the analysis, thereby affecting the accuracy of the prediction.

Therefore, using machine learning technology to analyze emotional texts to predict stock prices requires comprehensive consideration of multiple factors, and strict screening and validation of the data to ensure the accuracy and reliability of the prediction results. The emotion text analysis machine learning technology targeted in this article is aimed at compensating for the shortcomings of data filtering. It is also hoped that in future research, the role and methods of data filtering will be further explored, and it is also hoped that solutions and methods can be found for other key difficulties at the same time.

References

1. H. Lee, M. Surdeanu, B. Maccartney, et al., On the importance of text analysis for stock price prediction. surdeanu info (2014)
2. J. Devlin, M.-W. Chang, K. Lee, K. Toutanova, BERT: pre-training of deep bidirectional transformers for language understanding (2018). arXiv preprint arXiv:1810.04805
3. M. Welling, Y. Whye Teh, Bayesian learning via stochastic gradient Langevin dynamics. ICML (2011)
4. S. Kogan, T.J. Moskowitz, M. Niessner, Fake news: evidence from financial markets (2019). Available at SSRN 3237763
5. T. Mikolov, K. Chen, G. Corrado, J. Dean, Efficientestimation of word representations in vector space (2013). arXiv preprint. arXiv:1301.3781
6. A. Paszke, S. Gross, S. Chintala, G. Chanan, E. Yang, Z. DeVito, Z. Lin, A. Desmaison, L. Antiga, A. Lerer, Automatic differentiation in pytorch (2017)
7. J. Devlin, M.-W. Chang, K. Lee, K. Toutanova, Bert: pre-training of deep bidirectional transformers for language understanding. In: *Proceedings of the 16th Annual Conference of the North American Chapter of the Association for Computational Linguistics* (2018)
8. R.A. Kamble, Short and long-term stock trend prediction using decision tree (2017)
9. N. Vo, K. Lee, Hierarchical multi-head attentive network for evidence-aware fake news detection (2021)
10. A. Vaswani, N. Shazeer, N. Parmar, J. Uszkoreit, L. Jones, A.N. Gomez, L. Kaiser, I. Polosukhin, Attention isall you need, in *Advances in Neural Information Processing Systems*, pp. 5998–6008 (2017)
11. J. Pennington, R. Socher, C. Manning, Glove: global vectors for word representation, in*Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP)*, pp. 1532–1543 (2014)
12. W. Yang Wang, "liar, liar pants on fire": a new benchmark dataset for fake news detection, in *Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics* (Volume 2: Short Papers) (2017)
13. S. Madge, Predicting stock price direction using support vector machines (2015)
14. P. Shi, J. Rao, J. Lin, Simple attention-based representation learning for ranking short social media posts (2018). arXiv preprint. arXiv:1811.01013
15. Y. Guo, Stock price prediction based on LSTM neural network: the effectiveness of news sentiment analysis (2020)
16. Z. Yang, Z. Dai, Y. Yang, J. Carbonell, R. Salakhutdinov, Q.V. Le, Xlnet: generalized autoregressive pretraining for language understanding (2019). arXiv preprint. arXiv:1906.08237
17. E. Ranjan, Fake news detection by learning convolution filters through contextualized attention (2019)
18. X. Ding, Deep learning for event-driven stock prediction. IJCAI (2015)
19. W.Y. Wang, "liar, liar pants on fire": a new benchmarkdataset for fake news detection (2017). arXiv preprint. arXiv:1705.00648
20. H. Grigoryan, A stock market prediction method based on support vector machines (SVM) and independent component analysis (ICA) (2016)
21. T. Loughran, B. McDonald, When is a liability not a liability? Textual analysis, dictionaries, and 10-Ks. J. Financ. **66**(1), 35–65 (2011)
22. Y. Kim, Convolutional neural networks for sentence classification (2014). arXiv preprint. arXiv:1408.5882

Chapter 9
A Study of SME Financing Dilemma from Adverse Selection Perspective

Yuan Yi and Cui Beiqing

Abstract The difficulty of SME financing has been a hot topic of research for scholars. This paper analyzes the lending game between banks and SMEs by constructing an adverse selection model based on the relevant theories of information economics, and empirically analyzes the constructed adverse selection model based on SME financing data in Guangdong Province, and concludes that: (1) the adverse selection problem largely hinders the financing problem of SMEs. In the case of information asymmetry, the higher the interest rate of, the stronger the bank's willingness to lend; low-risk enterprises choose to give up the loan because they cannot afford the high loan interest; while high-risk enterprises tend not to repay the loan, which eventually leads to the generation of adverse selection. (2) In the case of complete information symmetry, banks only need to observe whether the lending enterprises are high-risk or low-risk, and then set different lending rates according to different enterprises, so that the enterprises can obtain no less than the level of risk-free return, and the banks can also maximize the return on loans. Based on the findings of the study, relevant recommendations are put forward, which have practical significance for solving the financing dilemma of SMEs.

Keywords SMEs · Financing dilemma · Information asymmetry · Adverse selection

9.1 Introduction

SMEs have an irreplaceable role in economic development and are the core force driving the development of the real economy. However, in the economic market, SMEs are not enjoying their due. The development of enterprises and technological progress cannot be achieved without the support of capital, and indirect financing through commercial banks is one of the most important financing means for SMEs.

Y. Yi · C. Beiqing (✉)
Hubei Business College, Wuhan, China
e-mail: 821949403@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_9

For a long time, SMEs have always faced the dilemma of difficult financing. Although SMEs are the foundation of economic development, their small size and imperfect business system prevent them from having the same access to equity financing in the financial market as large enterprises. What's more, due to the information asymmetry problem between SMEs and banks, it is also difficult to get indirect financing through banks. Although the state has introduced various policies to support SMEs, the actual effect is not good. Therefore, how to effectively alleviate the information asymmetry problem between banks and enterprises has some practical significance to solve the financing dilemma of SMEs.

Based on lemon market theory and information asymmetry theory, this paper analyzes the lending game relationship between banks and SMEs (including high-risk and low-risk enterprises). Using the adverse selection model and combined with empirical data, this paper explores the game process of banks' granting loans to enterprises, finds the reasons for SMEs' financing difficulties, and thus proposes solutions to SMEs' financing difficulties.

The innovation of this study is to apply the theories in information economics to the credit market where banks and enterprises play games, and to analyze the economic logic behind the difficulty of lending to SMEs, with more emphasis on empirical research to analyze through actual data.

9.2 Literature Review

The problem of SME financing has been the focus of research by domestic and foreign scholars. As early as the 1980s, some scholars suggested that information asymmetry between SMEs and financial institutions was considered as the root cause of SMEs' financing difficulties [7], and Berger and Udall [8] pointed out that the opacity of SMEs' financial information was the main reason for their financing difficulties. Opaque information of enterprises will increase the cost of financing and also affect the willingness of banks to lend. SMEs are often characterized by high business risk, poor asset quality, and lack of sufficient cash flow and collateral, which results in lack of credit [1]. Gao [2] points out that the fundamental reason for the difficulty of financing SMEs is the lack of credit of the enterprises themselves and the inability of banks to accurately assess their business status.

Due to their own characteristics, SMEs cause financing difficulties. Given the role of SMEs in economic development, some scholars then propose to increase support for SME loans. Luo [3] argues that commercial banks in China are in a capital dominant position in the financial market, and proposes that the government needs to guide commercial banks to change their existing lending habits, not only to incline credit resources to core enterprises, but also to support SMEs more and allocate credit resources rationally. However, the information asymmetry between SMEs and banks is prone to moral hazard and adverse selection. Throughout the credit process, it is difficult for banks to obtain effective information to understand the true risk level of SMEs, thus causing adverse selection and moral hazard. SMEs can use their information advantage to harm the interests of lenders, especially commercial banks and other financial institutions [5]. Zhou [6], on the other hand, argues that banks cannot effectively measure SME loans and may bank to the risks posed. Li [4], on the other hand, suggests that banks go through the credit rating of SMEs and then use the credit rating results to determine whether to give loans to enterprises. Therefore, SMEs need to establish a good credit system and adopt appropriate financing strategies according to their development stages.

A series of theoretical and practical studies have been conducted at home and abroad on the financing difficulties of SMEs, which have certain implications for solving the practical problems. However, previous literature tends to be more qualitative in analyzing the problem of SME financing difficulties. In this paper, we will study the problem of SME financing difficulties from both theoretical and empirical perspectives, using the adverse selection model.

9.3 Theoretical Analysis of SME Financing Dilemma from the Perspective of Adverse Selection

9.3.1 Model Construction

Based on the principal-agent theory, the disadvantaged party (i.e. the bank) and the advantaged party (i.e. the SME) are defined as the "principal" and "agent" respectively, and the adverse selection model of SME financing is constructed.

To facilitate the study and without prejudice to the results, we made the following assumptions before building the model.

(1) Assume that both the bank and the firm satisfy the "economic man" assumption and both seek to maximize their own interests.
(2) Assume that the bank is risk neutral.
(3) Assume that there are only two types of SMEs in the credit market, high-risk and low-risk. High-risk SMEs and low-risk SMEs are called firm H and firm L, respectively.
(4) Assume that the shares of firms L and H in the credit market are q and $1-q$ respectively.

Let the amount of the firm's loan to the bank be X. The firm will use the loan for investment. Assume that if firm L succeeds in its investment, the rate of return on investment it receives is RL; assume that if firm H succeeds in its investment, the rate of return on investment it receives is RH. Firm H is known to be a high-risk firm because it faces higher risk, so firm H tends to need a higher rate of return on investment to compensate for the high risk, then there is always RH > RL in general. U_0 is the retained utility (for the bank is its loan yield is higher than the risk-free rate, and for the firm it is the return on its loan followed by an investment that is higher than the interest rate on its loan), and I is the interest rate at which the bank lends

Table 9.1 Benefit matrix for banks and two types of SMEs

	L Enterprises	Enterprise H	Banks
Investment success	$XR^{L} - X(1 + I)$	$XR^{H} - X(1 + I)$	$X(1 + I)$
Investment failure	$- X(1 + I)$	$- X(1 + I)$	$- X$

Table 9.2 Matrix of investment success probability for two types of SMEs

	L Enterprises	Enterprise H
Investment success	P^{L}	P^{H}
Investment failure	$1 - P^{L}$	$1 - P^{H}$

to the SME. Assuming that the probability of successful investment for firm L and firm H is PL, PH, respectively, it is clear that there is PL > PH.

The returns for the bank and the two types of businesses are shown in the Table 9.1. Probability of successful investment in two types of businesses (Table 9.2).

Thus, the bank expects a return of.

$$E(Y) = q\left[XP^{L}(1 + I) - X\left(1 - P^{L}\right)\right] + (1 - q)\left[XP^{H}(1 + I) - X\left(1 - P^{H}\right)\right]$$

L Business Expected Returns.

$$E(L) = P^{L}\left[XR^{L} - X(1 + I)\right] + \left(1 - P^{L}\right)[-X(1 + I)] = XP^{L}R^{L} - X(1 + I)$$

Expected benefits for H-shaped companies.

$$E(H) = P^{H}\left[XR^{H} - X(1 + I)\right] + \left(1 - P^{H}\right)[-X(1 + I)] = XP^{H}R^{H} - X(1 + I)$$

Based on the above hypotheses, we specifically analyze the problems that may arise in the financing process of SMEs and explore two questions: (1) under which circumstances banks are willing to lend money to SMEs; and (2) why banks have adverse selection problems after lending to SMEs.

9.3.2 Analysis of the Question of Whether Banks Lend to SMEs

According to the above assumptions, there is an opportunity cost for the amount X that the bank lends to the SME, i.e., the bank can use that amount to invest in a risk-free asset. This opportunity cost is X $(1 + U_0)$, and since there is a risk and a cost to risk management in lending to SMEs, banks will only choose to lend to SMEs if the interest rate I is greater than the retained utility U_0, i.e.

$$I > U_0$$

$$E(Y) > X(1 + U_0)$$

Combining the bank's expected return formula given above yields.

$$q > \frac{2 + U_0}{(2 + I)\left(P^L - P^H\right)} - \frac{P^H}{P^L - P^H}$$

From this, it can be deduced that only when E(Y) $>$ $X(1 + \mathrm{U}_0)$, banks will only lend to SMEs. If the share of L firms in the credit market is lower than this proportion, banks will not lend. However, banks, as the information disadvantaged party, are often unable to accurately determine the proportion of low-risk firms L and high-risk firms H in the credit market.

A deformation of this inequality yields

$$I > \frac{2 + U_0}{P^H(1 - q) + \left(P^L - P^H\right)q} - 2$$

Combining the two inequalities above regarding q and I, it can be seen that I is negatively related to q. As the loan rate I becomes larger, the banks' willingness to lend is stronger, which is consistent with the actual situation. And as I increases, the market share of low-risk q is gradually becoming smaller. Since low-risk SMEs cannot afford high loan interest rates, they will slowly push out of the credit market, while high-risk SMEs themselves are more inclined not to repay, so they will still choose to continue lending despite the rising loan interest rates, which is adverse selection. The low-risk companies with good credit gradually exit the credit market, and eventually only the high-risk companies with poor credit are in the market.

9.3.3 Analysis of Adverse Selection Problems in Credit Markets

(1) Optimal bank lending decision under perfect information symmetry

With perfect information symmetry, banks can accurately distinguish between high-risk and low-risk firms and use this to set different lending rates. Suppose that the bank lends to firm L and firm H at rates of IL and IH, respectively.

When lending to a low-risk SME L, the model is developed as follows.

$$E_L(Y)_{\max} = XP^L(1 + I_L) - X\left(1 - P^L\right)$$

$$s.t.\, R^L P^L - I_L \geq U_0$$

The optimal solution for the loan to firm L is.

When $I_L = R^L P^L - U_0$ when EL (Y)max gets the maximum value.

When lending to a high-risk SME H, model the following.

$$E_H(Y)_{max} = XP^H(1 + I_H) - X\left(1 - P^H\right)$$

$$s.t.\ R^H P^H - I_H \geq U_0$$

Similarly, the optimal solution for lending to firm H can be obtained as.

When $I_H = R^H P^H - U_0$ when EH (Y)max gets the maximum value.

Since enterprise H is a high-risk enterprise, the return required to be earned by enterprise H to invest with this loan should be higher than that of a low-risk L enterprise, which generally has $R_H > R_L$ that therefore firm H tends to be able to accept a higher interest rate on the loan than firm L. Likewise banks lending to H firms also face higher risks than lending to L firms, so they also require a higher loan rate, i.e., in general there is $I_H > I_L$.

In summary, with complete information symmetry, the bank only needs to observe whether the lending enterprise is high-risk or low-risk, and then set different lending rates according to the nature of different enterprises, at which the enterprise can obtain no less than the level of risk-free rate of return, while the bank can also maximize the return on the loan.

(2) Formation of adverse selection

In the real credit market, banks are unable to accurately obtain private information about enterprises, and cannot distinguish which are low-risk enterprises and which are high-risk enterprises, so they can only set an expected lending rate, and the changes in the expected rate setting will affect the enterprises' exit or entry into the credit market, in which case the problem of adverse selection of bank loans arises.

According to the above model, a firm will choose to take out a loan only if the likely return after the loan is not less than the retained utility U_0. Assuming that the interest rate level at which the firm's post-loan return is equal to the retained utility U_0 is called the maximum acceptable loan rate for the firm, the maximum acceptable interest rates for firm L and firm H can be derived.

For firm L, the proceeds obtained after the loan are not less than the retained utility U_0, i.e.

$$R^L P^L - I_L \geq U_0$$

Solve for the maximum acceptable interest rate for firm L (i.e., its desired loan rate) as

$$I_L = R^L P^L - U_0$$

For firm H, the proceeds obtained after the loan are not less than the retained utility U_0, i.e.

$$R^H P^H - I_H \geq U_0$$

Solve for the maximum acceptable interest rate for firm H (i.e., its desired loan rate) as

$$I_H = R^H P^H - U_0$$

Since PL > PH, RH > RL, and in the real credit market the high-risk SME H tends to accept higher interest rates, assume that PL RL < PH RH. When the bank lending rate exceeds the maximum acceptable interest rate for enterprise H, the "non-compliant" among enterprises H and L choose not to repay the loan and continue to The bank has no way to determine whether firm H will repay the loan. High-risk firms have a high probability of default and are seen as mostly defaulting when the interest rate exceeds the maximum acceptable rate; low-risk firms are assumed to have a very low probability of default and will not choose to lend when the interest rate exceeds their maximum acceptable rate.

In a credit market with asymmetric information, banks can only set an expected interest rate to extend loans to SMEs. If the bank sets a lower interest rate I1 at the beginning, at this time I1 < IL, at this time the bank sets a loan rate I1 is smaller than the expected loan rate of L enterprises, L enterprises and H enterprises will make loans, because the loan rate is lower and the probability of default of H enterprises is higher, and the risk management of them is also higher cost, at this time the bank does not achieve the maximum benefit, so it will choose to increase the loan rate. If the bank sets a higher interest rate of I2, then I2 > IH, then the bank sets the loan interest rate I2, higher than the expected loan interest rate of H enterprises, then H enterprises will still choose to lend, then H enterprises are "non-compliance". This will lead to adverse selection, which will cause those "trustworthy" enterprises (i.e., L enterprises) to withdraw from the credit market, while "non-trustworthy" enterprises (i.e., H enterprises) will flood the entire credit market, when the bank loans will be very likely to default, the banking industry cannot obtain the maximum benefit The banking sector will not be able to obtain the maximum benefit. Therefore, banks can maximize the return on loans only if they adjust the interest rate to a value between IL and IH, and In. However, the maximum acceptable interest rate for L firms is always less than In, so L firms, as "trustworthy" ones, will still choose to exit the credit market, so that only "untrustworthy" H firms remain in the market, which also leads to adverse selection.

9.4 Empirical Study

Based on the above research model, this paper selects the data of bank loans for inclusive SMEs in Guangdong Province from 2018–2021 to conduct an empirical study (Table 9.3).

Using 2018 as the base period, the amount of SME loans X = 26,160.69. Assume that the proportion of low-risk SME L enterprises in the credit market at the beginning of 2018 is 50% and the proportion of high-risk H enterprises is also 50%; assume that the probability of successful investment in L enterprises is 80% and the probability of successful investment in H enterprises is 20%. Based on the annual net profit attributable to SMEs in the A-share market, it is reasonable to assume that the return of successful investment in L enterprises is 30% and the return of successful investment in H enterprises is 500%. The retention utility U_0, measured by the yield on our 10-year treasury bonds, is about 3%.

Based on the above data and assumptions, bringing in the data yields the maximum acceptable loan interest rate (i.e., its desired loan interest rate) for firm L as

$$I_L = \frac{26160.69 \times (1 + 30\%) \times 80\% - 3\% - 26160.69}{26160.69} \approx 4.00\%$$

The maximum acceptable loan rate (i.e., its desired loan rate) for Firm H is.

$$I_H = \frac{26160.69 \times (1 + 500\%) \times 20\% - 3\% - 26160.69}{26160.69} \approx 20.00\%$$

Since the above assumes a 50% share of each of firm L and firm H in the credit market, it can be concluded that the bank's desired lending rate would be if, in the absence of any other factors, the

$$I_Y = 50\% \times 4.00\% + 50\% \times 20.00\% = 12.00\%$$

Although in practice, the ratio of firm L to firm H is not necessarily 50%, it can be seen that the interest rate is still higher than the expected loan rate for firm L. Therefore, according to the adverse selection model, there will be SMEs that choose not to lend and exit the credit market.

Table 9.3 Amount of inclusive SME loans by banking financial institutions in Guangdong Province, 2018–2021 (unit: billion yuan)

Loan amount (billion yuan)	2018	2019	2020	2021
Banking and financial institutions in Guangdong Province	26,160.69	9786.95	12,725.34	15,897.21

Data source Guangdong Regulatory Bureau of China Banking and Insurance Regulatory Commission

Assume that the share of L firms is 20% and the share of H firms is 80% in 2019. Other factors remain unchanged. From the formula of the maximum acceptable loan interest rate for small and medium enterprises, it is clear that the factors affecting the expected loan interest rate for enterprises are not related to the loan amount, but to the probability of successful investment and the rate of return. So at this time IL, IH unchanged, while the bank's expected loan rate will change due to the change in the percentage of L and H enterprises. At this time the bank's expected lending rate is

$$I_{Y'} = 20\% \times 4.00\% + 80\% \times 20.00\% = 16.80\%$$

As banks expect lending rates to rise, creditworthy SMEs further withdraw from the market, and so the cycle continues eventually leaving only poor creditworthy, high-risk SMEs in the credit market.

In summary, it can be seen that the problem of adverse selection does largely hinder the financing problem of SMEs, and with complete information symmetry, banks are able to effectively solve this problem by setting different lending rates, which also suggests the need to establish a more complete information system for SMEs in China and eliminate the information asymmetry between banks and SMEs.

9.5 Conclusion

Based on lemon market theory and information asymmetry theory, this paper analyzes the game relationship of lending between SMEs and banks, uses the adverse selection model and combines with empirical data to explore the game process of banks giving loans to enterprises, and concludes that: (1) the adverse selection problem hinders the financing problem of SMEs to a large extent. In the case of information asymmetry, the higher the interest rate, the stronger the bank's willingness to lend; low-risk enterprises choose to give up the loan because they cannot afford the high loan interest; while high-risk enterprises tend not to repay the loan, which eventually leads to adverse selection. (2) In the case of complete information symmetry, banks only need to observe whether the lending enterprises are high-risk or low-risk, and then set different lending rates according to different enterprises, whereby the enterprises can obtain returns no less than the level of risk-free return, and the banks can maximize the return on loans. Based on the findings of the study, the following recommendations are made: (1) Deepen the reform of the New Third Board, enhance the inclusiveness of the New Third Board, support the development of SMEs, and allow more high-quality SMEs to join. (2) Improve the guarantee system in financing to make up for the lack of credit problem that exists in SMEs, which can effectively solve the problem of information disadvantage of banks. SMEs should take the initiative to publish relevant information in accordance with the information disclosure standards of the securities market and allow auditing institutions to conduct audits. The transparency and authenticity of information published by enterprises play a crucial role in alleviating the information asymmetry between the two. In addition, relevant authorities should also strengthen the regulation and review of SME information.

Funding Presided over the Hubei Provincial Department of Education project "Research on Green Technology Innovation Paths under the Carbon Emission Right Trading Mechanism" (No. B2022441).

References

1. J. Guan, *Research on the Causes and Counter Measures of Financing Difficulties of Small and Medium-Sized Enterprises* (Chongqing University of Technology, Chongqing, 2021)
2. J. Gao, *Information, Collateral Security and SME Financing* (Shandong University, Shandong, 2019)
3. D. Luo, *Research on the Analysis of Credit Loans to Small and Micro Enterprises of Commercial Banks in China Based on Game Theory* (Tianjin University, Tianjin, 2018)
4. C. Li, *Research on Information Asymmetry in Financing Decision of Small and Medium-Sized Enterprises* (Heilongjiang University, Harbin, 2018)
5. Y. Han, Research on financing risks of small and medium-sized enterprises from the perspective of information disclosure. Bus. Dev. Econ. **7**, 41–44 (2020)
6. Y. Zhou, How to effectively solve the problem of "information asymmetry" in SME financing. Qual. Market **17**, 88–90 (2021)
7. Stieglitz and Weiss, Credit rationing in markets with imperfect information. Am. Econ. Rev. **71**, 393–410 (1981)
8. A.N. Berger, G.F. Udall, A more complete conceptual framework for SME finance. J. Bank. Financ. **11**, 225–312

Chapter 10
The Effect and Mechanism of Digital Finance on Green Urbanization

Hongyan Wu and Xiaojun Zhang

Abstract Digital finance is a new model of financial greening development, which is efficient, convenient and low-cost, and promotes green urbanization. This paper examines the effect, heterogeneity and transmission mechanism of digital finance on green urbanization based on inter-provincial panel data in China from 2011 to 2019, using fixed effects model and mediating effect. The results show that digital finance can significantly promote the development of green urbanization. However, there is regional heterogeneity and structural heterogeneity in the impact of digital finance on green urbanization, with the eastern region playing a significant role, the coverage of digital finance playing a significant role, and the digitalization playing a suppressive role. Further research shows that technological innovation is an important intermediary channel for digital finance to influence the development of green urbanization.

Keywords Digital finance · Green urbanization · Technological innovation · Fixed effects model

10.1 Introduction

Urbanization is the driving force of economic development and a necessary way to modernization of China. China has made remarkable achievements in urbanization, with the urbanization rate reaching 65.22% by the end of 2022. However, the long-term extensive growth with high consumption, high pollution and low efficiency has led to increasingly serious ecological and environmental problems. The 18th National Congress proposed to integrate the concept of ecological civilization in the process of new urbanization construction, the 19th National Congress clearly

---

H. Wu (✉) · X. Zhang
Wuhan Technology and Business University, Wuhan, China
e-mail: hbwhy26@126.com

Hubei Business Service Development Research Center, Wuhan, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_10

pointed out the need to promote green development, and The report of the 20th National Congress of the Communist Party of China continues to put forward that promoting green development, promoting harmonious coexistence between human and nature, and promoting green and low-carbon economic and social development are the key links to achieve high-quality development. In this context, the promotion of people-centered new urbanization must be deeply integrated with green development, continue to promote green urbanization, take the concept of ecological civilization as the guide, take the coordinated development of economic, social, cultural, ecological and other aspects as the goal, and take "intensive, intelligent, low-carbon, efficient" as the main characteristics of high-quality urbanization construction mode.

The construction of new urbanization has entered a new stage of development and needs to further strengthen the financial guarantee. All along, financial support has been an important basic guarantee for the construction of new urbanization, which has greatly promoted the development of new urbanization. Research has found that inclusive finance can promote urbanization [1, 2]. However, in the process of supporting the development of new urbanization, the traditional financial model has problems such as resource mismatch, insufficient supply, supply and demand contradiction, which leads to the low efficiency and high cost of financial services to the real economy, and to some extent restricts the development of new urbanization. For example, western finance has insufficient support for the construction of new urbanization [3], and inclusive finance has a restraining effect on land urbanization.

With the development of big data, cloud computing, artificial intelligence and other technologies, digital finance has emerged and developed rapidly, and the efficiency of financial service entities has been continuously improved. Digital finance has the advantages of high efficiency, convenience, low cost and wide coverage, which improves the coverage and service efficiency of traditional finance. Digital finance is an important part of the digital economy. It is a green development model in itself. It coincides with the concept of green development and can effectively promote green development. Research has found that digital finance can significantly promote the growth of China's green economy [4, 5]. At the same time, digital finance also improves the ability of technological innovation, which is conducive to technological innovation [6, 7]. Technological innovation is an important guarantee for the development of green urbanization. Therefore, has digital finance effectively promoted the development of green urbanization? Does digital finance affect the development of green urbanization through technological innovation? The in-depth study of this issue has important practical significance.

Although a large amount of literature has been published to study issues related to financial support for the development of new urbanization, relatively few results have been published to study the impact of digital finance on green urbanization from the perspective of digital finance. Based on this, this paper explores the impact, heterogeneity and mediating mechanism of digital finance on green urbanization based on panel data of 30 Chinese provinces from 2011 to 2019, using a two-way fixed effects model.

10.2 Variable Selection, Data Sources and Model Construction

10.2.1 Variable Selection

(1) Explained variables: The explained variable of this paper is green urbanization (urb).The index is based on the basic concept of green development, referring to the green urbanization development evaluation index system constructed by Chen et al. [8], which constructs a comprehensive evaluation index system of green urbanization from three dimensions: economic, social and ecological, and a total of 14 specific indicators are selected to measure the development level of green urbanization by using the entropy value method, and the specific indicators are shown in Table 10.1.

Table 10.1 Green urbanization evaluation index system

Green urbanization	System layer	Indicator layer	Unit	Properties
	Economy	GDP per capita	Yuan	Positive
		Secondary and tertiary industry output value as a proportion of GDP	%	Positive
		Per capita disposable income of urban residents	Yuan	Positive
	Social	Per capita financial expenditure on education	Yuan	Positive
		Number of beds in medical and health institutions per 1,000 population	Zhang	Positive
		Urban road area per capita	Square meters	Positive
		Public transportation vehicles per 10,000 people	Marking table	Positive
	Ecology	Greening coverage of built-up areas	%	Positive
		Green space per capita	Square meters	Positive
		Comprehensive utilization rate of industrial solid waste	%	Positive
		Industrial sulfur dioxide release per unit of GDP	Tons/million	Negative
		CO_2 emissions per capita	Tons/person	Negative
		Harmless treatment rate of urban domestic waste	%	Positive
		Urban sewage treatment rate	%	Positive

Table 10.2 Green urbanization development level and ranking

Province	Value	Province	Value	Province	Value
Beijing	0.675 (1)	Ningxia	0.419 (11)	Hainan	0.359 (21)
Jiangsu	0.572 (2)	Anhui	0.412 (12)	Sichuan	0.353 (22)
Shanghai	0.549 (3)	Shanxi	0.405 (13)	Henan	0.345 (23)
Zhejiang	0.547 (4)	Xinjiang	0.397 (14)	Jilin	0.341 (24)
Tianjin	0.545 (5)	Hubei	0.393 (15)	Guizhou	0.334 (25)
Shandong	0.524 (6)	Hunan	0.382 (16)	Guangxi	0.333 (26)
Guangdong	0.485 (7)	Liaoning	0.372 (17)	Yunnan	0.329 (27)
Fujian	0.465 (8)	Qinghai	0.372 (18)	Shanxi	0.325 (28)
Chongqing	0.445 (9)	Hebei	0.371 (19)	Heilongjiang	0.320 (29)
Neimeng	0.420 (10)	Jiangxi	0.366 (20)	Gansu	0.296 (30)

Table 10.2 gives the values and rankings after averaging the green urbanization indicators for each province from 2011 to 2019, and the top five provinces are Beijing, Jiangsu, Shanghai, Zhejiang and Tianjin in order, which shows that there is a strong relationship between the level of green urbanization development and the level of high-quality economic development.

(2) Core explanatory variables: The core explanatory variable in this paper is the level of digital financial development (dif). The word count of digital financial inclusion published by Peking University is used as a proxy indicator of the level of digital financial development [9]. This indicator includes three dimensions of breadth of coverage (cov), depth of use (use) and digitization (dig) in addition to the total index.

(3) Mediating variables: Technological innovation (tec): This paper uses the number of patent applications received by 10,000 people in a region to indicate as a proxy variable for technological innovation.

(4) Control variables: Based on the existing literature, the control variables selected in this paper that affect the development of green urbanization mainly include: government support (gov): measured by the ratio of fiscal expenditure to GDP in each region; industrial structure (str): expressed by the ratio of the total value of tertiary industry to GDP; environmental regulation (enr): measured by the ratio of carbon emissions to GDP in each region, where carbon emissions are measured using the China Carbon Accounting database measured carbon emissions data [10–13]; foreign direct investment (fdi): measured by the proportion of foreign direct investment in GDP.

10.2.2 Data Sources

Considering the accuracy and availability of data, this paper selects data from 30 provinces in China (excluding Tibet and Hong Kong, Macao and Taiwan) from

Table 10.3 Descriptive statistics

Variables	N	Mean	Std.Dev	Minimum	Maximum
lnurb	270	3.692	0.264	3.023	4.320
lndif	270	5.151	0.669	2.936	5.960
lngov	270	3.141	0.374	2.476	4.114
lnstr	270	3.818	0.192	3.466	4.389
lnenr	270	0.451	0.760	−1.386	2.447
lnfdi	270	0.262	1.092	−3.233	1.997
lntec	270	1.801	1.024	−0.0955	3.887

2011 to 2019, with a total of 270 observations. The data are mainly from the China Statistical Yearbook, Digital Inclusive Finance Index of Peking University, the official website of the National Bureau of Statistics, the statistical yearbooks of each province and region, EPS statistical database, and the Chinese carbon accounting database ceads.net, and the missing data are supplemented by interpolation. To mitigate the effect of heteroskedasticity, all variables were logarithmized. The detailed descriptive statistical characteristics of each variable are shown in Table 10.3.

10.2.3 Model Construction

According to the previous analysis, in order to verify the impact of digital finance on green urbanization, model (1) is constructed for analysis.

$$\mathrm{urb}_{\mathrm{it}} = \alpha_0 + \alpha_1 \mathrm{dif}_{\mathrm{it}} + \sum \theta_{\mathrm{j}} \mathrm{control}_{\mathrm{it}}(\gamma \mathrm{X}_{\mathrm{it}}) + \mu_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{it}} \tag{10.1}$$

Urb is the explained variable, indicating the level of new urbanization; dif is the core explanatory variable, indicating the level of digital finance development; control (X_{it}) is a set of control variables, including government support, industrial structure, environmental regulation, and foreign direct investment; i and t denote provinces and years, respectively, μ_i denotes regional individual effect, λ_t denotes the time effect, and ε_{it} is a random disturbances.

10.3 Analysis of Empirical Results

10.3.1 Baseline Regression

In this paper, 30 inter-provincial panel data from 2011 to 2019 were selected, before constructing the panel data regression model, it is necessary to test whether to choose a fixed-effects model or a random-effects model. According to the Hausman test, the result shows that the *P* value is 0.0001, the original hypothesis is rejected, and the fixed-effects model should be used. In the regression, the following treatments were performed: first, in the regression test, the robust standard error was used by default; second, in order to absorb the relevant fixed effects, the paper followed the most typical "two-way fixed effects model (controlling for the 'time-province' dummy variable)" for the test.

The regression results are shown in Table 10.4, where digital finance has a significant positive effect on green urbanization both without and with the inclusion of control variables. The results in column (2) of Table 10.4 show that controlling only for the time and region fixed effects, the coefficient of the effect of digital finance on green urbanization is 0.194 and is significant at the 1%.

The results in column (3) of Table 10.4 show that after controlling for time and region fixed effects while including the relevant control variables, the coefficient of the effect of digital finance on green urbanization is 0.209 and is significant at

Table 10.4 Baseline regression results

Variables	lnurb	lnurb	lnurb
lndif	0.276*** (15.999)	0.194*** (3.631)	0.209*** (4.066)
lngov			0.011 (0.148)
lnstr			−0.079 (−0.618)
lnenr			−0.136*** (−4.540)
lnfdi			0.009 (0.575)
Constant term	2.271*** (25.155)	2.698*** (13.760)	2.998*** (5.678)
Time fixed effects	No	Yes	Yes
Regional fixed effects	No	Yes	Yes
N	270	270	270
R^2	0.489	0.911	0.924

Note ***, **, and * represent the significance level at 1%, 5%, and 10% respectively; t-values are in brackets. The following table is the same as the 1%. The above results show that digital finance has a significant promoting effect on green urbanization. Digital finance reduces industry energy consumption through digital technology, promotes industrial transformation and upgrading, and facilitates the development of green urbanization; digital finance greatly enhances the service efficiency of green finance through accurate portrayal, thus promoting the construction of green urbanization; digital finance is conducive to enhancing the supply of green financial products, promoting the development of low-carbon economy, and accelerating the development of green urbanization.

10.3.2 Robustness Tests

(5) Replacement estimation method: Considering that the data used in this paper are short panel data, the problems of heteroskedasticity, autocorrelation and cross-sectional correlation cannot be ignored. Although the data are logarithmically processed and inter-provincial clustering standard errors are adopted to reduce the effect of heteroskedasticity, the problems of autocorrelation and cross-sectional correlation still need to be paid attention to. Therefore, this paper uses Driscoll-Kraay adjusted standard errors for regression to overcome the above three problems. The results are shown in column (1) of Table 10.5, and the coefficient of the effect of digital finance on new urbanization is 0.209 and passes the 1% significance test, which is consistent with the baseline regression results, indicating that digital finance significantly promotes green urbanization and supports the previous conclusion.

(6) Excluding regional samples: Due to the large specificity of municipalities directly under the central government, there may also be differences in the development levels of digital finance and green urbanization, etc. In this regard, this paper excludes the four municipalities directly under the central government of Beijing, Tianjin, Shanghai and Chongqing, and re-runs the regression test on the remaining samples. The results are shown in column (2) of Table 10.5. The impact coefficient of digital finance is 0.142 and significant at the 1% level, and the estimated parameters and significance levels are basically consistent with the previous estimation results. The conclusion that digital finance contributes to green urbanization still holds, which proves that the estimation results are robust.

(7) One-period lagged treatment of explanatory variables: Considering the possible lags of the effects of each explanatory variable on the explanatory variables, all first-order lags are treated for digital finance and all control variables, and the results are shown in column (3) of Table 10.5, with a regression coefficient of 0.212 and significant at the 1%, indicating the robustness of the previous estimation results.

Table 10.5 Robustness tests

Variables	lnurb	lnurb	lnurb
lndif	0.209*** (4.404)		
lndif		0.142*** (2.971)	
L.dif			0.212*** (3.487)
Control variables	YSE	YSE	YSE
Time fixed effects	YSE	YSE	YSE
Regional fixed effects	YSE	YSE	YSE
N	270	234	240
R^2		0.942	0.901

10.4 Heterogeneity Analysis

10.4.1 Regional Heterogeneity

Different regions have significant differences in digital finance and green urbanization development. In order to explore the regional heterogeneity of the impact of digital finance on green urbanization, this paper examines the analysis in three regions, namely, the east, central and west, respectively. The results are shown in Table 10.6, which shows that there are significant differences between the east, central and west regions in terms of digital finance on green urbanization. The coefficient of digital finance in the east region is significantly positive, while the coefficients of digital finance in the central and west regions do not pass the significance test, which indicates that digital finance significantly promotes green urbanization in the east region, but the effect is not significant in the central and west regions.

This may be due to the higher level of digital finance development in the eastern region while the central and western regions are relatively lagging behind. Although the government has increased the support for financial and digital industry development in the central and western regions in recent years, its overall level of digital finance development is still smaller than that in the eastern regions compared to the innate development advantages in the east, thus leading to the less obvious role of digital finance in promoting green urbanization.

10.4.2 Structural Heterogeneity

To further investigate the specific impact of digital finance on green urbanization, this paper incorporates three dimensional indicators of the breadth of digital finance

Table 10.6 Regional heterogeneity analysis

Variables	East	Middle	West
	(1) lnurb	(2) lnurb	(3) lnurb
lndif	0.168** (2.443)	−0.056 (−0.391)	0.046 (0.575)
lngov	0.044 (0.372)	−0.114 (−1.212)	0.473** (2.330)
lnstr	−0.097 (−0.354)	−0.267 (−1.493)	−0.457* (−2.099)
lnenr	−0.130 (−1.326)	−0.098** (−2.882)	−0.235** (−3.126)
lnfdi	0.005 (0.130)	0.048 (1.283)	−0.020 (−1.140)
Time fixed effects	YSE	YSE	YSE
Regional fixed effects	YSE	YSE	YSE
N	99	72	99
R^2	0.916	0.972	0.933

coverage, depth of use, and degree of digitization into structural heterogeneity regression analysis.

The regression results are shown in Table 10.7, the impact coefficient of the breadth of digital financial coverage is 0.095 and passes the 1% significance test, the depth of digital financial use does not pass the significance test, and the impact coefficient of the degree of digitalization of digital finance is significantly negative, which indicates that the breadth of coverage promotes green urbanization the most, while the degree of digitalization inhibits the development of green urbanization. The possible reason for this is that the expansion of the breadth of coverage of digital finance makes financial services more accessible, especially some emerging technology and other environmentally friendly enterprises have easier access to financing, which can provide a better financial environment for green urbanization. The degree of digitization is a measure of the level of convenience and affordability of digital financial services. The current degree of digitization has, to a certain extent, improved the convenience of financial services and reduced the cost of access and product prices, but this advantage is not reflected in green development, or even detrimental to green development, thus inhibiting the development of green urbanization.

10.5 Mechanism Analysis

The aforementioned study shows that digital finance significantly contributes to the development of green urbanization, through what specific channels does it exert the mediating effect? To further verify the mechanism of the channel through which digital finance affects green urbanization, based on the existing research results, this

Table 10.7 Analysis of dimensional heterogeneity

Variables	Coverage	Usage	Digitization
	(1) lnurb	(5) lnurb	(6) lnurb
lncov	0.095*** (3.934)		
lnuse		0.122* (1.956)	
lndig			−0.100** (−2.469)
lngov	−0.010 (−0.149)	−0.013 (−0.146)	−0.043 (−0.451)
lnstr	−0.044 (−0.370)	−0.051 (−0.296)	−0.025 (−0.150)
lnenr	−0.128*** (−4.476)	−0.150*** (−3.953)	−0.151*** (−4.063)
lnfdi	0.010 (0.673)	0.009 (0.494)	0.009 (0.538)
Time fixed effects	YSE	YSE	YSE
Regional fixed effects	YSE	YSE	YSE
N	270	270	270
R^2	0.924	0.912	0.912

paper selects technological innovation (tec) as the mediating variable and uses the mediating effect model to test the mechanism, and the specific regression results are shown in Table 10.6.

As shown in column (1) of Table 10.8, it has been verified that digital finance has a significant positive effect on green urbanization and the total utility is 0.209. Then, the mediating variable is used as the explanatory variable to verify whether there is a significant effect of digital finance on technological innovation. As shown in column (2) of Table 10.6, the coefficient of the effect of digital finance on technological innovation is 0.732 and passes the 1% significance test, indicating that digital finance can greatly promote the development of technological innovation. Finally, it is verified whether the mediating effect plays a role. Column (3) of Table 10.6 shows that after adding the mediating variable of technological innovation, the impact coefficients of digital finance and technological innovation are both significantly positive, indicating that digital finance can indirectly promote the construction of green urbanization through the mediation of technological innovation. After adding the mediating variable, the estimated coefficient of digital finance decreases from 0.209 to 0.177, indicating that technological innovation is the mechanism of action of digital finance to promote green urbanization.

Table 10.8 Intermediary mechanism test results

Variables	lnurb	lntec	lnurb
lndif	0.209*** (4.066)	0.732*** (5.423)	0.177*** (3.405)
TEC			0.043** (2.368)
lngov	0.011 (0.148)	0.518* (1.829)	−0.012 (−0.180)
lnstr	−0.079 (−0.618)	−0.354 (−0.896)	−0.063 (−0.479)
lnenr	−0.136*** (-4.540)	−0.263 (−1.594)	−0.124*** (−3.866)
lnfdi	0.009 (0.575)	0.028 (0.567)	0.008 (0.483)
Time fixed effects	YSE	YSE	YSE
Regional fixed effects	YSE	YSE	YSE
N	270	270	270
R^2	0.924	0.843	0.926

10.6 Conclusions and Recommendations

Green urbanization is an important strategic initiative for green development, a booster for China's high-quality economic development, and a sure way to achieve Chinese-style modernization. Digital finance, as a green development model, serves the green development of economy and society more efficiently and has a significant impact on the development of green urbanization. Based on China's inter-provincial panel data from 2011 to 2019, this paper empirically examines the impact and transmission mechanism of digital finance on green urbanization using a two-way fixed-effects model and a mediating-effects model.

The findings are as follows: first, digital finance can significantly promote the development of green urbanization. Second, the impact of digital finance on green urbanization has significant regional heterogeneity, with the promotion effect of digital finance in the eastern region being obvious, but none of the effects in the central and western regions are obvious. Third, the structure of digital finance has a heterogeneous impact on green urbanization, with the greatest promoting effect of coverage breadth and insignificant effect of use depth, while the degree of digitalization inhibits the development of green urbanization. Fourth, technological innovation is an important intermediary, and digital finance can promote green urbanization through technological innovation.

Based on the findings, this paper suggests the following: first, promote the development of digital technology and data elements, enhance the development of digital finance, and provide strong basic support for green transformation and upgrading of manufacturing industries and emerging green industries, etc., so as to promote the development of green urbanization. Second, promote the coordinated regional development of digital finance. Strengthen the construction of digital technology and digital talents in the central and western regions to improve their digital finance development. At the same time, to drive the central and western regions by the east, enhance the spatial spillover effect, promote the coordinated development of various regions, ease the regional disparity in digital finance development, and provide basic support for the development of green urbanization. Third, strengthen the development level of all dimensions of digital finance. Financial institutions and related departments continue to improve the breadth of coverage, strengthen the depth of use, consolidate the degree of digitalization, and improve the quality, convenience and affordability of use, so as to increase the role of digital finance in promoting green urbanization. Fourth, the regulatory effect of technological innovation is emphasized, institutional policies favorable to technological innovation are formulated, scientific and technological innovation activities are carried out, a favorable technological innovation environment is created, the integration and symbiosis of relevant subjects are encouraged, the technological innovation capacity and spatial spillover effect are enhanced, and the intermediary effect of technological innovation on green urbanization is brought into play.

Acknowledgements This research is supported by: (1) Foundation Program of Humanities and Social Sciences Research of Education Bureau of Hubei Province: "Research on Financial Service Innovation for the Development of New Urbanization in Hubei Province—Based on the Perspective of Internet Finance" (15G156). (2) Foundation Program of Hubei Business Service Development Research Center: "Research on Innovation of Internet Financial Services in the Context of New Urbanization" (2017Y009).

References

1. Y. Xu, The impact of inclusive financial development on the construction of new urbanization-an empirical analysis based on systematic dynamic GMM estimation and threshold regression. Wuhan Financ. **8**, 33–38 (2019)
2. Z.B.A. Ma, Y.L. Liu, Research on the relationship between new urbanization and financial inclusion in regional economic development. Financ. Dev. Res. **5**, 9–17 (2021)
3. W. Li, Y.M. Zhuang, A comprehensive measurement and financial support study of new urbanization construction in western China. Explor. Econ. Issues **1**, 72–81 (2017)
4. W.J. Ouyang, M.F. Lu, An empirical study of digital finance-driven green economy development under the goal of "double carbon." Financ. Theory Pract. **1**, 1–10 (2023)
5. M.L. Liu, X. Huang, J. Sun, The impact mechanism of digital finance on green development. China Popul.-Resour. Environ. **32**(6), 113–122 (2022)
6. S. Tang, X. Wu, Z.J. Chuan, Digital finance and corporate technology innovation-structural characteristics, mechanism identification and differences in effects under financial regulation. Manag. World **36**(5):52–66+9 (2020)
7. S.H. Yin, H.X. Luo, Digital finance, technological innovation and regional economic growth. J. Guizhou Univ. Financ. Econ. **1**, 41–49 (2023)
8. F. Chen, H.M. Shi, Q. Chen, Spatial and temporal evolution of the coupling coordination degree of green urbanization system in Yangtze River Delta and its influencing factors. J. Central South Univ. For. Sci. Technol. (Social Science Edition) **16**(2), 26–35 (2022)

9. F. Guo, J.Y. Wang, F. Wang et al., Measuring the development of digital inclusive finance in China: indexing and spatial characteristics. Econ. (Quarterly) **19**(4), 1401–1418 (2020)
10. Guan et al., Assessment to China's Recent Emission Pattern Shifts (2021)
11. Shan et al., China CO_2 emission accounts 2016–2017. Sci. data (2020)
12. Shan et al., China CO_2 emission accounts 1997–2015. Sci. Data (2018)
13. Shan et al., New provincial CO_2 emission inventories in China based on apparent energy consumption data and updated emission factors. Appl. Energy (2016)

Chapter 11
The Impact of Innovation on IPO Underpricing in the STAR Market

Shuijing Hu

Abstract IPO underpricing refers to the phenomenon of excess returns at the beginning of an IPO. This paper selects 505 companies listed on the STAR Market from 2019 to 2022 as samples, and examines the impact of technological innovation on IPO underpricing from the perspectives of R&D investment and R&D output. The results show that R&D investment, which is characterized by information asymmetry, leads to uncertainty in the market's valuation of companies, which will intensify IPO underpricing, but the signal effect of patents will significantly reduce the degree of IPO underpricing. The study suggests that companies should pay more attention to patent applications while increasing R&D investment, and focus on converting the results of R&D investment into patents in order to obtain more commercial value.

Keywords IPO underpricing · Technological innovation · Innovation input · Innovation output · Information asymmetry

11.1 Introduction

Technological innovation is an important factor in promoting economic growth and sustainable development of enterprises. It can help enterprises develop new products and services, and improve the competitiveness and potential value of enterprises. Companies use Initial Public Offerings (IPOs) to secure financial resources to finance research and development initiatives, enabling them to create new and innovative products and services, as well as to expand their scale and achieve strategic growth. In order to break through the current situation that the existing capital market is insufficient to serve technological innovation, in November 2018, China established the STAR Market (STAR Market) and piloted the registration system, emphasizing that the STAR Market aims to improve the ability to serve technological innovation enterprises. Starting from July 22, 2019, when the initial group of 25 companies

S. Hu (✉)
Shanghai University of Political Science and Law, Shanghai 201701, China
e-mail: husj_11@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_11

made their debut on the STAR Market, to December 31, 2022, a total of 505 companies were listed on the STAR Market. These companies are primarily focused in the software and information technology service sector, as well as in the manufacturing of computer, communication, and other electronic devices., and most of them are leading enterprises in the industry segments with high technological content or attributes.

The STAR Market has been entrusted with the historical mission of assisting the strategic transformation of the country's economic development. Its establishment is a supplement and improvement of the multi-level capital market system, and it is also an important leading reform of the securities market. According to the Efficient Market Hypothesis (EMH), the stock price should reflect all available information regarding the intrinsic value of the stock [1]. Enterprises on the STAR Market have shown certain innovation capabilities in terms of the amount of R&D investment and the data of invention patents obtained. However, technological innovation has not been fully reflected in stock pricing. Since its establishment, the STAR Market has always had a relatively high level of IPO underpricing. It is very necessary to measure how and why the internal activities of enterprises affect the pricing power of IPOs from the perspective of R&D investment and innovation results of enterprise innovation.

11.2 Literature Review and Theoretical Analysis

11.2.1 Literature Review

IPO underpricing is demonstrated by the phenomenon of the first-day closing price of a newly listed company being considerably higher than the initial public offering (IPO) price, indicating that the pricing is on the low side [2]. Although IPO underpricing is common in global financial markets, there are still large differences between various markets and between different listed companies in the same market. Regarding the causes of IPO underpricing, existing studies have developed three types of theories starting from the information asymmetry between different stakeholders in IPO: (1) Winner's curse theory, which discusses the relationship between informed investors and Information asymmetry between uninformed investors, and the inter-market arbitrage generated by IPO underpricing is considered to be information risk compensation for uninformed investors [3, 4]. This explanation is also known as the "winner's curse"; (2) Signaling theory, studied the information asymmetry between investors and issuers, and issuers transmit their real value signals through underpricing of new shares. Through the underwriter's reputation, it sends a signal of its true value [5]. At the same time, reducing the price of new shares can also cause the effect of "oversubscription" to drive investor sentiment [6]; (3) principal-agent theory, discussing the information between issuers and underwriters Asymmetrical, the sponsor has gained pricing power in the development of the issuance business, and when the issuer lacks effective information and cannot carry out effective supervision, the sponsor tends to lower the price to ensure the success of the issuance, so as to determine the success rate of its own project and gain market recognition [7].

Compared with the traditional capital market, the STAR Market has the characteristics of distinctive technological attributes, high openness and information transparency, and the adoption of a market-oriented pricing mechanism [8]. Due to its more market-oriented issuance system, information disclosure mechanism and investor participation system, the STAR Market is expected to reduce IPO underpricing. However, since its establishment, the STAR Market has always had a relatively high level of high IPO underpricing.

The STAR Market is positioned to play a leading role in capital market innovation, and has the characteristics of good corporate innovation capabilities, fast growth, and more market-oriented issuance systems and trading rules. Therefore, traditional institutional factors are difficult to explain its IPO underpricing. Combining the special attributes and positioning of STAR Market companies in terms of access, transactions, etc., this article will explore the reasons for their IPO underpricing from the perspective of technological innovation.

11.2.2 Theoretical Analysis

Technological innovation refers to the transformation or creation of products and services by enterprises using their own material resources, knowledge and skills in a specific environment to meet market and social needs, and to obtain economic benefits. Technological innovation includes the whole process of integrating a new technology into the production and sales of products, which is essentially the first commercial application of a new technology or new process. At present, research at home and abroad mainly uses R&D investment and patents to measure the technological innovation of enterprises.

Based on the existing literature research, the information asymmetry inside and outside the company is the most important reason for the underpricing of IPO by R&D investment. R&D investment is an important factor affecting information asymmetry [9]. On the one hand, the conversion of R&D investment into output takes a long period, and there are huge uncertainties [10]. It is difficult for investors to predict the probability of successful R&D and the status of R&D results in the market, thereby reducing the impact on enterprises. valuation. The more R&D investment, the higher the IPO underpricing; on the other hand, the information disclosure of R&D investment is easily manipulated by the management [11]. With the continuous increase of R&D investment, it is becoming more and more difficult for ordinary investors to judge whether a company is in financial distress [12]. In the short term, it is easy to see a sharp increase in the stock price. Accordingly, this paper proposes the following hypothesis:

H1: The greater the proportion of R&D investment of enterprises on the STAR Market, the higher the degree of IPO underpricing.

Unlike the impact of R&D investment on IPO pricing, existing studies have shown that the more patents a company has, the lower the IPO underpricing. According to the explanation of signal theory, this is because the number of patents is relatively more definite information, which more fully demonstrates the transformation efficiency of enterprise innovation achievements [13]. Patents can provide forecasts of a company's future revenue and require compliance with stricter intellectual property rules and disclosure of more information, such as patent applications and grants. This can help investors better understand a company's competitive advantage, innovation capabilities and intellectual property status [14]. These factors can reduce the degree of information asymmetry and may lead to more accurate IPO pricing. Therefore, it can be deduced that the number of intellectual property rights of enterprises on the STAR Market is large, and the lower the first-day return rate of enterprises is, the lower the degree of IPO underpricing is.

H2: The greater the number of patents of enterprises on the STAR Market, the lower the degree of IPO underpricing.

11.3 Research Design

11.3.1 Sample Selection and Data Sources

This paper selects the IPO data of 505 listed companies on the STAR Market from July 22, 2019 to December 31, 2022 as the original sample. The research is divided into the following steps: (1) collect initial sample data, eliminate extreme values and missing data, and make descriptive statistics; (2) establish relevant index calculation methods and classify samples; (3) analyze the obtained data Build empirical models and conduct statistical analysis. Filtered for missing and outlier values. The original data sources of this article are: (1) The "IPO Prospectus" submitted by the listed companies on the STAR Market, which was downloaded from the CSMAR database and the Oriental Fortune Choice database, and the missing data refers to the listed company information queried by the Shanghai Stock Exchange. Disclosure manual top-up. (2) Other variables are derived from the CSMAR database and Oriental Fortune Choice database and are directly used or calculated.

11.3.2 Main Variable Definition

Explanatory variables. The explanatory variables in this paper include R&D investment and innovation achievements of companies listed on the STAR Market. Innovation achievements (Patent) are measured by the logarithmic value ln (PATENT + 1) of the number of effective patents that the company has already obtained when it goes public. Due to the different business scales of enterprises, the absolute level of R&D investment also varies. Therefore, the concept of relative R&D investment, that is, R&D intensity (RD), is introduced to measure the real R&D investment level of a company.

$$\mathrm{RD} = \mathrm{Current\,R\&D\,investment/Current\,operating\,income}$$

Explained variable. The explained variable in this paper is the IPO underpricing rate of listed companies on the STAR Market. Referring to the methods of Loughran and McDonald [15], the rate of return (UP) on the day of listing is used as the measurement method of IPO underpricing [15]. The larger the indicator, the greater the degree to which the IPO price of the issuer is lower than the market value, that is, the higher the degree of IPO underpricing. The specific formula is as follows:

$$UP = (P_1 - P_0)/P_0$$

Among them, P0 is the issue price, and P1 is the closing price on the listing day.

Control variable. Referring to the research of Loughran and McDonald [15], the control variables in this paper are the first-day turnover rate, whether the sponsor is in the top 10, and the asset-liability ratio are control variables [16].

The first-day turnover rate (T-rate), the first day of listing transaction size/total stock issuance size * 100%. The first-day turnover rate is usually used to measure market sentiment. The first-day turnover rate of new IPOs is almost over 40%, and the lowest is 57% on the STAR Market. The relay and exchange of bullish funds in the secondary market on the first day of listing. It is included as a control variable to exclude the impact of market investor sentiment on the IPO underpricing on the day of listing.

Sponsor, whether the sponsor of the IPO is the top 10 securities firms in the previous year, is 1 if it is, and 0 if it is not. Sponsor underwriting institutions are deeply involved in IPO from due diligence to listing pricing to underwriting and issuance. According to the investment bank theory of IPO underpricing, the better the reputation of the sponsor institution, the lower its underwriting risk and the less motivation to issue at a low price.

Asset-liability ratio (Lever), the capital structure of a company before IPO, is the ratio of total liabilities to total assets. According to the pecking order financing theory, the ratio of corporate debt has an impact on corporate value and business performance through signaling effects and financial distress risks. Therefore, it is included as a control variable to exclude the influence of the internal capital structure of the enterprise on IPO underpricing and enterprise performance.

11.3.3 Model Building

To test hypothesis H1, this paper constructs model (1):

$$UP_i = \beta_0 + \beta_1 RD_i + \beta_2 T{-}rate_i + \beta_3 Sponsor_i + \beta_4 Lever_i + \varepsilon_i$$

To test hypothesis H2, this paper constructs model (2):

$$UP_i = \beta_0 + \beta_1 Patent_i + \beta_2 T{-}rate_i + \beta_3 Sponsor_i + \beta_4 Lever_i + \varepsilon_i$$

Among them, UP $_i$ is the IPO underpricing rate measure of the i-th sample, RD i is the research and development intensity of the i-th sample, and Patent i is the logarithmic value ln (PATENT + 1). T-rate i is the first-day turnover rate of sample i, Sponsor i is the lead underwriter ranking of sample i, and Lever i is the asset-liability ratio of sample i. β0–β4 are the parameters to be estimated, and εi represents the residual item.

11.4 Outcome of Practice

11.4.1 Descriptive Statistics

Table 11.1 lists descriptive statistics for all variables in the study sample. The results show that the average underpricing rate of the sample IPO companies is 133.9%, and the highest underpricing level reaches 1273.9%, indicating that the IPO underpricing on the STAR Market is relatively high overall. The R&D intensity ranges from a minimum of 2.6% to a maximum of 62.3%, with an average value of 12.7%. These results indicate that the disparity in R&D intensity among companies listed on the STAR Market is relatively minor, and the overall level of R&D investment is relatively high.

11.4.2 Correlation Analysis

In order to avoid the problem of multi-collinearity between variables, a correlation analysis was performed on the variables used in the above two groups of relationships, as shown in Table 11.2.

Table 11.1 Descriptive Statistics of Research Samples of Corporate Innovation Affecting IPO Underpricing

Variable	Obs	Mean	Std. dev	Min	Max
UP	505	1.339	1.479	−0.36	12.739
Patent	505	4.193	1.732	0	7.093
RD	505	0.127	0.063	0.026	0.623
T-rate	505	0.731	0.59	0.532	0.99
Sponsor	505	0.411	0.472	0	1
Lever	505	0.336	0.169	0.047	0.839

Table 11.2 Correlation analysis of each main variable

Variable	UP	Patent	RD	T-rate	Sponsor	Lever
UP	1.000					
Patent	−0.322	1.000				
RD	0.216	0.319	1.000			
T-rate	0.363	−0.038	0.109	1.000		
Sponsor	−0.031	0.012	0.092	−0.087	1.000	
Lever	−0.083	0.015	−0.216	−0.062	0.001	1.000

11.4.3 Analysis of Regression Results

R&D Intensity and IPO Underpricing (Hypothesis H1). From the regression results in Table 11.3, it can be observed that the innovation investment of the sci-tech board companies is positively correlated with the degree of IPO underpricing. Consistent with the H1, the greater the **investment** in innovation, the higher the degree of IPO underpricing. This shows that companies' increased R&D investment before IPO will lead to information asymmetry, which will lead to a certain degree of IPO underpricing.

R&D Output and IPO Underpricing (Hypothesis H2). From the regression results in Table 11.4, it can be seen that consistent with H2, the number of innovative achievements of enterprises is negatively correlated with the IPO underpricing rate,

Table 11.3 H1 empirical regression results

Variable	UP
RD	0.021
T-rate	0.479
Sponsor	−0.272
Lever	0.002
Obs	505

Table 11.4 H2 empirical regression results

Variable	UP
Patent	−0.021
T-rate	0.481
Sponsor	−0.271
Lever	0.002
Obs	505

that is, the more patents, the lower the IPO underpricing. This shows that when the issuer is more inclined to announce the innovation results before the IPO, especially the number of patent applications and granted patents, it is beneficial to reduce the degree of information asymmetry, send a **positive** signal to the market, and help investors correctly identify and evaluate the value of the company, to reduce listing costs. Thus higher innovation outcomes lead to lower IPO underpricing.

11.5 Conclusion

This paper takes 505 companies listed on the STAR Market from July 22, 2019 to December 31, 2022 as a research sample, and examines the impact of the company's innovation intensity and innovation output on IPO underpricing. The research discovers that IPO's initial return is impacted differently by innovation input and innovation output, i.e., the underpricing rate. The study demonstrates that the IPO underpricing rate is significantly higher due to information asymmetry associated with innovation input and the uncertainty of valuation. However, the number of patents, as an indicator of innovation ability, provides a positive signal to the market and reduces the degree of information asymmetry. This assists investors in accurately identifying and evaluating the company's value, resulting in lower IPO underpricing rates linked to higher innovation outcomes.

Drawing from the aforementioned findings, this paper suggests the following policy recommendations. First, the China Securities Regulatory Commission and the stock exchange should strengthen the construction of the information disclosure system. According to the previous analysis, the investment in R&D by the company has obvious information asymmetry inside and outside the company, which leads to the low price of IPO. Under the existing IPO issuance system, the R&D investment intensity of Chinese enterprises is highly positively correlated with the degree of IPO underpricing. Therefore, when the stock exchange reviews the company's initial public offering prospectus, it must require the company to more clearly disclose the detailed data on the capitalization and expense of R&D expenses. This would assist in reducing the degree of information asymmetry and enhance the pricing efficiency of IPOs in the capital market. Second, while increasing investment in R&D, companies should pay more attention to patent applications and focus on converting the results of R&D investment into patents to obtain more commercial value.

References

1. X. Gabaix, R.S.J. Koijen, In search of the origins of financial fluctuations: the inelastic markets hypothesis. National Bureau of Economic Research (2021)
2. F. Jamaani, M. Alidarous, Review of theoretical explanations of IPO underpricing. J. Account. Bus. Financ. Res. **6**(1), 1–18 (2019)
3. K. Rock, Why new issues are underpriced[J]. J. Financ. Econ. **15**(1–2), 187–212 (1986)
4. L. Fergusson, P. Querubin, N.A. Ruiz et al., The real winner's curse. Am. J. Polit. Sci. **65**(1), 52–68 (2021)
5. M. Grinblatt, S. Titman, Mutual fund performance: an analysis of quarterly portfolio holdings. J. Bus., 393–416 (1989)
6. O.A. Obrimah, A new test of the signaling theory of IPO underpricing (2019). Available at SSRN 2896777
7. T. Loughran, J. Ritter, Why has IPO underpricing changed over time? Financ. Manag., 5–37 (2004)
8. Y. Ma, G. Liu, C. Qi, IPO pricing, investor behavior, and IPO underpricing of high-tech companies: evidence from SSE STAR market and Nasdaq market. Discret. Dyn. Nat. Soc., 2022 (2022)
9. D. Aboody, B. Lev, Information asymmetry, R&D, and insider gains. J. Financ. **55**(6), 2747–2766 (2000)
10. D. Salerno, G. Sampagnaro, V. Verdoliva, Fintech and IPO underpricing: an explorative study. Financ. Res. Lett. **44**, 102071 (2022)
11. K.J. Merkley, Narrative disclosure and earnings performance: evidence from R&D disclosures. Account. Rev. **89**(2), 725–757 (2014)
12. S. Morricone, F. Munari, R. Oriani et al., Commercialization strategy and IPO underpricing. Res. Policy **46**(6), 1133–1141 (2017)
13. J.M. Rahman, M. Yang, Effects of venture capital, R&D, and technology on IPO Underpricing: evidence from China. Cap. Mark. Rev. (2021)
14. L.J. Zhou, M. Sadeghi, The impact of innovation on IPO short-term performance–evidence from the Chinese markets. Pac. Basin Financ. J. **53**, 208–235 (2019)
15. T. Loughran, B. McDonald, IPO first-day returns, offer price revisions, volatility, and form S-1 language. J. Financ. Econ. **109**(2), 307–326 (2013)
16. H. Guo, Y. Wang, B. Wang et al., Does prospectus AE affect IPO underpricing? A content analysis of the Chinese stock market. Int. Rev. Econ. Financ. **82**, 1–12 (2022)

Chapter 12
The Spatial Effect of Fiscal Decentralization and Financial Decentralization on Carbon Productivity in China

Mingbo Sun, Xiaoxiao Zhang, and Zhaorong Wei

Abstract In the context of carbon peak and carbon neutrality constraints, China is faced with the challenge of balancing economic development and environmental protection. In China, economic decentralization under centralized political power influences local economic and environmental policy. Based on panel data of 30 provinces in China from 2010 to 2018 and four spatial weight matrices, the spatial Durbin model was used to explain the effects of fiscal decentralization and financial decentralization on carbon productivity. Further, the synergistic effect of "fiscal decentralization-financial decentralization" on carbon productivity was studied in this paper. The results show that (1) China's carbon productivity is on an increasing trend, and there is an obvious spatial spillover phenomenon in the region. (2) Fiscal and financial decentralization contribute to carbon productivity not only within a region, but also within the surrounding areas. (3) The synergistic effect of fiscal decentralization and financial decentralization inhibits the increase of regional carbon productivity and spatial spillover.

Keywords Component · Fiscal decentralization · Financial decentralization · Carbon productivity · Spillover effects

12.1 Introduction

In recent years, the contradiction between China's rapid economic development and environmental degradation has become increasingly serious. Carbon emissions are an important component leading to environmental pollution. In the context of the global response to climate change, carbon emission space has become a more scarce factor of production than labor, capital, and natural resources such as land. Development with

M. Sun · X. Zhang (✉) · Z. Wei
School of Management Engineering, Zhengzhou University, Zhengzhou, China
e-mail: 1518959485@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_12

carbon emissions as an input factor and binding indicator is increasingly becoming the key to future economic and social development. Carbon productivity is the maximum amount of economic output per unit of carbon dioxide emitted. It can be used to evaluate the effectiveness of a country or region to cope with climate change. In addition, the improvement of carbon productivity also represents the improvement of carbon sinks and economic development potential [1]. Therefore, it is particularly important to examine the influencing factors of carbon productivity.

In the process of decentralization reform, economic decentralization and political centralization constitute a Chinese governance model. Economic decentralization refers to the division of fiscal and financial resource allocation authority between the central government and local governments, which is characterized by "fiscal decentralization + financial decentralization" [2]. Local governments have greater autonomy on economic growth and environmental protection. Existing studies have demonstrated the importance of "Chinese decentralization" for China's economic growth. However, the crude economic development under Chinese-style decentralization can also cause environmental problems. There are many studies on the economic or pollution effects of fiscal and financial decentralization, but the results are inconsistent. Moreover, the existing studies only consider economic and pollution effects separately, and neglect to consider the impact on the composite index, such as carbon productivity. In addition, fiscal decentralization and financial decentralization are somewhat related. Their interactions will have a significant impact on resource allocation and local government affairs, so they cannot be evaluated separately in the analysis of China's economic problems. Therefore, placing fiscal decentralization and financial decentralization in the same analytical framework, this paper aims to examine the relationship between fiscal decentralization, financial decentralization, and carbon productivity. On the basis of this, further analysis of the synergies effect between fiscal decentralization and financial decentralization on carbon productivity.

12.2 Literature Review

Before and after the Fenshuizhi reform of 1994, studies on fiscal decentralization and economic growth produce different results [3]. Before the Fenshuizhi reform, fiscal decentralization mostly showed a suppressive effect on economic growth [4]; After the Fenshuizhi reform, fiscal decentralization mostly showed a promotional effect on economic growth [5]. It may be due to the fact that the Fenshuizhi reform enhances policy coordination among levels of government, which in turn helps to promote fiscal decentralization's positive effects. Local governments gained greater control over their local economies through fiscal decentralization, while local GDP championships boosted China's overall economic growth. In addition, some scholars argue that the impact of fiscal decentralization on economic growth is diverse, not simply positive or negative. Sun used county-level panel data from 1997 to 2015, obtained an inverted U-shaped relationship between the fiscal decentralization and economic growth [6].

There are two mainstream views on fiscal decentralization and environmental pollution: one is the “Race to the bottom” theory. It believes that, under decentralization reform, local governments have more autonomy in allocating resources and regulating the environment. To improve local economic capacity, governments drive more factors to industries with greater economic benefits and pay less attention to the ecological environment. This eventually aggravates the environmental degradation [7]. Cheng argues that fiscal decentralization will promote carbon emissions and exacerbate environmental pollution [8]; The other is the “Voting with feet” theory, in which the preference of residents for their environment can be reflected by their “voting with feet” behavior. Under this constraint, local governments can attract more factors to local areas by reallocating public resources such as the environment, thus achieving environmental improvement while promoting economic development [9]. In the context of market completeness and redistributive public policies, local governments’ goals shift to maximizing welfare and thus creating better levels of environmental quality in their regions [10].

There is relatively little research on financial decentralization. Since Montinola proposed “financial decentralization”, scholar start focused on its economic effects. For example, Xie and He believed that financial decentralization has a facilitating effect on both the improvement of economic scale and economic quality [11]. However, financial decentralization can also exacerbate financial risks, which will lead to instability in economic development [12]. Lv also reached a similar conclusion that financial decentralization is detrimental to local economic, but it is opposite influence to the neighboring region [13]. There are even fewer studies on the pollution effects of financial decentralization. Liu [14] argued that higher financial decentralization is conducive to the local information advantage of local governments and financial institutions, which can strengthen the emission reduction effect. Zhu [15] also reached a similar conclusion.

Based on a review of the literature, we have found that existing research only takes a single perspective on the economic effects or pollution effects of fiscal and financial decentralization, and the conclusions of the research are not uniform. Now the Chinese government no longer restricts itself to GDP growth rates, but emphasizes high-quality development that balances economic and carbon emissions and promote the formation of a low-carbon economic growth model. So this paper incorporates fiscal decentralization and financial decentralization into the same analytical framework, and considers spatial factors by constructing a spatial Durbin model based on four spatial weight matrices, to quantitatively analyze the influence mechanism of fiscal decentralization and financial decentralization on carbon productivity. Also future analysis of the synergistic effect of both on carbon productivity. This will provide a theoretical and decision-making basis for promoting the optimization of fiscal and financial decentralization policies.

12.3 Indicator Selection and Data Sources

12.3.1 Dependent Variable

Carbon productivity (CP). According to the definition of carbon productivity by Kaya, The calculation formula of carbon productivity is shown in Formula (12.1), which indicates the GDP output per unit of CO_2 emissions

$$CP = GDP \big/ CO_2 \tag{12.1}$$

12.3.2 Dependent Variables

Fiscal decentralization (*FIS*).

$$\text{FIS} = \text{R}\mathit{egional\ budget\ expenditure} \big/ \text{C}\mathit{entral\ budget\ expenditure} \tag{12.2}$$

Financial decentralization (*FIN*).

$$\text{FIN} = \text{R}\mathit{egional\ loans} \big/ \text{N}\mathit{ational\ loans} \tag{12.3}$$

12.3.3 Control Variables

Energy consumption structure (*ECS*):

$$\text{ECS} = \text{C}\mathit{oal\ consumption} \big/ \text{E}\mathit{nergy\ consumption} \tag{12.4}$$

Economic development level (*ECO*):

$$\text{ECO} = \text{GDP} \big/ \mathit{Number\ of\ people} \tag{12.5}$$

Openness to the outside world (*OPEN*)):

$$\text{OPEN} = \text{T}\mathit{otal\ import\ and\ export} \big/ \text{GDP} \tag{12.6}$$

Technological progress (*TECH*):

$$\text{TECH} = \text{I}\mathit{nternal}\ R\&\text{D}\ \mathit{expenditure} \big/ \text{GDP} \tag{12.7}$$

Table 12.1. Summary statistics of key variables

	Variables	Mean	SD	Min	Max
Dependent variable	CP	3.894	0.627	2.471	5.870
Independent variables	FIS	3.635	2.777	0.244	14.360
	FIN	3.342	2.586	0.352	10.810
Control variables	ECS	4.117	0.469	1.592	5.030
	ECO	10.260	0.459	9.303	11.400
	OPEN	2.843	0.960	0.528	5.042
	TECH	0.290	0.525	0.028	3.054

The summary of variables and descriptive statistics of the data are shown in Table 12.1.

12.4 Empirical Results and Analysis

12.4.1 Spatial Autocorrelation Test of Variables

This paper test autocorrelation of variables by Moran's I index [16]. The software we use is stata16.0. In order to ensure the reliability of the results, autocorrelation of variables are tested under geographic adjacency matrix (W1), geographic distance matrix (W2), economic distance matrix (W3), and economic-geographic nested matrix (W4). Moran's I values of carbon productivity, fiscal decentralization, and financial decentralization are all greater than zero and significant. There are obvious spatial clustering characteristics nationwide and spatial spillover effects on the surrounding provinces. It is necessary to explore the relationship between carbon productivity, fiscal decentralization, and financial decentralization by incorporating spatial factors. Therefore, a spatial econometric model is constructed for empirical analysis in the next section of this paper.

12.4.2 Selection of Spatial Econometric Model

To select the spatial econometric model, the LM test, Robust LM test, LR test, Wald test, and Hausman test were performed on the data. After testing, the paper finally chooses the spatial Dubin model and fixed effect [17]. To validate the synergistic effect between fiscal decentralization and financial decentralization, this paper introduces an interaction term FIS*FIN between them. Therefore, the spatial Durbin model in this paper is as follows:

$$\begin{aligned} CP_{it} &= \rho WCP_{it} + \beta_1 FIS_{it} + \beta_2 FIN_{it} + \beta_3 FIS_{it} * FIN_{it} + \beta_\gamma X_{it} \\ &\quad + \theta_1 WFIS_{it} + \theta_2 WFIN_{it} + \theta_3 WFIS_{it} * FIN_{it} + \theta_\gamma WX_{it} + \lambda_i + \varepsilon_{it} \end{aligned} \tag{12.8}$$

12.4.3 Regression Analysis of the Spatial Durbin Model

Table 12.2 shows the regression results. Compared with the SDM model, the OLS model overestimates the effects of fiscal decentralization, financial decentralization, and their interactions on carbon productivity. Under the four spatial weight matrices assumptions, the spatial autocorrelation coefficients of carbon productivity are significant and respectively. are 0.743, 0.598, 0.761, and 0.766. The robustness of the spatial econometric model estimation results is ensured. This indicates that the carbon productivity of a region is positively influenced by the surrounding region.

The regression coefficients of fiscal decentralization are 0.038, 0.045, 0.072, and0.055, respectively, and are significant under all four spatial weight matrices. It

Table 12.2 Regression results of the spatial Durbin model

Variables	OLS	W1	W2	W3	W4
FIS	0.309***	0.038*	0.045*	0.072***	0.055**
	(9.310)	(1.690)	(1.880)	(3.390)	(2.550)
FIN	0.077**	0.046**	0.063***	0.035	0.045**
	(2.390)	(2.240)	(2.950)	(1.580)	(2.090)
FIS*FIN	−0.026***	−0.002	−0.004	−0.006**	−0.005
	(−5.780)	(−0.870)	(−1.400)	(−2.060)	(−1.630)
W*FIS		0.071**	0.112	0.064	0.043
		(2.050)	(1.260)	(1.430)	(0.700)
W*FIN		0.012	0.130	0.131***	0.144*
		(0.350)	(0.920)	(2.590)	(1.740)
W*FIS*FIN		−0.007*	−0.018	−0.008	−0.004
		(−1.730)	(−0.910)	(−1.040)	(−0.340)
W*CP		0.743***	0.598***	0.761***	0.776***
		(20.160)	(7.830)	(17.870)	(14.710)
Control variables	Yes	Yes	Yes	Yes	Yes
R2	0.6549	0.679	0.561	0.539	0.584
Province	30	30	30	30	30
Observations	270	270	270	270	270

Note ***, ** and * are significant at 1%, 5% and 10% confidence levels, respectively indicates that fiscal decentralization is beneficial to carbon productivity. The regression coefficients of financial decentralization are positive and significant under W1, W2, W4, but is not significant under W3. It indicates that financial decentralization has a direct contribution to carbon productivity only under W1, W2, W4. The interaction term of fiscal decentralization and financial decentralization are negative and significant under the W3, but is not significant under the other matrices. It indicates that the synergistic effect of fiscal decentralization and financial decentralization inhibits the improvement the carbon productivity only under W3.

To further verify the spatial spillover effects of fiscal decentralization, financial decentralization, and their interaction terms, this paper uses partial differencing method to calculate the direct effect and indirect effect of each independent variable on carbon productivity, respectively. The results are shown in Table 12.3. The direct effects of fiscal decentralization, financial decentralization, and their interaction terms under the four spatial weight matrices are basically same with the result in Table 12.2. From the indirect effect of fiscal decentralization, the spatial spillover effect on carbon productivity is significantly positive under W1, W2, W3. The effect value is higher under W3 compared with other matrices, indicating that the spatial spillover effect of economic linkage on carbon productivity is explained more strongly compared with geographic adjacency linkage and geographic distance linkage. From the indirect effect of financial decentralization, the spatial spillover effect on carbon productivity is significantly positive under W3 and W4, indicating that the spillover effect of financial decentralization is more influenced by economic linkages. In terms of the indirect effect of the interaction between fiscal decentralization and financial decentralization, the spatial spillover effect on carbon productivity is significantly negative under W1, indicating that the synergistic effect of fiscal decentralization and financial decentralization in the region suppresses the increase of carbon productivity in neighboring regions.

12.5 Conclusions and Recommendations

Based on panel data of 30 provinces in China from 2010 to 2018 and four spatial weight matrices, the spatial Durbin model was used to explain the effects of fiscal decentralization and financial decentralization on carbon productivity. Further, the synergistic effect of fiscal decentralization and financial decentralization on carbon productivity was studied in this paper. The results show that (1) China's carbon productivity is on an increasing trend, and there is an obvious spatial spillover phenomenon in the region. (2) Fiscal and financial decentralization contribute to carbon productivity not only within a region, but also within the surrounding areas. (3) The synergistic effect of fiscal decentralization and financial decentralization inhibits the increase of regional carbon productivity and spatial spillover.

Based on the above findings, this study proposes the following policy recommendations: (1) Under Chinese decentralization, the central government should take both fiscal and financial into account when decentralizing power, which can effectively

Table 12.3 Decomposition results of spillover effects of the spatial Durbin model

Variables	W1			W2		
	Direct effect	Indirect effects	Total effect	Direct effect	Indirect effects	Total effect
FIS	0.071***	0.343***	0.414***	0.054**	0.313*	0.366*
	(2.890)	(3.960)	(4.270)	(2.100)	(1.660)	(1.850)
FIN	0.061**	0.163	0.223	0.073***	0.412	0.485
	(2.240)	(1.310)	(1.540)	(3.020)	(1.200)	(1.350)
FIS*FIN	−0.005	−0.028**	−0.033**	−0.005	−0.046	−0.052
	(−1.480)	(−2.270)	(−2.270)	(−1.450)	(−0.970)	(−1.040)
Variables	W3			W4		
	Direct effect	Indirect effects	Total effect	Direct effect	Indirect effects	Total effect
FIS	0.103***	0.454***	0.557***	0.069***	0.352	0.421
	(4.090)	(2.840)	(3.200)	(2.820)	(1.370)	(1.570)
FIN	0.077***	0.628***	0.705***	0.072***	0.792**	0.865**
	(3.140)	(3.610)	(3.780)	(3.060)	(2.270)	(2.390)
FIS*FIN	−0.009**	−0.046	−0.054	−0.005	−0.030	−0.036
	(−2.290)	(−1.50)	(−1.640)	(−1.500)	(−0.540)	(−0.610)

Note ***, ** and * are significant at 1%, 5% and 10% confidence levels, respectively

play a synergy role. To further expand local governments' regulatory and allocation power in "fiscal and finance", and to match the financial and administrative powers as much as possible, so that local governments can have enough financial power and authority to maintain the harmonious development of the economy and environment at the same time. In addition, the central government can use advanced technologies, such as big data, to establish a better environmental monitoring mechanism. It can effectively reduce the phenomenon of "collusion between government and enterprises" caused by excessive financial decentralization. (2) Actively use the spatial spillover effect of fiscal decentralization to form a healthy competition mechanism among local governments. While chasing the GDP performance assessment, we should focus on building a scientific and rationalized assessment mechanism about environmental governance performance, to truly realize the importance of sustainable development. At present, Bank is still the main platform for local governments to finance, so they should form an effective incentive mechanism by policy way to actively guide financial institutions, to increase their financial support for low-carbon and green-technology industries. (3) Emphasize the positive spillover effect of carbon productivity. By building inter-regional synergy mechanisms, strengthening exchanges and cooperation between provinces, deepening the concept of resource sharing, giving full play to the leading demonstration role of high carbon productivity regions, further generating radiation-driven effects to low carbon productivity regions, and helping to achieve balanced development of a low-carbon economy.

References

1. X.Z. Wang, S. Wang, X.X. Zhang, Heterogeneity and influence factors of carbon productivity: evidence from Chinese manufacturing enterprises. J. Clean. Prod., 404 (2023)
2. X.G. Chen, J.J. Li, Chinese-style decentralization and shared development. Econ. Rev. J., 447 (2023)
3. F. Guo, S.L. Xue, Does fiscal decentralization promote or inhibit the improvement of carbon productivity? Empirical analysis based on China's data. Front. Environ. Sci. **493**, 1–10 (2022)
4. T. Zhang, H. Zou, Fiscal decentralization, public spending, and economic growth in China. J. Public Econ., 67 (1998)
5. J. Li, Y.B. Xu, Does fiscal decentralization support green economy development? Evidence from China. Environ. Sci. Pollut. Res. Int. **30**(14) (2023)
6. M. Sun, H. Tai, Fiscal decentralization and economic growth: theoretical analysis and empirical evidence. Econ. Rev. **5**, 3–21 (2019)
7. Q.Y. Ran, J.L. Wang, X.L. Yang, Fiscal decentralization, environmental decentralization and china green development efficiency: research on spatial Dubin model based on prefecture level city level. East China Econ. Manag. **35**, 54–65 (2021)
8. Z. Cheng, Y. Zhu, The spatial effect of fiscal decentralization on haze pollution in China. Environ. Sci. Pollut. Res., 1–14 (2021)
9. B. Zhao, K.L. Wang, R.Y. Xu, Fiscal decentralization, industrial structure upgrading, and carbon emissions: evidence from China. Environ. Sci. Pollut. Res. Int. **30**(13) (2023)
10. K. Wang, B. Zhao, L. Ding, G. Wu, Fiscal decentralization, government innovation preference and haze pollution. China Popul., Resour. Environ. **31**, 97–108 (2021)
11. J. Xie, W. He, Chinese style decentralization and economic growth mode: influence mechanism and path. Commer. Res. **4**, 98–109 (2021)
12. D. He, W. Miao, Does the fiscal decentralization impact the financial decentralization? Econ. Res. J. **51**, 42–55 (2016)
13. Y. Lv, Z. Jin, Y. Fu, Spatial relationship between fiscal decentralization, financial decentralization and local economic growth. Public Financ. Res. **1**, 25–44 (2020)
14. G. Liu, Y. Fang, S. Yang, Financial development, financial decentralization and urban environmental pollution.J. Univ. Jinan (Social Science Edition) **31**, 91–102+159 (2021)
15. F.Z. Zhu, Y.X. Lu, Carbon emission reduction effect of china's financial decentralization. Sustainability **14**(22) (2022)
16. T. Decai, Y. Rui, D. Dan et al., Foreign direct investment entry mode and China's carbon productivity based on spatial econometric model. Front. Environ. Sci. **1368**, 1–14 (2022)
17. Q. Guo, Y. Dong, F.B. Yong, H. Zhang, Can green finance development promote total-factor energy efficiency? Empirical evidence from China based on a spatial Durbin model. Energy Policy,177 (2023)

Chapter 13
The Influence Mechanism of Investors on the Value-Added Service Effect of Startups

NaQing Mo

Abstract Value-added services exert a substantial impact on the interaction between startups and investors, leading to a win–win situation. Exploring the mechanisms through which investors exert their influence on the value-added services offered to startups can facilitate this goal. Such an investigation can aid startups in increasing their value, while also enabling investors to reap benefits through investment appreciation. Additionally, it can facilitate the growth of the equity investment industry in a healthy manner. As part of this study, six startups that have received value-added services from investors have been selected as typical cases. A SETC theoretical model has been constructed using grounded theory to extract the main influencing mechanisms of the value-added services' effects. The research results show that value-added services, in addition to directly affecting the value-added service effect, may also instigate principal-agent conflicts between investors and startups, driven by the external environment and the both parties' traits, which ultimately influence the value-added service effect. Value-added service is an internal direct driver of the value-added service effect; the external environment is a external direct driver, both parties' traits are situational drivers, and principal-agent conflict is an intermediary driver.

Keywords Equity investment · Startups · Value-added service effect · Grounded theory · SETC theoretical model

13.1 Introduction

With the impetus and backing of entrepreneurship and innovation policies, the number of startups and equity investment (including venture capital) institutions has grown significantly. According to the "Youth Entrepreneurial City Vitality Report

N. Mo (✉)
School of Management, Shanghai University, Shanghai, China
e-mail: monaqingmo@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_13

(2021)," China added over 44 million new startups from 2011 to 2020. Data from the Qingke Research Center indicates that as of 2021, equity investment institutions in China have reached 15,000, and the total amount of equity investment has surpassed 1.42 trillion yuan, accounting for 21% of the global market. China has become the world's second-largest equity investment market, trailing only the United States. The equity investment industry is advancing towards refinement and specialization, with value-added services serving as a crucial component of post-investment management. These services significantly impact the development of startups and determine whether investors can add value to their investments. The capability of providing tailored value-added services to portfolio companies has emerged as a crucial indicator of investment institutions' investment abilities. In situations where multiple investment institutions vie for the same startup, the availability of value-added services has become a key consideration for startups when selecting investors.

Presently, several research findings exist regarding "management" in the areas of fundraising, investment, management, and retirement, which are helpful in safeguarding investors' unilateral interests. However, such research outcomes do not necessarily promote startups' development. Consequently, it is more crucial to investigate value-added services from the standpoint of promoting innovation and entrepreneurship, and fostering a mutually beneficial growth trajectory for both startups and investors.

Despite the importance of value-added services in promoting the development of startups and equity investment institutions, there is a dearth of academic literature on their impact. No industry scholars have conducted systematic and detailed studies on this segment. Rather, only a few media reports and general articles are available. Consequently, theoretical advancements in this field lag behind the practice, necessitating alignment with the needs of the entrepreneurial and investment communities. To address this gap, this study focuses on actual cases as research objects, employs programmed grounded theory to undertake an in-depth analysis of the behavior and impact of value-added services, constructs a model for investors' influence mechanism on the effect of value-added services for startups, and provides recommendations for improving value-added services. The ultimate goal of this study is to promote the interactive development of startups and equity investment institutions, foster a win–win situation for all stakeholders.

13.2 Literature Review

13.2.1 Concepts Related to Equity Investment and Value-Added Services

Private equity investment is commonly referred to as Private Equity or PE, and it involves investments in unlisted startups at different developmental stages. In this study, equity investment pertains to private equity investment in a broad sense, which includes venture capital investment. The investors studied here refer to equity investment institutions, encompassing venture capital institutions.

Equity investment funds encompass four primary stages: "raising, investing, managing, and withdrawing." However, much of the domestic and international literature such as those conducted by Lerner and Nanda [1] on whether equity investment affects corporate performance or innovation, and Lehnertz et al. [2] on its impact on IPOs, are frequently focused on the "withdrawing" stage. Conversely, comparatively less attention has been given to the "managing" stage, which refers to post-investment management.

Tyebjee and Bruno [3] first put forward the concept of post-investment management. Then it was further subdivided into two categories by Knockaert et al. [4]: value-added services and supervisory services. In summary, this study defines value-added services as investment and financing, and management services offered by investors to startups after the investment. These services are in addition to the legal acts that pertain to shareholders' rights and obligations and are conducive to enhancing the value of startups. Value-added services typically include subsequent financing, matching of business and technical resources, talent recommendation, and strategic decision-making. Hereafter, these services will be referred to as "value-added services."

13.2.2 Overview of Research on the Impact of Value-Added Services on Startups

From both theoretical and empirical perspectives, many scholars have demonstrated that reasonable value-added services have a promoting effect on investee companies. Wang et al. [5] discovered that offering superior value-added services post-investment can augment the success rate of IPOs or the probability of being acquired. Standaert et al. [6] revealed that active post-investment participation of investors has a positive correlation with a firm's business performance and social responsibility. Additionally, some scholars have highlighted the role of value-added services in advancing corporate innovation [7]. Cumming et al. [8] asserts that value-added services render a company's board of directors more autonomous and proficient, thereby refining the internal governance structure.

13.2.3 Overview of Research to Improve the Effect of Value-Added Services

Many scholars have examined ways to enhance the effect of value-added services. Macmillan et al. [9] observed that the influence of value-added services on performance is subject to variation based on the extent of investor participation in the venture. According to Cheng et al. [10], investor reputation exhibits a significantly positive correlation with post-IPO performance because investors with high reputations will be more actively involved in corporate governance after investing. Gompers and Mukharlyamov [11] highlighted that investors' entrepreneurial experience can enhance the performance of portfolio companies. Blank and Carmeli [12] contend that a CEO with inadequate experience and expertise leads to greater agency risks, thereby restricting the impact of value-added services. Concurrently, some scholars have questioned whether entrepreneurs with high absorptive capacity can instead maximize the effect of value-added services [13]. Piazza et al. [14] discovered that an equitable communication relationship between the investor and the enterprise management team enhances the value-added impact of the firm. Xu [15] established that non-capital value-added services, such as professional business knowledge, contributed to achieve win–win cooperation.

13.2.4 Review of Existing Studies

While there is no academic consensus on the content, role, extent, and influencing factors of value-added services, this activity is undoubtedly a critical aspect that sets it apart from other investment approaches. As such, this study establishes the influence mechanism model of investors on the value-added service effect of startups based on the theoretical basis of the influence mechanism. This is achieved by conducting grounded theory research on multiple cases. Ultimately, this model can assist investors and startups in creating value for each other in both directions, preventing and minimizing conflicts, and promoting the attainment of investment objectives.

13.3 Methodology and Design

13.3.1 Research Methodology

Considering that only a limited number of scholars have systematically researched the mechanism of investors' influence on the effect of value-added services of startups and that equity investment operates in the primary market, obtaining comprehensive and standardized data, as with listed companies, is impossible. Hence, this study

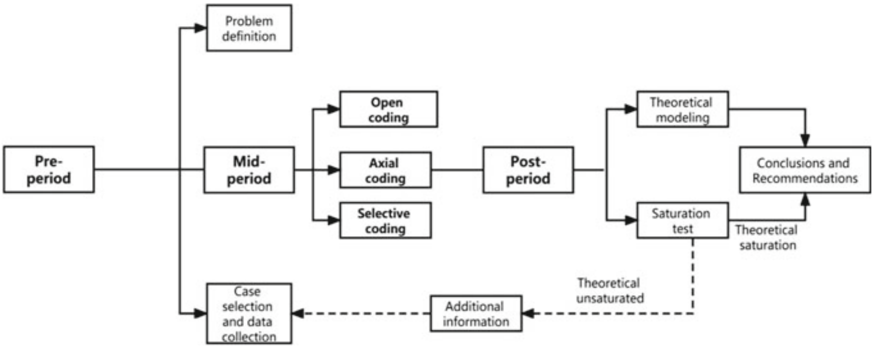


Fig. 13.1 Grounded theory process

will utilize the programmatic grounded theory, proposed by Corbin and Strauss [16]. The principal notion is to select representative cases of value-added services and gather the primary data through online literature collection and offline interviews. Finally, the data will be analyzed and summarized using three coding procedures: open coding, axial coding, and selective coding (see Fig. 13.1).

13.3.2 Case Selection and Information Collection

This study strictly adheres to the principles of case selection and research methods, primarily encompassing the following aspects: (1) the case's subject must comprise the startups and the investor; (2) the case should pertain to the industry focused on equity investment in recent years; (3) the case should have ample information and materials that can furnish sufficient data for the study; and (4) the scope of the case study must cover all stages of the startups' development. Finally, the study selected the following six cases (see Table 13.1). As direct interviews with the core participants were impossible in some cases, and value-added services have a short timeline. Thus, this study employs a literature-grounded-based approach, with interview grounded serving as a supplement.

13.4 Model Construction Based on Grounded Theory

13.4.1 Open Coding

This study entered the information in its original form. After the research group's three researchers organized and analyzed the data, the study extracted 234 phenomenon summaries, which were further summarized and conceptualized to

Table 13.1 Basic information of value-added service cases after investors' investment in startups

Value-added services cover stages	Case	Case introduction	Financing time	Financing rounds
Start-up period	GuluGulu	China's leading sports education and training institution for children	December 2016	Series A
Start-up period	FlowerPlus	China's leading flower subscription-commerce company	April 2015	Angel round
			……	……
			October 2019	Series B+
Start-up period—growth period	Meituan bicycle	One of the three giants of bike-sharing in China	October2015	Series A
			……	……
			April 2018	M&A
Startup-Maturity	Alibaba	China's largest retail trading platform	December1999	Series A
			……	……
			November 2019	IPO listing
Startup-Maturity	JD.COM	China's largest self-operated e-commerce company	August 2007	Series A
			……	……
			June2020	IPO listing
Incubator Case	Mytech	China's leading business incubator	September 2015	Series B
			……	……
			January 2022	Angel round

obtain 234 concepts. Additionally, initial concepts that had the same or similar meanings were normalized, concepts repeated less than three times were eliminated, and concepts unrelated to value-added services were removed to obtain 16 categories (see Table 13.2).

13.4.2 Axial Coding

This study identified the logical relationships among the 16 categories, primarily according to the coding paradigm pattern of phenomenon formation conditions → theoretical phenomena → vein background → intermediary conditions → action strategies → results, and ultimately extracted five primary categories from them (see Table 13.3).

Table 13.2 Open coding example

Examples of original materials	Phenomenon summary	Conceptualization	Categorization
FlowerPlus received a seed round investment from Suhehui, and then completed a multi-million angel round of funding through Suhe Investment	c1: Completed angel round fund raising	cc1: Fund raising	CC1: Capital operation support
Masayoshi Sun led Yahoo to take a stake in Ali in exchange for a 40% stake in the company, sowing the hidden danger of control struggle between Ali and Yahoo	c2: Exchange of equity, sowing the hidden danger of control struggle	cc2: Exchange of equity buried hidden dangers	CC2: Control distribution
Shareholders have great trust in JD because Liu's disclosure reports at each shareholder meeting are clear in detail and logical	c3: Disclosure reports are clear and logica	cc3: Disclosure report	CC3: Interaction
TDF and GGV founder Alan Wu accompanied Alibaba for ten years, eventually successfully taking it to the Hong Kong Stock Exchange for listing	c4: Successfully listed on the Hong Kong stock exchange	cc4: HKEx listing	CC4: Capital market performance
When the financial crisis broke out and Liu's new round of financing fell through, he was so distraught that he found Xu Xin and told her he hadn't slept for two nights	c5: The financial crisis broke out and the financing fell through	cc5: Financial crisis	CC5: Macro environment uncertainty
Mobike completed strategic financing from Foxconn, which will provide Mobike with five million volume bicycle capacity to complement Mobike's capabilities at the supply chain	c6: Strengthening capabilities at the supply chain	cc6: Supply chain end capabilities	CC6: Business Development Support (C6, C7, C8)

(continued)

Table 13.2 (continued)

Examples of original materials	Phenomenon summary	Conceptualization	Categorization
WeChat has opened the three major entrances of applet, sweep and wallet to Mobike, which has greatly improved the customer acquisition ability and experience	c7: Improve customer acquisition ability	cc7: Customer resources	……
After moving into the Suhehui campus, FlowerPlus introduced partners through Suhehui and adjusted its business model from B2C to monthly subscription	c8: Adjustment of business model	cc8: Business model	……

13.4.3 Selective Coding

After analyzing the five primary categories obtained in the previous phase and comparing them with the original materials, it became apparent that all the category elements would ultimately affect the value-added service effect of the company. As such, "value-added service effect" was established as the core category. The coding stage adhered to the logic of Services, Environment, Traits, and Conflict (see Table 13.4).

The study developed the SETC model (see Fig. 13.2) based on a storyline of the effect of investors' value-added services on startups. Among them, value-added services, in addition to directly affecting the value-added service effect, may also instigate principal-agent conflicts between investors and startups, driven by the external environment and the both parties' traits, which ultimately influence the value-added service effect. Value-added service is an internal direct driver of the value-added service effect; the external environment is a external direct driver, both parties' traits are situational drivers, and principal-agent conflict is an intermediary driver.

13.4.4 Theoretical Saturation Test

After incorporating information to the existing cases and analyzing them, and discovering no new concepts, the research team selected two additional case companies for

Table 13.3 Main categories of axial coding formation

Main category	Corresponding categories	Scope content
Value added services	Corporate governance support	Investors use their own professionalism experience to help companies enhance their operational efficiency
	Business development support	The investor coaches the company's business model, product roadshows and other industrial resources to achieve effective market expansion
	Capital operation support	With rich experience in capital operation, the investor helps the startups dock to the capital market and realize value fission
	Contingency support	By building a high-frequency tracking risk control system, the investor helps the startups to resolve unexpected crises and helps the startups to develop stably
External environment	Macro environment uncertainty	Macro environmental uncertainties such as the volatile international situation, the changing economic environment, and the persistence of the new crown epidemic
	Industry development fluctuations	The industry is in a period of volatile development and the government's policy changes
	Intense market competition	The rapid development of companies with similar business models will force startups to accelerate their expansion as well as investors to refine their services
Traits of both parties	Investor traits	Factors such as the investor's professionalism, brand reputation and resources limit the content of value-added services and the quality of value-added service results
	Startup traits	Factors such as the quality and management tradition of the startup itself can influence its behavior and post-investment performance
	Interaction	Value-added services are better recognized when investors and startups form a trusting, open and frequent interactive relationship
Principal-agent conflict	Control distribution	The investor's provision of external financing and other services can dilute the company's equity and influence the board structure
	Goal consistency	Investors are more concerned with returns, while companies pay more attention to long-term development goals, thus creating divergent goals
	Involvement	Investors need to be involved in the business process when providing services, but it is difficult to accurately grasp the scale of involvement

(continued)

Table 13.3 (continued)

Main category	Corresponding categories	Scope content
Value-added service effect	Capital market performance	Trends in apparent changes in the listing status, valuation, and subsequent financing of companies
	Business performance	Trends in market development, business transformation, and apparent changes in profitability and growth capacity of startups
	Compliance regulation	The trend of obvious changes in the social and brand image of companies through external compliance with laws and internal regulation of internal control

coding analysis (see Table 13.5). The results revealed that no new concepts or categories emerged and were consistent with the SETC model. Therefore, this study passed the theoretical saturation test.

13.4.5 Level of Importance of Factors Influencing the Value-Added Service Effect

The importance of the factors that influence the value-added service effect was scored based on the original grounded code (see Table 13.6). For instance, "capital operation support" was present in all six cases, and therefore, it was scored as 6. The higher the score, the more significant the factor.

Table 13.6 indicates that some categories have lower scores due to the individuality of the cases, leading to unique drivers of their value-added service effects. Overall, value-added services and both parties' traits scored higher, indicating that the external environment and principal-agent conflict only play a secondary role in influencing the value-added service effect. In contrast, value-added services and investment parties play a primary role.

13.5 Model Interpretation and Research Findings

13.5.1 Mechanism of Action

The grounded theory analysis yielded sixteen categories, five primary categories, and one core category, with four basic mechanisms of action surrounding the five primary categories. Figure 13.3 displays the factors that impact the effect of investors' value-added services on startups, with the four mechanisms of action as follows.

Table 13.4 Typical relationship structure of the main category

Relationship structure	The connotation of relationship structure	Examples of original materials
Value-added services → value-added service effect	Value-added services are the internal direct drivers	Suhehui suggested that Flower Plus adapt its business model to a monthly subscription, and this model was replicated nationwide
		While the conflict between Ali and Yahoo was rapidly heating up, China Development Bank provided a loan of USD 1 billion to Alibaba, preparing Ali for privatization and relisting
External environment → value-added service effect	The external environment is the external direct drivers	After the first round of investment in JD by Capital Today, JD grew very fast, and then went to finance when the financial crisis came and the valuation plummeted from \$200 million to \$80 million
		The competitive pressure of the short-competition made Mobike conquer the city faster than imagined, completing its goal of covering 100 cities worldwide six months ahead of schedule
Traits of both parties → value-added service effect	Traits of both parties are situational drivers	"The SoftBank side thought Ma's team was very good and had very strong execution skills". In just a few months, Taobao surpassed the then leader Ebay China, with annual turnover breaking \$8 billion
		Zhu Linan and Lu Zhengyao held monthly review meetings to discuss the development of China Car Rental, accompanying each other all the way from the creation to the listing process

(continued)

Table 13.4 (continued)

Relationship structure	The connotation of relationship structure	Examples of original materials
Principal-agent conflict → value-added service effect	Principal-agent conflict is an intermediary driver	Carol Bartz, known as the "Iron Lady", has shown great ambition to control Ali after she came to power. Yahoo sold 1% of Alibaba shares in order to cash out, causing the stock to plummet that day
		Investors pressuring the founders and amplifying discord within the organization have to some extent split GuluGulu's internal team, intensifying conflicts

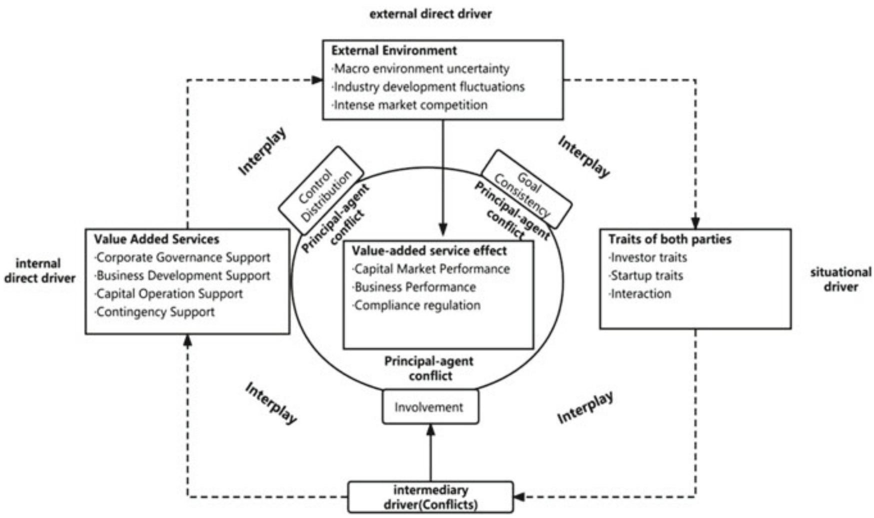


Fig. 13.2 Mechanism of investors' influence on the effect of value-added services of startups (SETC model)

(1) Mechanism of action: value-added services → value-added service effect

The value-added service constitutes an internal direct driver and the principal influencing factor. The impact of value-added services is mainly influenced by the following four aspects:

- Support for corporate governance positively impacts the efficacy of value-added services.

Table 13.5 Basic information of theoretical saturation test cases

Value added services stages covered	Case	Case introduction	Financing time	Financing rounds
Start-up period	Biyang technology	Established in May 2019 in Suzhou, China's leading e-commerce brand for women's consumer goods	September 2019	Angel round
Start-up period-maturity	NAYUKI	Established in May 2014 in Guangdong, China's leading tea beverage brand	February 2017	Angel round
			July 2017	Series A
				……
			June 2021	IPO listing

- Assistance with business development positively impacts the efficacy of value-added services.
- Assistance with capital operation positively impacts the efficacy of value-added services.
- Emergencies positively impact the efficacy of value-added services throughout the entire process and have minimal effects on the overall value-added services of startups.

(2) Mechanism of action: external environment → value-added service effect

The external environment represents the external direct driver, and it mainly affects the efficacy of value-added services from the following three perspectives:

- The uncertainty in the macro-environment negatively impacts the efficacy of value-added services.
- The fluctuations in industry development negatively affect the efficacy of value-added services.
- Intense market competition positively impacts the efficacy of value-added service.

(3) Mechanism of action: both parties' traits → value-added service effect

The situational driver and the principal influencing factors are the traits of both parties. The following three aspects mainly impact the efficacy of value-added services:

- The traits of investors significantly impact the efficacy of value-added services.
- The traits of startups significantly impact the efficacy of value-added services.
- Interaction positively affects the efficacy of value-added services.

(4) Mechanism of action: principal-agent conflict

The principal-agent conflict represents an intermediary driver, mainly influencing the efficacy of value-added services from the following three aspects:

Table 13.6 Statistics on the importance of factors influencing the value-added service effect

		GuluGulu	FlowerPlus	Meituan bicycle	Alibaba	JD.COM	Mytech	Level of importance
Value added services	Corporate governance support			√	√	√	√	4
	Business development support		√	√	√		√	4
	Capital operation support	√	√	√	√	√	√	6
	Contingency support		√	√	√	√		4
External environment	Macro environment uncertainty		√			√	√	3
	Industry development fluctuations	√		√	√			3
	Intense market competition			√		√		2
Traits of both parties	Investor traits		√	√	√	√	√	5
	Startup traits	√			√	√	√	4
	Interaction		√		√	√	√	4
Principal-agent conflict	Control distribution			√	√	√		3
	Goal consistency	√		√			√	3
	Involvement	√			√	√	√	4

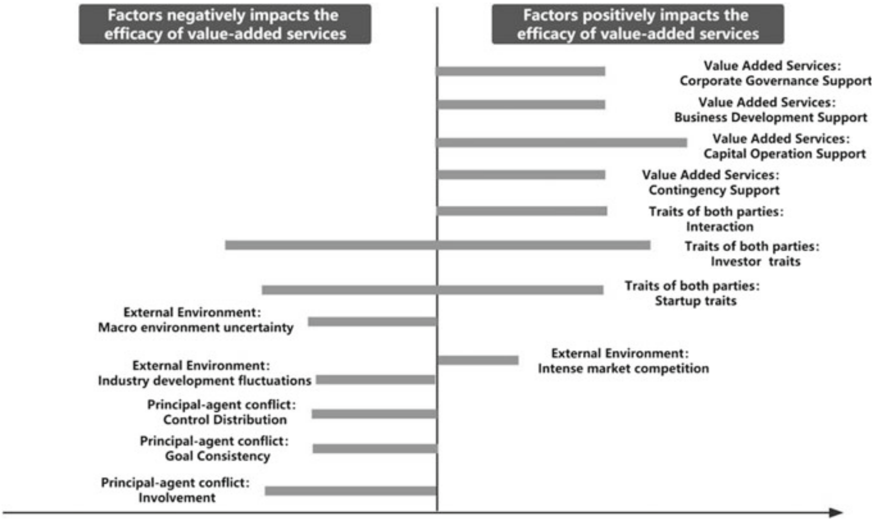


Fig. 13.3. Factors influencing the effect of investors' value-added services to startups

- Control distribution negatively impacts the efficacy of value-added services.
- Goal consistency negatively impacts the efficacy of value-added services.
- The degree of participation negatively impacts the efficacy of value-added services.

13.5.2 Derive Discussion

The mechanisms of action of the five primary categories in the SETC model vary. Specifically, the degree of impact of value-added services, the external environment, and principal-agent conflict on the efficacy of value-added services will exhibit different intensities depending on the degree of influence of the traits of both parties.

Moreover, the analysis of the original material's relationship reveals that there are interactions among the 16 categories. For instance, there exists a clear causal relationship between the traits of entrepreneurial startups and control distribution.

13.6 Conclusion and Discussion

This study employs the programmed grounded theory research method to examine the mechanism by which investors affect the effect of value-added services of startups, resulting in the construction of the SETC model, which comprises five main categories: value-added services, external environment, traits of both parties, principal-agent conflict, and value-added service effect, and generates four basic mechanisms of action.

Regarding theoretical significance, this study provides a detailed analysis of the actual needs and interest games of both sides of equity investment, laying the groundwork for subsequent empirical studies and providing new reference ideas for research in the field of value-added services. Concerning practical value, this study assists entrepreneurs in understanding the significance of receiving equity investment and the challenges they may encounter, aids investors in comprehending how to create value for startups, and contributes to the healthy development of the equity investment industry.

Then this study puts forward some suggestions from the perspective of startups and investors. Startups, firstly, should enhance their sensitivity to the entrepreneurial environment and self-analysis. Secondly, pay attention to screening before financing, communication after financing, and finally devote themselves to improving strength. Investors, firstly, value-added services should be closely linked with their strategic positioning. Secondly, actively maintain a harmonious relationship between the two sides. Finally, it is better to provide differentiated value-added services and improve the ability of emergency management for emergencies.

This study also has limitations, which include: first, the equity investment industry is a non-public market, leading to possible omissions and biases in obtaining information. Additionally, the study's sample size and proportion of offline interviews could be increased in the future to enrich data sources. Moreover, qualitative research based on grounded theory necessitates significant primary data over an extended period. Due to the limited completion time and raw data obtained, this study is unavoidably subjective in the coding process, which empirical studies can test in the future. To improve the robustness of the research, additional investigative factors, such as personal relationships between investors and startups, synergistic effects, and conflict handling, can be incorporated.

Acknowledgements The work was supported by the General project of Shanghai philosophy and social science planning of China (Grant No. 2018BGL006).

References

1. J. Lerner, R. Nanda, Venture capital's role in financing innovation: what we know and how much we still need to learn. J. Econ. Perspect. **34**(3), 237–261 (2020)

2. N. Lehnertz, C. Plagmann, E. Lutz, Effects of venture capital mega-deals on IPO success and post-IPO performance. Financ. Anal. J. **78**(4), 99–120 (2022)
3. T.T. Tyebjee, A.V. Bruno, A model of venture capitalist investment activity. Manag. Sci. **30**(9), 1051–1066 (1984)
4. M. Knockaert, A. Lockett, B. Clarysse et al., Do human capital and fund characteristics drive follow-up behaviour of early stage high-tech VCs? Int. J. Technol. Manag. **34**(1–2), 7–27 (2006)
5. D. Wang, E.C. Pahnke, R.M. McDonald, The past is prologue? Venture-capital syndicates' collaborative experience and start-up exits. Acad. Manag. J. **65**(2), 371–402 (2022)
6. T. Standaert, M. Knockaert, S. Manigart, Venture capital winners: a configurational approach to high Venture capital-backed firm growth. Br. J. Manag. **33**(1), 211–230 (2022)
7. R. Yi, H. Wang, B. Lyu et al., Does venture capital help to promote open innovation practice? Evidence from China. Eur. J. Innov. Manag. **26**(1), 1–26 (2023)
8. D. Cumming, L.H. Hass, L.A. Myers, et al., Does venture capital backing improve disclosure controls and procedures? Evidence from management's post-IPO disclosures. J. Bus. Ethics, 1–25 (2022)
9. I.C. MacMillan, D.M. Kulow, R. Khoylian, Venture capitalists' involvement in their investments: extent and performance. J. Bus. Ventur. **4**(1), 27–47 (1989)
10. C. Cheng, Y. Chu, Z. Deng et al., Venture capital and corporate social responsibility. J. Corp. Finan. **75**, 102208 (2022)
11. P.A. Gompers, V. Mukharlyamov, Transferable skills? Founders as venture capitalists. National Bureau of Economic Research (2022)
12. T.H. Blank, A. Carmeli, Does founding team composition influence external investment? The role of founding team prior experience and founder CEO. J. Technol. Transf. **46**, 1869–1888 (2021)
13. J. Jeong, J. Kim, H. Son, et al., The role of venture capital investment in startups' sustainable growth and performance: focusing on absorptive capacity and venture capitalists' reputation. Sustainability **12**(8), 3447 (2020)
14. M. Piazza, E. Mazzola, G. Perrone, et al., How does disruptive innovation influence the funding decisions of different venture capital investors? An empirical analysis on the role of startups' communication. Long Range Plan. (2023)
15. N. Xu, Research on value-added effect of venture capital on enterprises based on data mining technology. J. Cases Inf. Technol. (JCIT) **24**(5), 1–12(2022)
16. J.M. Corbin, A. Strauss, Grounded theory research: procedures, canons, and evaluative criteria. Qual. Sociol. **13**(1), 3–21 (1990)

Chapter 14
Intelligent Early-Warning Method for Financial Risk of Engineering Construction Projects Based on Industrial Cluster Network Technology

Huiling Wang

Abstract Some intelligent early warning methods for financial risks of engineering construction projects have the defects of large errors. To solve this problem, an intelligent early warning method for financial risks of engineering construction projects based on industrial cluster network technology is designed. Identify the characteristics of engineering construction projects, extract the crisis life cycle according to the characteristics, adopt differentiated calculation indicators, build a cost deviation control model, calculate the average total assets, and optimize the financial risk intelligent early warning model based on industrial cluster network technology. The experimental results show that the average error of this method is 11.21%, which indicates that this method has high accuracy after fully combining industrial economy and technology.

Keywords Computer technology · Industrial cluster network technology · Industrial economy and technology · Engineering construction projects · Financial risks · Intelligent warning · Tax planning · Risk cycle

14.1 Introduction

Financial risk intelligence early warning, also known as financial crisis early warning, is an extension of early warning theory in the financial field [1, 2]. Its definition is to establish an early-warning model by selecting early-warning indicators of financial risk information, and through the analysis of the early-warning indicators, and then urge the management to take corresponding countermeasures before the crisis

H. Wang (✉)
Shenyang Urban Construction University, Shenyang, Liaoning 110167, China
e-mail: 1181862431@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_14

comes, so as to be able to reduce or avoid losses. Engineering construction projects are the construction industry enterprises with special grade qualification in construction general contracting sequence and first grade qualification in construction general contracting sequence, mostly restructured from state-owned enterprises, which are the foundation of economic development and the first officer of the national economy, and it is classified by economists as the first type of nature, i.e. the double enterprises with significant social benefits and second to none economic benefits. Traditional project cost control methods and techniques tend to focus on the implementation phase of the project, which is difficult to achieve the global optimum. However, this nature does not avoid encountering fierce market competition. With the rapid growth of the scale of construction enterprises, there is a loss of control of internal management, and there are numerous loopholes in cost, quality, safety, financial and personnel management, which makes the project gain very little and the capital turnover is not good. Project cost control is still based on ex post facto control, and there is a certain degree of passivity and lag in cost control work. After the cost deviation occurs in the project, there is a lack of a set of scientific, perfect and effective correction process considering the project control subject. Intelligent management information system for cost deviation control of engineering construction projects has not been established, and information technology has a broad application prospect in the field of construction project cost control. In addition, some small construction enterprises are inexpensive and prone to irregularities, leading to chaos and disorder in the construction market, making engineering construction projects more financially risky than small construction enterprises. Engineering construction projects, especially state-owned enterprises, face greater financial risks as overseas markets continue to expand and a large number of excellent foreign construction companies enter the Chinese market, making industry competition more intense. Therefore, it is necessary to re-examine the present situation of cost management of engineering construction projects, strengthen the research on cost management of engineering construction projects, and focus on analyzing the influencing factors of cost deviation of engineering construction projects, so as to build an early warning and forecasting model and scientifically sort out the cost deviation correction process of engineering construction projects.

14.2 Identifying the Characteristics of Engineering Construction Projects

The definition of financial risk is usually divided into two aspects: broad level and narrow level. The narrow definition of financial risk is to identify the uncertainty of loss as financial risk. The broad definition of financial risk refers to the specific performance of the enterprise's comprehensive variety of financial risks, including debt risk, cash flow risk and profitability risk. Financial risks are divided into internal financial risks and external financial risks according to their sources and scope, and internal financial risks can be effectively prevented by establishing sound internal control and risk warning system mechanisms to control the risks within tolerable limits [3, 4]. Affected by the industry and its own operating characteristics, financial risks of construction enterprises are generally characterized by complexity, consistency and fluidity. The objective nature of risk makes it always inevitable that it exists and occurs in the enterprise and always causes certain losses and hazards to the enterprise, therefore, the enterprise must take timely and effective measures to minimize its impact on the enterprise. The characteristics of engineering construction projects are shown specifically in Fig. 14.1.

As can be seen from Fig. 14.1, different characteristics lead to corresponding financial risks and may generate new risks with changes in the market or policies. Financial risks are throughout the whole life cycle of construction enterprises, such as the bidding stage, construction stage, tax planning stage, etc. They may also be caused by improper project cost management, operation management and other

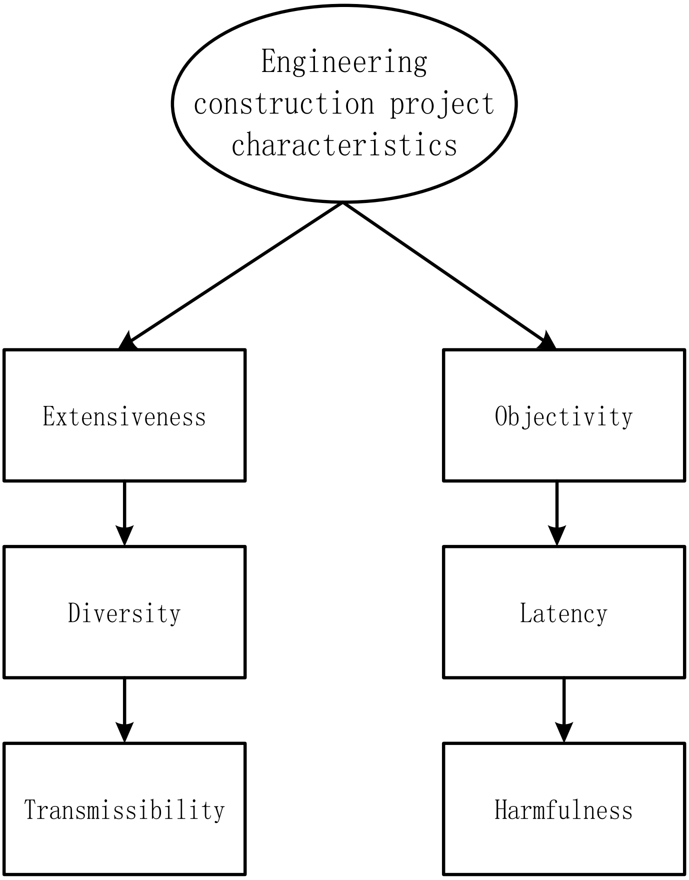


Fig141414...1. Characteristics of engineering construction projects aspects of financial risks, therefore, construction enterprises must understand the characteristics of their financial risks before risk prevention. However, the objective existence of risks also determines that enterprises cannot eliminate risks completely. Construction enterprises can eliminate all risks at one time, and some risks at all times, but not all risks at all times. To a large extent, enterprises have to accept partial and sometimes even total losses on a regular basis. When assessing financial risks, building construction enterprises mainly consider system loopholes or management blind spots in investment risks, operation risks and security and stability risks. Risk warning involves many branches, and financial risk intelligent warning is classified as one of them, an emerging management discipline accumulated in the study of risk warning. The financial risks of construction enterprises have obvious characteristics of long latency time compared with other industries. This is because, first of all, construction enterprises have a long construction cycle for individual projects, usually two years, sometimes reaching 4–5 years. Secondly, the unit cost of construction enterprise projects is high, the investment is large, and the impact of loss is not as great as the impact of capital. Financial risk intelligent warning should establish a dynamic tracking management system, the enterprise according to the macro environment, industry environment, business environment and other changes constantly adjust their risk response strategy, in the identification, analysis and control of financial risks and other links, according to the real-time changes of financial risks, timely adjust and correct strategies, and establish and improve the intelligent alarm system. Finally, construction enterprises can cover up many conflicts as long as they can make construction tasks one after another, resulting in longer time for construction enterprises to discover problems and longer latent period of risks. These factors determine the long latency of financial risks of construction enterprises and the drastic harm. Enterprises can adopt higher financial management flexibility, risk awareness and decision-making ability to implement early warning. Effective implementation of financial risk intelligent early warning can improve financial planning and management, assist leaders in making good decision support, provide channels for comprehensive and effective management of financial risks, and guarantee the stability of financial activities and the safety of funds.

14.3 Extraction of the Crisis Life Cycle

An enterprise internal control system is a means of control used by an enterprise that plays a very important role in the healthy development of the enterprise and the market economy as a whole, and is designed to achieve corporate control objectives. The enterprise crisis life cycle can be divided into five stages. The first stage is the gestation period, which is the process of qualitative change from quantitative change to qualitative change in a crisis. The second stage is the outbreak period, which means that the crisis enters the outbreak stage, and if not handled properly, the impact of the crisis will be further expanded. Enterprises should implement control procedures for all important operations and matters according to the actual situation of their own business, throughout the whole process of enterprise decision-making, execution and supervision, to achieve full staff and whole process control, leaving no internal control gaps. Through scientific supervision means to achieve risk control, effectively ensure the standardization of business management, understand the potential risks of the enterprise, and analyze the impact size of the risks, and develop relatively scientific management measures to make the risks controllable. The third stage is the diffusion period, which means that the crisis may sometimes lead to the result of "one hair moving the whole body", and the crisis will have a cascading effect on other areas. The fourth stage is the treatment stage, which is the key stage of the life cycle, and the subsequent development will depend entirely on the professional competence of the crisis manager. With the capital budget, efficiency budget and cost budget as the grasp, we implement comprehensive budget management, standardize the management of reserve funds, and improve the efficiency of capital use [5]. Based on the principle of "keeping expenditure within the limits of income and determining expenditure based on income", the expenditure items are classified in a hierarchical manner, and priority is given to priority and key expenditure items, while secondary and non-key expenditure items are arranged if there are surplus funds. The fifth stage is the period of treatment results and sequelae, which means that the crisis can be effectively solved after proper treatment, but if the treatment is ineffective, it may also lead to a new round of crisis brewing period. Solvency is the ability of the company to pay back the borrowed money. Generally speaking, the company uses its own capital to pay off its debts and liabilities, and on the other hand, the company uses its own capital to obtain greater benefits and thus fill the borrowing hole. Then whether the company can repay the funds borrowed when due will greatly affect the company's development, the ability to repay borrowing, including long-term and recent two categories, and for different repayment of borrowing strength to use differentiated calculation indicators, the relevant budget method expressed in the formula:

$$L = \frac{\delta}{\varepsilon} \tag{14.1}$$

$$W = \frac{(\delta - u - \beta)}{\varepsilon} \tag{14.2}$$

$$H = \frac{h}{R} \tag{14.3}$$

In Eqs. (14.1)–(14.3), L denotes current ratio, W denotes quick ratio, H denotes gearing ratio, δ denotes current assets, ε denotes current liabilities, u denotes inventory, β denotes other current assets, h denotes total liabilities, and R denotes total assets. The investment of funds should be inclined, and should be closely integrated with corporate strategies to direct the flow of funds to business segments with high revenue and profit contributions. In addition, the management, allocation and use of financial instruments such as letters of guarantee should be reasonably planned. Financial diagnosis refers to the use of rigorous scientific procedures and methods by professionals based on enterprise financial information, with the goal of helping enterprises upgrade their financial and overall management capabilities, identifying problems and helping them make better decisions. Financial diagnosis can be further subdivided into internal and external diagnosis. External diagnosis refers to the enterprise hiring external third-party institutions to analyze the financial operation of the enterprise. We will do our best to collect external accounts receivable and clear internal overdue loans, exhaust all legal means to revitalize the stock capital, strive to improve the enterprise's assets, and take multiple measures to control the group's asset and liability ratio within 90%. Financial diagnosis is divided into five main steps: First, to assess whether the enterprise needs financial diagnosis at present. Second is to select the diagnostic personnel and determine whether to diagnose internally or hire an external third party to conduct the diagnosis. Third is to collect relevant information. Fourth, use scientific methods to analyze the collected information and judge whether the enterprise has financial risks. Fifth, complete the diagnosis and propose corresponding solution measures based on the analysis results. In addition, building construction enterprises do a good job of bank reversal, bond payment and succession issuance in a timely manner, strictly prevent the occurrence of loan restrictions and bond defaults, continuously improve the financial credibility of enterprises and innovate financing methods.

14.4 Building an Expense Deviation Control Model

As an extremely important work in the whole process management activities of engineering projects, cost deviation control is the gap between the planned cost value and the actual cost value at each node in the construction process of complex large-scale projects. According to the classification of cost deviation purposes, the cost deviation control of engineering construction projects can be divided into construction and installation project costs, equipment and work equipment acquisition costs and other costs of engineering construction. Profitability is the strength of the company's business process to obtain benefits, and indicators such as return on total assets, return on net assets, and gross sales margin can effectively respond. Then the formula for calculating the return on total assets is as follows:

$$\phi = \frac{(g + l)}{v} \times 100\% \tag{14.4}$$

In Eq. (14.4), g represents total profit, l represents interest expense, and v represents average total assets. Under the influence of industrial economy and technology, the method of risk decision making is a method by which the decision maker selects a solution that is compatible with the enterprise's own risk tolerance by analyzing and comparing various feasible solutions under certain risk conditions. In different stages of financial activity, the methods of risk decision making used differ. In the financing stage, the commonly used methods include the financial leverage factor method and the marginal cost of capital method. Based on the already determined contract price of the project, the cost control in the mid-term implementation stage has an already determined goal, and this stage needs to make full use of the subjective and dynamic role of the stakeholders of the engineering construction project, so as to use scientific and efficient cost deviation control methods to achieve the economic goals of the project in this stage. Risk avoidance is a strategy to avoid risks. When the potential threat of the risks involved is too high, the adverse consequences are too serious, and there are no other strategies available, risks can usually be avoided by voluntarily abandoning the project or changing the project objectives and action plans [6]. It is the simplest and the most negative of the various risk management techniques. Any enterprise's production and operation activities are carried out without violating the law, and in the process of production and operation, the inability to meet or violate legal requirements leads to disputes that may cause economic losses to the enterprise, so that the legal environment may be an external cause of financial risk. The internal causes of financial risk mainly include unsound internal mechanisms, low level of financial management and unreasonable capital structure of the enterprise. The cost control of the later operation and maintenance stage is mainly to gather all the costs actually spent in the engineering construction project after the completion of the project, find out the stage where the cost deviation occurs, analyze its causes and formulate the corresponding strategies for deviation control at this stage. According to the above analysis, it can be seen that the cost deviation control of engineering construction project mainly arises in the engineering design in the decision-making stage and the engineering construction in the mid-implementation stage. The formula for calculating the average total assets is:

$$\eta = \frac{s}{d} \times 100\% \tag{14.5}$$

In Eq. (14.5), s denotes net income and d denotes average net assets. By interrupting the risk source, the company will avoid potential losses or uncertainties that may arise, but the company also loses the possibility of gaining benefits from the risk source, not to mention that some risks cannot be avoided at all. The risk reduction method is a more important risk prevention method than the risk avoidance method, and it is also the most applicable one for enterprises. The investment decision stage is the key to cost deviation control of engineering construction projects. Therefore, the investment decision stage is closely related to the economy of engineering projects. The formula for calculating the gross sales margin is:

$$\lambda = \frac{(p - q)}{c} \times 100\% \tag{14.6}$$

In Eq. (14.6), p represents operating income, q represents operating cost, and c represents operating income. Therefore, the cost deviation control of engineering construction projects should mainly focus on the pre-decision stage. In addition, the project value is mainly realized in the middle implementation stage, and the cost control in this stage is also the most direct and closest to the actual construction of the project, therefore, this stage is the key to the cost deviation control of the engineering construction project. Then the mathematical expression formula of cost deviation control model is:

$$Z = \sum \sum (\phi + \eta + \lambda) \times \frac{1}{Q} \tag{14.7}$$

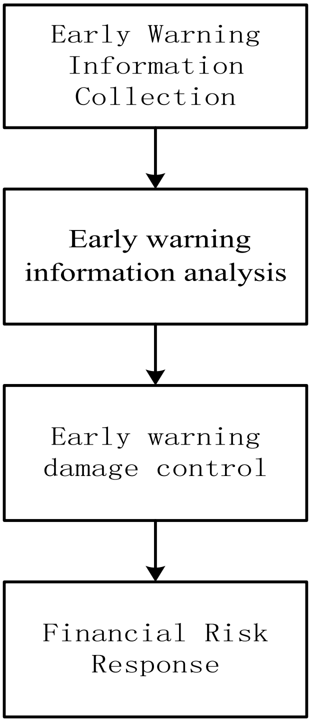
In Eq. (14.7), Q represents the project O&M budget. The project scale of engineering construction projects is relatively large, so the project itself and its cost management are bound to be constrained by various factors such as the availability of resources, management level, and the technical and economic environment in which the project is located. In addition, the construction standard determines whether the project is in line with the development of social economy and the future market, so this stage has a far-reaching and whole process impact on the cost of engineering construction projects.

14.5 Optimization of Financial Risk Intelligence Warning Model Based on Industrial Cluster Network Technology

Industrial cluster network technology refers to a kind of technology formed by an industry with the help of advanced equipment under the dual promotion of science and technology and economy. Intelligent early warning of financial risk plays an important role in whether enterprises can find financial crisis. If the problems existing in enterprise operation can be found as early as possible and solved in time, it will be conducive to the stable development of enterprises. The first stage is the signal detection stage, which refers to identifying the precursors of a crisis through existing experience and determining whether there are signals that may lead to the occurrence of a crisis. The first step in intelligent early warning of financial risks is early warning information collection. To be effective in early warning, companies need to understand the various financial risk factors that form the potential wei-li,. The information collection must be comprehensive and should include not only relevant financial data within the enterprise, such as relevant financial ratio indicators, but also relevant external data, such as industry development data. The analysis of early warning information is the core process of financial risk intelligent early warning and is a key step in diagnosing financial risks. By analyzing the financial and non-financial data in the early warning system, various technical means are adopted to identify existing and potential financial risks. The basic steps of intelligent early warning for financial risks of engineering construction projects are as follows (see Fig. 14.2).

After processing the collected information through accounting information and other industrial and economic technologies, enterprises need to find the causes of

Fig141414...2. Basic steps of financial risk intelligence warning for engineering construction projects



risks and the magnitude of risks based on the risks found, so that they can develop corresponding control measures. A good financial risk intelligence early warning system can accurately predict the degree of risk faced and the development trend of the company's financial risk based on the various financial and non-financial information collected, so that the possible risks can be detected and responded to early. The second stage is the detection and prevention stage, which mainly prepares for the possible crisis and prevents it from occurring. The third stage is the damage control stage, which reduces various losses caused by the occurrence of crisis by taking various measures. The fourth stage is the recovery stage, which refers to the enterprise's ability to recover from the crisis through risk management measures. The expression of Z-score scoring model is introduced here to derive the expression formula of multivariate linear determination model of financial risk intelligent early warning:

$$M = \sum \frac{(0.012\mu_1 + 0.14\mu_2 + 0.033\mu_3 + 0.006\mu_4 + 0.999\mu_5)}{Z} \tag{14.8}$$

In Eq. (14.8), μ_1 represents the ratio of working capital to total assets, μ_2 represents the ratio of retained earnings to total assets, μ_3 represents the ratio of EBITDA to total assets, μ_4 represents the ratio of the market value of preferred and common stock to the face value of total liabilities, and μ_5 represents the ratio of total sales to total assets. The fifth stage is the learning stage, which refers to learning lessons from the crisis and improving the risk management of the company. Both the three-stage theory and the five-stage theory illustrate that risk management runs through the whole process of a company's production and operation. Although there is uncertainty about what kind of financial risks a company may have in the future, through industrial cluster network technology, it is possible to effectively judge the financial crisis that will occur in the future by detecting some relatively sensitive indicators. After identifying and diagnosing the financial risks, it is necessary to find the factors affecting the financial risks, especially to identify the key financial risk factors, to report to the management, and to formulate targeted responses and solutions. In the process of analyzing risks, a high degree of staff independence is required in order to make the analysis more objective and fair. Once problems are identified, timely action is taken. The ability to handle risks correctly and propose the right control measures depends on a good financial risk handling mechanism. As the financial risk intelligent early warning is based on different dimensions of financial and non-financial indicators to make effective early warning, when a certain indicator with a high correlation with the early warning results changes, the early warning model can effectively identify the changes in the indicator and reflected in the early warning results, to achieve the purpose of effective risk identification.

14.6 Experimental Analysis

14.6.1 Simulation Overview

Project A: The investor is the traffic department of X prefecture-level city, a first-class highway (12 km long), with a construction period of one year, requiring an advance of 22 million yuan, which needs to be invested upfront, and the rest of the funds can be paid for the project according to the progress. In order to ensure the successful completion of the air separation unit turbine ramp-up target, S Company specially set up a project manager-led "air separation unit commissioning" excellent Communist Party members responsibility area, and actively organize and coordinate with the owner's project team, suppliers, patentees, construction units, S Company production and transportation personnel to carry out special conditions for turbine ramp-up. "Three checks and four determinations" work. The advance part of the funds can be paid in full in a lump sum when the project is completed in half a year minus the 4% quality guarantee (paid in full minus the maintenance cost part when it is completed in one year) part, and the expected return is 22.5 million yuan.

14.6.2 Analysis of Results

In order to reflect the effectiveness of the research methods in this paper more intuitively, the intelligent early-warning method of financial risks of engineering construction projects based on cluster analysis and the intelligent early-warning method of financial risks of engineering construction projects based on neural network are selected and compared. The errors of three kinds of intelligent early warning methods for financial risks of engineering construction projects under different risk scenarios are shown in Table 14.1–14.5:

According to Tables 14.1, 14.2, 14.3, 14.4 and 14.5, the average error of this method is 11.21% under five risk scenarios; The average error of intelligent early warning method for financial risks of engineering construction projects based on cluster analysis is 14.30%; The average error of intelligent early warning method for financial risk of engineering construction project based on neural network is 14.89%.

Table 14.1 Funding Risk Error (%)

Number of experiments	An intelligent early warning method for financial risk of engineering construction projects based on cluster analysis	An intelligent early warning method for financial risk of engineering construction projects based on neural network	Intelligent early warning method for financial risks of engineering construction projects in the text
10	12.34	11.76	10.46
20	11.09	12.43	9.33
30	12.68	11.25	10.11
40	12.44	12.12	9.78
50	11.26	12.90	10.87

Table 14.2 Delay Risk Error (%)

Number of experiments	An intelligent early warning method for financial risk of engineering construction projects based on cluster analysis	An intelligent early warning method for financial risk of engineering construction projects based on neural network	Intelligent early warning method for financial risks of engineering construction projects in the text
10	4.35	5.09	2.35
20	5.98	5.23	2.46
30	4.02	5.15	3.74
40	5.36	4.26	2.89
50	5.18	4.78	3.32

Table 14.3 Material cost risk error (%)

Number of experiments	An intelligent early warning method for financial risk of engineering construction projects based on cluster analysis	An intelligent early warning method for financial risk of engineering construction projects based on neural network	Intelligent early warning method for financial risks of engineering construction projects in the text
10	27.84	27.78	21.56
20	21.77	26.89	19.57
30	27.46	24.04	18.83
40	23.49	23.22	15.25
50	22.33	25.25	16.27

Table 14.4 Tax risk error (%)

Number of experiments	An intelligent early warning method for financial risk of engineering construction projects based on cluster analysis	An intelligent early warning method for financial risk of engineering construction projects based on neural network	Intelligent early warning method for financial risks of engineering construction projects in the text
10	16.35	13.89	12.36
20	15.32	16.67	13.80
30	14.16	18.45	13.45
40	15.43	18.21	14.67
50	17.22	18.36	13.08

Table 14.5 Other risk errors (%)

Number of experiments	An intelligent early warning method for financial risk of engineering construction projects based on cluster analysis	An intelligent early warning method for financial risk of engineering construction projects based on neural network	Intelligent early warning method for financial risks of engineering construction projects in the text
10	3.44	4.55	2.09
20	5.51	4.67	2.46
30	4.62	5.08	1.32
40	4.37	5.12	1.19
50	3.48	3.06	2.23

14.7 Conclusion

Based on the industrial cluster network technology, this paper describes the theory related to financial risk and designs a new intelligent early warning method for financial risk of engineering construction projects. It includes both the theory of enterprise external environment and the theory related to enterprise internal control. The construction project cost deviation control model is innovative and forward-looking, which is of great significance to enrich the project management theory, methods and project practice. In the future, the focus will be to break the time limit of sample selection, which can be further studied.

14.8 Fund Project

The second batch of industry university Cooperative Education Project of the Department of Higher Education of the Ministry of Education in 2021 "Construction and Practice Research on the Management Mode of Technological Innovation in Science and Technology Enterprises under the" Internet+ "Environment" (Project No.: 202102306012).

References

1. A. Adelusi, L. Anifowose, Assessment of financial risk and its impact on an informal finance institutions profitability. Can. Soc. Sci. **18**(1), 133–139 (2022)
2. E. Payzan-LeNestour, M. Woodford, Outlier blindness: a neurobiological foundation for neglect of financial risk. J. Financ. Econ. **143**(3), 1316–1343 (2022)
3. S. Osipov, A. Krupnov, N. Semenova et al., Ecologically responsible entrepreneurship and its contribution to the green economy's sustainable development: financial risk management prospects. Risks **10**(2), 44 (2022)
4. N. Zhilkina, V. Karp, V. Bodiako et al., Socially-oriented approach to financial risk management as the basis of support for the SDGs in entrepreneurship. Risks **10**(2), 42 (2022)
5. G. Rabbani, W. Heo, M. Lee, A latent profile analysis of college students' financial knowledge: the role of financial education, financial well-being, and financial risk tolerance. J. Educ. Bus. **97**(2), 112–118 (2022)
6. G. Vagin, I. Kostyukova, E. Spiridonova et al., Financial risk management based on corporate social responsibility in the interests of sustainable development. Risks **10**(2), 35 (2022)

Chapter 15
Empirical Analysis of Factors Influencing the Price of Commercial Housing in Anhui Province Based on Multiple Regression Model

Xinyu Tu, Dawei Zhang, and Janguo Li

Abstract The real estate industry has boosted the development of national economy, but the rise of housing prices has caused many economic and social problems, so it is particularly necessary to study the factors affecting housing prices. Why are housing costs increasing so quickly? This paper selects five associated indexes based on the data of commodities house prices in Anhui Province from 2000 to 2021, including gross regional product, urban per capita disposable income, and the number of real estate development firms, establishes a multivariate linear model of influencing factors using EViews software, corrects the results using statistical tests such as multiple covariance and heteroskedasticity, and conducts model adjustment analysis to propose specificinfluencing factors. The model is adjusted and analyzed to propose specific measures to better promote the stable and healthy development of the real estate market.

Keywords Multiple regression model · Commodity housing prices · EViews · Empirical analysis

15.1 Introduction

Since ancient times in China, the people have had a deep attachment to houses, as evidenced by the saying "one who dwells has a house." Houses serve as a symbol of human survival and fulfill people's basic living needs. The issue of housing is directly related to the well-being of the people, and the direction of real estate market prices

X. Tu · D. Zhang (✉) · J. Li
School of International Business and Economics, Anhui University of Finance and Economics, Bengbu 233030, China
e-mail: 1371626906@qq.com

X. Tu
e-mail: tuxinyu1203@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_15

has become a topic of great concern of the entire nation. The current housing costs have significantly increased peoples' housing burdens; the quick increase in housing costs will cause a number of social issues; it will also create a bubble economy; and it is one of the key things stifling domestic demand. The growth rate of national income has once again lagged behind the rise in housing prices, which has led to a situation where housing prices "cannot win at high places" and is discouraging to people. The report of the 20th Party Congress elaborated on the future development direction of the real estate industry from the perspective of "promoting people's well-being and improving people's quality of life", and pointed out that "we will speed up the establishment of a housing system with multiple main bodies supplying, multiple channels guaranteeing, and renting and purchasing". How to scientifically understand the commodity housing market and introduce relevant policies to control the stable development of commodity housing prices is of great significance to the life and investment of Anhui residents. The overheated and excessive rise of the commodity housing market in Anhui Province has become a hot topic of general concern for the public because it can impede the growth of the local economy, have a number of detrimental effects that can affect social stability, and affect the improvement of living standards for local residents [1]. National economic policies and market forces determine the price of commercial real estate, but due to the oversupply in market and people's rising expectations for fixed asset investments, the price of real estate has risen quickly in recent years, especially in well-developed first-and second-tier cities. This has created an unhealthy and unregulated commercial real estate investment market. An unhealthy and subpar commercial housing investment market can negatively impact people's expectations of society and their level of happiness in life in the absence of strict regulation.

Currently, researchers in China have studied commodity housing prices from various angles. Changes in the interest rate on first-lien loans, according to research by Fei Li, Yining Shi, Zhan Xu, and Ocean Zhang, can successfully account for changes in real estate prices. Additionally, the impact of interest rate policies on housing prices varies significantly by city, the more sensitive the city experiences, the stronger the regulatory effect [2]. The time series data of the consumer price index (CPI) and Chinese housing price index (HPI) in Beijing and Shanghai are used to study the relationship between inflation and commodity housing prices. Hong Zhang and Hui-Zhan Zhang used econometric models as the foundation [3]. Liting Shao, David Shao, and Dianming Wu, reveal deeply revealed the law of the role of park green areas on residential prices, and the scarcity of unconventional factors such as green areas and other ecological resources and high-quality landscape conditions are exacerbating the spatial heterogeneity of residential prices and producing a strong value-added effect on residential prices in surrounding areas [4]. Through the research perspective of behavioral economics, Li Junli focuses on the role and influence of individual participation behavior of real estate market plays on the market as a whole from the psychological aspect and uses "prospect theory", "cognitive bias" and "herding effect" to explain the irrational behavior of Chinese residents in purchasing houses. The goal of housing for the people [5].

There is a close relationship between housing price and living standard, national macroeconomic development environment, financial environment and so on. Therefore, objectively requires the healthy development of the real estate industry to ensure the reasonable purchase of property buyers. After the development of Anhui Province in recent years, the real estate market has been gradually mature and perfect, and has a strong market vitality. However, in the process of market economy development, there are also some problems, such as the high price of commercial housing, housing supply structure is unreasonable. This paper uses multiple regression model to analyze the factors affecting the price of commercial housing in Anhui province, find out the main factors affecting the price change of commercial housing in Anhui province and put forward relevant policy suggestions, which is of great significance for improving the real estate market and promoting the healthy development of the real estate industry in Anhui province, and also has certain reference value for other regions.

This paper will make the following contributions. Firstly, the paper can provide valuable insights into the factors that drive commodity housing prices in Anhui Province. This can help policymakers, real estate developers, and investors to make informed decisions and formulate effective strategies. Secondly, the paper can contribute to the academic literature on the determinants of commodity housing prices. By using a multiple regression model, the paper can identify the relative importance of different factors and their impact on housing prices, thus advancing the understanding of the housing market. Thirdly, the paper can help to improve the accuracy of housing price forecasting. By identifying the key determinants of housing prices, it can provide a better understanding of the market and enable more accurate predictions of future trends. Overall, the empirical analysis of the influencing factors of commodity housing price in Anhui Province based on the multiple regression model can have important implications for both practical decision-making and academic research in the field of housing economics.

15.2 Variable Selection and Data Sources

The scope of this paper is Anhui Province, and the research object is commodity house prices, and the data are obtained from the National Bureau of Statistics and Anhui Provincial Statistical Annual Report. There are many factors affecting house price, and because of the availability of data, this paper collects the following seven relevant data, and takes the average sales price of commercial houses (Y) in Anhui Province in each period as the explanatory variable, and introduces the regional gross domestic product (X1) and per capita disposable income of urban residents (X2) in Anhui Province on the demand side; the number of real estate development enterprises (X3) and the sales area of commercial houses (X4) on the supply side; and the year-end resident population (X5) on the macro side. (X4) on the supply side, and the year-end resident population of Anhui Province (X5) on the macro side. The collected data are processed accordingly and then detailed in Table 15.1.

Table 15.1 Average price of commercial housing in Anhui from 2000 to 2021 and its influencing factors

T	Y	X1	X2	X3	X4	X5
2000	1173	3125.3	5277	988	535.86	6093
2001	1163	3502.8	5645	1112	679.58	6128
2002	1290	3827.7	6001	1220	794.82	6144
2003	1513	4307.8	6735	1388	1093.27	6163
2004	1782.14	5129.1	7456	2013	1429.24	6228
2005	2220.2	5675.9	8399	1909	1907.21	6120
2006	2321.89	6500.3	9677	2182	2307.83	6110
2007	2664.37	7941.6	11350	2391	3083.39	6118
2008	2949	9517.7	12836	3277	2785.83	6135
2009	3420	10864.7	13903	3097	4030.92	6131
2010	4205	13249.8	15566	3281	4154.26	5957
2011	4776.1	16284.9	18345	3209	4605.58	5972
2012	4824.95	18341.7	20729	3402	4828.81	5978
2013	5080	20584.0	22789	3418	6265.35	5988
2014	5394	22519.7	24839	3731	6202.18	5997
2015	5457	23831.2	26936	3620	6174.09	6011
2016	5924	26307.7	29156	3768	8499.65	6033
2017	6375	29676.2	31640	3889	9200.71	6057
2018	7049.86	34010.9	34393	3939	10038.43	6076
2019	7393	36845.5	37540	4112	9229.38	6092
2020	7705	38061.5	39442	4143	9534.13	6105
2021	7784	42959.2	43009	4240	10460.9	6113

Data source National Bureau of Statistics [6]

15.3 Model Construction and Parameter Estimation

According to the setting of the above variables and the actual economic significance, the following model is established after the preliminary processing of the data:

$$Yi = \beta 0 + \beta 1X1t + \beta 2X2t + \beta 3X3t + \beta 4X4t + \beta 5X5t + Ui \tag{15.1}$$

where the significance of each variable is as follows: Y: average sales price of commercial houses in Anhui Province in each period (yuan/m^2); X1: gross regional product (billion yuan), X2: per capita disposable income of urban residents (yuan); X3: number of real estate development enterprises (one); X4: sales area of commercial houses (m^2); X5: year-end resident population (10,000 people). Observing the trend changes in Fig. 15.1, it can be seen that the differences in the house prices and their influencing factors in Anhui Province are obvious, but the direction of their changes is consistent.

The processed data were brought into the multiple linear regression model developed above, and the OLS regression estimation of the data in Table 15.1 using the ordinary least squares method yielded the results shown in Fig. 15.2.

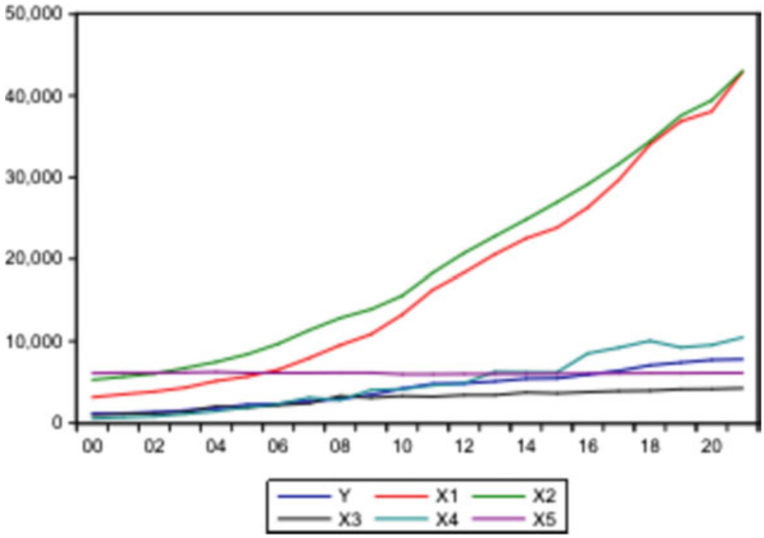


Fig. 15.1 Trend graph of variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	16880.15	3715.963	4.542605	0.0003
X1	0.150715	0.067182	2.243374	0.0394
X2	-0.047898	0.077207	-0.620390	0.5437
X3	0.533628	0.109042	4.893796	0.0002
X4	0.093450	0.065221	1.432813	0.1712
X5	-2.694315	0.597545	-4.508978	0.0004

R-squared	0.996048	Mean dependent var	4202.936
Adjusted R-squared	0.994813	S.D. dependent var	2263.070
S.E. of regression	162.9821	Akaike info criterion	13.25216
Sum squared resid	425010.8	Schwarz criterion	13.54972
Log likelihood	-139.7737	Hannan-Quinn criter.	13.32225
F-statistic	806.5770	Durbin-Watson stat	1.937282
Prob(F-statistic)	0.000000		

Fig. 15.2 Multiple regression estimation results

The linear regression equation between the average price of commodity houses and its influencing factors can be obtained initially:

$$Y = 16880.1516 + 0.1507X_1 - 0.0479X_2 + 0.5336X_3 + 0.0935X_4 - 2.6943X_5 \tag{15.2}$$

$$t = (4.5426)(2.2434)(-0.6240)(4.8938)(1.4328)(-4.5090) \tag{15.3}$$

$$R2 = 0.9960,\ R2 = 0.9984,\ F = 806.5770,\ DW = 1.9373 \tag{15.4}$$

15.4 Model Testing and Correction

15.4.1 Economic Significance Test

The partial regression coefficient of 0.1507 indicates the marginal impact of GDP on house price, i.e., for every 100 million Yuan increase in GDP, the house price in Anhui Province will increase by 0.1507 Yuan/m^2, provided that other influencing factors remain unchanged. Similarly, under the premise that other influencing factors remain unchanged, for every increase of 1 yuan in per capita disposable income of urban residents, the house price in Anhui Province will decrease by 0.0479 yuan/m^2; for every increase of 1 number of real estate development enterprises, the house price in Anhui Province will increase by 0.5336 yuan/m^2; for every increase of 10,000 m^2 in the sales area of commercial houses, the house price in Anhui Province will increase by 0.0935 yuan/m^2; for every increase of 1,000,000 people in year-end X1, X3, and X4 are positively correlated with Y, which is consistent with the theoretical analysis. X2 and X5 are negatively correlated with Y, indicating that each increase in the sales area of commercial houses and the increase in the resident population at the end of the year will lead to a decrease in the average price of commercial houses in Anhui Province, which is not consistent with the actual economic significance, so the speculative model may have quality problems and needs to be revised. The model needs to be revised.

15.4.2 Statistical Tests

From the above analysis, the model has $R^2 = 0.9960$ and the corrected decidable coefficient $\overline{R^2} = 0.9984$, indicating that the proposed model fits the sample data well and the degree of explanation of the model exceeds 95%. The F-test was used to infer whether there is a significant linear relationship between the explained variables and all explanatory variables, Prob$(F - statistic) = 0.000000$ at significance level

$\alpha = 0.05$, indicating that the regression equation is significant overall and the model passes the F-test.

Significance tests can be conducted for each explanatory variable separately using t-test, and the corresponding probabilities of the coefficients of each explanatory variable in Fig. 15.2 are observed at the significance level $\alpha = 0.05$. With other explanatory variables unchanged, X1, X3, and X5 have significant effects on the explanatory variable Y. The accompanying probabilities of t-tests for variables X2 and X4 are greater than 0.05, indicating that urban residents' disposable income and sales area of commercial houses have insignificant effects on the price of commercial houses in Anhui Province.

15.4.3 Econometric Testing

Multicollinearity. To verify the multicollinearity of the model, the correlation coefficient matrix can be constructed using EViews software to make a judgment, and the correlation coefficient matrix is shown in Table 15.2, the correlation coefficients between all explanatory variables except X5 are greater than 0.8, which can be judged to be highly correlated and there may be more serious multicollinearity, and the variance inflation factor method is used for further testing.

Experience shows that if the variance inflation factor $VIFj \geq 10$, it usually indicates that there is severe multicollinearity between the explanatory variables and the remaining explanatory variables, and this multicollinearity may unduly affect the least squares estimation. As can be seen from Fig. 15.3, the variance inflation factors of the variables are much larger than 10, indicating the existence of severe multicollinearity in the model.

The stepwise regression method is used to correct the multicollinearity. The stepwise regression method can eliminate the statistically insignificant explanatory variables, and finally, the explanatory variables retained in the model have insignificant multicollinearity among them and have a better explanatory contribution to the explained variables. The results are shown in Fig. 15.4. After stepwise regression, two explanatory variables X1 and X3 were finally left and X2, X4, and X5 were excluded, and the corrected model was:

Table 15.2 Correlation coefficient matrix

Variables	Y	X1	X2	X3	X4	X5
Y	1	0.982370767	0.986596335	0.94479295	0.983916732	−0.45614057
X1	0.982370767	1	0.998585807	0.887009997	0.98103118	−0.332265794
X2	0.986596335	0.998585807	1	0.90257076	0.984635	−0.348088969
X3	0.94479295	0.887009997	0.90257076	1	0.917055588	−0.496886491
X4	0.983916732	0.98103118	0.984635	0.917055588	1	−0.377133383
X5	−0.45614057	−0.332265794	−0.348088969	−0.496886491	−0.377133383	1

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	13808380	11436.30	NA
X1	0.004513	1713.576	580.2545
X2	0.005961	2595.670	695.0275
X3	0.011890	95.05768	10.86073
X4	0.004254	122.9709	38.31771
X5	0.357059	10931.41	1.436260

Fig. 15.3 Variance inflation factor VIF test results

$$Y = -8.7024 + 0.1201X_1 + 0.7250X_3 \tag{15.5}$$

$$t = (-0.0464)(13.8586)(7.0498) \tag{15.6}$$

$$R^2 = 0.9960, \overline{R}^2 = 0.9984, F = 973.3958, DW = 1.5029 \tag{15.7}$$

It can be seen that the multicollinearity of each explanatory variable has been largely eliminated at the given significance level of 0.05, and it can also be concluded that the price of commercial housing in Anhui Province for the 21 years from 2000 to 2021 is influenced by the factor of the number of real estate development enterprises in the gross regional product and is significantly correlated.

Heteroskedasticity. Heteroskedasticity refers to random error terms with different variances, one of the premises of the OLS method used in this paper is that there is no heteroskedasticity, which will make the estimated variance and parameter estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-8.702431	187.5482	-0.046401	0.9635
X1	0.120131	0.008668	13.85856	0.0000
X3	0.724991	0.102838	7.049812	0.0000

R-squared	0.990335	Mean dependent var	4202.936
Adjusted R-squared	0.989317	S.D. dependent var	2263.070
S.E. of regression	233.9047	Akaike info criterion	13.87383
Sum squared resid	1039517.	Schwarz criterion	14.02261
Log likelihood	-149.6121	Hannan-Quinn criter.	13.90888
F-statistic	973.3958	Durbin-Watson stat	1.502945
Prob(F-statistic)	0.000000		

Fig. 15.4 Corrected multiple regression estimation results

no longer effective. The White method is used to test whether there is heteroskedasticity in the model, it not only tests whether there is heteroskedasticity in the model but also determines which variable is responsible for the heteroskedasticity. As can be seen from the figure, at 95% confidence level, $nR^2 = 1.2144$ is less than the critical value of 5.9915, and $P = 0.5449$ is less than the significance level of 0.05, so this model does not have heteroskedasticity.

Autocorrelation. Autocorrelation means that the model does not satisfy the assumption of no autocorrelation of the random error term. When the model has autocorrelation, if ordinary least squares are still used to estimate the parameters, it may underestimate the standard error of the coefficients, reduce the reliability of the t-test, increase the estimation error, and invalidate the least squares estimation. This paper uses bias correlation coefficients to test for autocorrelation, and the results in the figure show that the bias correlation coefficients are all over the dashed line, indicating that the model does not have autocorrelation problems.

This leads to the following final results of the model

$$Y = -8.7024 + 0.1201X_1 + 0.7250X_3 \tag{15.8}$$

$$t = (-0.0464)(13.8586)(7.0498) \tag{15.9}$$

$$R^2 = 0.9960, \overline{R}^2 = 0.9948, F = 973.3958, DW = 1.5029 \tag{15.10}$$

The model results illustrate that for every unit increase in X1 gross regional product, the average price of commercial housing in Anhui Province increases by 0.1201 units; when X3 the number of real estate development enterprises increases by one unit, the average price of commercial housing in Anhui Province increases by 0.7250 units.

15.5 Conclusions and Recommendations

The purpose of this study was to conduct multiple regression analysis on five related variables that affect the price of commercial properties in Anhui Province. To ensure that the variables met the basic requirements for multiple regression, we performed multiple covariance, heteroskedasticity, and autocorrelation tests and corrections. We ultimately came to the conclusion that the gross regional product and the number of real estate development enterprises in Anhui Province have more significant effects on the house price. GDP is a measure of economic development that directly affects home prices. Because these two variables are positively connected, with the growth of GDP, house prices will rise over time. The government must thus take the effects of GDP and the number of real estate development companies into account in order to manage home prices. Hence, in order to keep housing costs under control, the government must consider how the GDP and the availability of real estate development companies on the market would affect housing costs. According to the results of model analysis, along with a number of initiatives put forth by Anhui Province to control commodities home prices, the following suggestions are put forward.

First, alter the supply and demand of land and strengthen supervision. China's real estate market is overheating, the pace of growth is recklessly accelerating, land resources are not being completely exploited, there are some deteriorating structures, and so on. Relevant departments should enhance the land supply system, manage vacant land, increase land usage, and regulate the price supply of real estate developers [7]. To prevent real estate development companies from unduly inflating home prices, tighten up the rules governing land purchases, financing, and supervision of such businesses. In order to guarantee the steady growth of the real estate market, the government must also fairly guide investment and conduct accurate asset risk evaluations for new entrants. Give the market its due consideration, and hasten the modernization of the industrial structure.

Second, put the "de-stocking" program into action. First, offer interest rates and tax breaks to incentivize home purchases and boost housing demand. Next, raise the entry barrier to the real estate market, make it more expensive for speculators to do so, and lower the number of speculators to enter the real estate market, and reduce the real estate market bubble brought by them; then, take various measures to respond to the "de-stocking" policy, continue to promote the conversion of stocked commercial housing into low-cost housing and subsidized housing. Finally, we should take various measures to respond to the "de-stocking" policy, and continue to promote the conversion of stocked commercial housing into low-rent housing and subsidized housing, achieve the complementarity of stocked commercial housing and subsidized housing, and realize both renting and selling [8]. For example, in cities where population inflow exceeds outflow and housing prices are high, the government should focus on curbing the rapid rise in housing prices and providing more subsidized housing and subsidized rental housing, with restrictions on purchase and sale as a more direct and powerful means. In the second, third, and fourth-tier cities, the government should fully release the residents' housing demand and better meet their housing needs and improvement needs, take more active measures in restricting purchase and sale policies and relaxation, focus on promoting housing consumption, and can give benefits in provident fund, housing subsidies, tax concessions, etc. [9].

Third, given the different levels and concepts of housing consumption in China at present, the government should focus on active guidance, advocate healthy consumption concepts, establish a reasonable consumption structure of the real estate industry, change consumers' incorrect psychological expectations of real estate prices, encourage consumers to gain a deeper understanding of the real estate industry and its changes in housing prices, and gradually correct consumers' inner psychological expectations of excessive housing prices so that they can purchase correctly and reasonably to better promote the stable and healthy development of the real estate market.

Appendix

Average price of commercial housing in Anhui from 2000 to 2021 and its influencing factors.

Time	Average sales price of commercial houses (yuan/m^2)	Gross regional product (billion yuan)	Per capita disposable income of urban residents (yuan)	The number of real estate development enterprises (a)	Sales area of commercial properties (m^2)	Year-end resident population (million)
T	Y	X1	X2	X3	X4	X5
2000	1173.0	3125.3	5277	988	535.86	6093
2001	1163.0	3502.8	5645	1112	679.58	6128
2002	1290.0	3827.7	6001	1220	794.82	6144
2003	1513.0	4307.8	6735	1388	1093.27	6163
2004	1782.1	5129.1	7456	2013	1429.24	6228
2005	2220.2	5675.9	8399	1909	1907.21	6120
2006	2321.9	6500.3	9677	2182	2307.83	6110
2007	2664.4	7941.6	11350	2391	3083.39	6118
2008	2949.0	9517.7	12836	3277	2785.83	6135
2009	3420.0	10864.7	13903	3097	4030.92	6131
2010	4205.0	13249.8	15566	3281	4154.26	5957
2011	4776.1	16284.9	18345	3209	4605.58	5972
2012	4825.0	18341.7	20729	3402	4828.81	5978
2013	5080.0	20584.0	22789	3418	6265.35	5988
2014	5394.0	22519.7	24839	3731	6202.18	5997
2015	5457.0	23831.2	26936	3620	6174.09	6011
2016	5924.0	26307.7	29156	3768	8499.65	6033
2017	6375.0	29676.2	31640	3889	9200.71	6057
2018	7049.9	34010.9	34393	3939	10038.43	6076
2019	7393.0	36845.5	37540	4112	9229.38	6092
2020	7705.0	38061.5	39442	4143	9534.13	6105
2021	7784.0	42959.2	43009	4240	10460.9	6113

References

1. X. Rui, D. Yue, Z. Jiaming, An econometric analysis of factors influencing house prices in Anhui based on multiple regression. J. Nat. Sci., Harbin Norm. Univ. **38**(04), 36–42 (2022)

2. L. Fei, S. Yining, X. Zhan, Z. Ocean, Credit and house prices: the impact of first-suite loan interest rates on house prices in China. J. Southwest Univ. Natl. (Humanities and Social Sciences Edition) **43**(01), 132–142 (2022)
3. Z. Hong, Z. Huizan, An empirical analysis of the relationship between inflation and commodity residential prices. J. Tsinghua Univ. (Natural Science Edition) Netw. Preview (03), 329–332 (2008)
4. L.T. Shao, D.W. Shao, D.M. Wu, The impact of park green space on residential prices and its scale difference law. China Urban For., 1–13
5. L. Junli, Analysis of psychological factors of urban residents' house purchasing behavior: a perspective of behavioral economics. Inn. Mong.Ia Sci. Technol. Econ. **487**(21), 55–57 (2021)
6. China Statistical Yearbook, *National Bureau of Statistics, People's Republic of China* (Beijing: China Statistics Press). https://data.stats.gov.cn/
7. P. Lihua, Analysis of the influence of property management on the price of commercial properties in Tianhe District, Guangzhou based on Hedonic model. Commer. Hous. World **11**, 16–19 (2021)
8. L. Junke, Analysis of regional differences in commodity housing prices and their influencing factors in major cities in central China. Guangdong University of Foreign Studies (2021)
9. Q. Xijing, J. Zhang, Q. Jiaojiao, Z. Liang, Analysis and countermeasures for the unbalanced development of real estate market in Liaoning Province. J. Northeast. Univ. (Natural Science Edition) (05), 731–735 (2013)

Chapter 16
Research on Fine Decision-Making Management of Budget Performance in Universities Boosted by the Integration of Industry and Finance

Guangmin Hao, Yizhong Gong, and Mengxin Shang

Abstract The management focus of colleges and universities has been on educational activities, and the lack of attention to financial budget management, therefore, colleges and universities should strengthen the cooperation between business and financial departments, through the implementation of fine decision-making management to improve the accuracy of the budget, for performance management to enhance power. This paper expounds the importance of budget performance management in colleges and universities and analyzes the changes of budget performance management in colleges and universities driven by the integration of industry and finance. It also puts forward the countermeasures of budget performance fine decision management from the aspects of timely changing consciousness, transforming organizational structure of colleges and universities, perfecting organizational system of budget performance fine decision management, constructing fine decision management model, strengthening information construction and so on.

Keywords Integration of industry and finance · Budget performance · Fine decision management

If universities want to develop, they must pay great attention to financial management and reform financial management according to their actual situation. From the current financial management status of colleges and universities, there are still some shortcomings in the financial budget work, which needs to be adjusted and improved under the guidance of the concept of the integration of industry and finance, and through the implementation of the budget performance fine decision-making management mode to improve the level of financial management, to promote the steady development of colleges and universities.

G. Hao (✉) · Y. Gong · M. Shang
Haojing College, Shaanxi University of Science and Technology, Xi'an, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_16

16.1 The Importance of Budget Performance Management in Colleges and Universities

The so-called budget performance management is actually to carry out reasonable planning and allocation of budget funds, so that budget funds can be reasonably allocated and budget results can be achieved. Budget performance management plays a very important role in the whole performance management, among which budget results are the most important link. Generally speaking, budget performance is a new model of budget management. The financial department of colleges and universities adopts the budget performance management mode when carrying out the financial management work, which can comprehensively improve the budget management level of the financial department, and make the budget funds of colleges and universities more reasonable, standardized and maximize the benefits in the use process. In addition, the implementation of budget performance management in colleges and universities is also conducive to their own reform, so that colleges and universities can obtain strong competitive strength in the increasingly fierce competitive environment and enhance their sustainable development in the future [1]. The education cause of our country has been in the process of reform and development, all the reforms must involve a large number of funds expenditure. At present, there are many problems in universities such as unreasonable allocation of resources and the low utilization rate of funds, like the use of funds caused unnecessary waste, but under the budget performance management, we can effectively solve such problems, improve the maximum utilization rate of funds and make full use of its resources. In order to train more quality personnel and provide services.

16.2 Changes of Budget Performance Management in Colleges and Universities Driven by the Integration of Industry and Finance

16.2.1 Integration of Business and Finance to Realize Optimal Allocation of Resources

The financial integration of colleges and universities into the industry is to integrate the activities of business departments and financial departments together, so that financial personnel participate in various business activities, analyze the relevant financial information, and manage the business work, and then make the right decision after analysis. In this process, it is necessary to ensure the effective transmission and sharing of various data. Enable all departments to enhance the implementation of work in close communication process [2]. The promotion and application of the industry-finance integration model not only contributes to the integrity and authenticity of data, but also helps to supervise and manage various business activities, so as to timely grasp the information of the financial operation of colleges and universities, capital budget, expenses, personnel performance appraisal results and other information, timely discover the problems in related links, and make appropriate adjustments. To ensure the rationality of budget performance management, so as to ensure that universities can achieve maximum economic benefits in the process of carrying out work.

16.2.2 Coordinated Budget and Performance Management Helps Colleges and Universities Develop Connotatively

For colleges and universities, although financial budget work and performance management work are two different work, but there is a corresponding relationship between them. Colleges and universities realize the fine decision-making management of budget performance through the integration of industry and finance. On the one hand, it can realize the coordinated development between departments, on the other hand, it can ensure the more authentic and accurate performance evaluation. Ensure that the performance assessment indicators can meet the development needs of colleges and universities, and promote the realization of conformal development of colleges and universities on the basis of reducing the financial risks of colleges and universities (Fig. 16.1).

16.3 Ease of Use

Budget decision management is a common and very complicated problem in colleges and universities. The relaxation of budget execution affects the efficiency of using financial funds. In recent years, the Ministry of Finance and the Ministry of Education

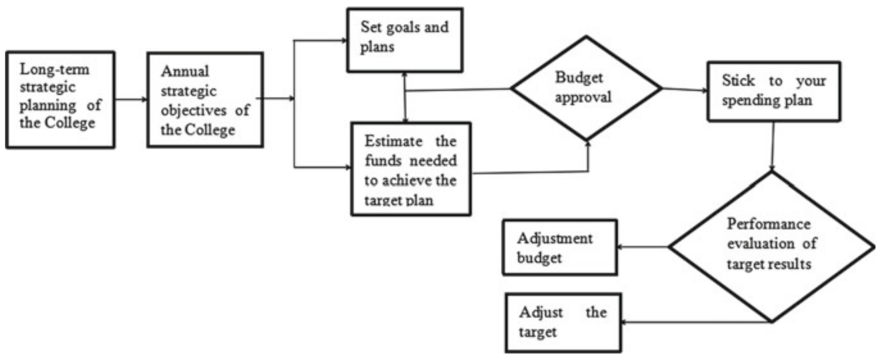


Fig. 16.1 Descriptive statistics

has strengthened the management of the budget implementation schedule of colleges and universities by issuing a series of measures and regularly reporting the budget implementation schedule.

16.3.1 Sample Selection and Data Sources

In this paper, 75 central universities from 2018 to 2022 are selected as research samples. The data are derived from the Announcement of Statistics on the Implementation of National Education Funds 2018–2022 by the Ministry of Education and the Ministry of Finance (www.cee.edu.cn), the Collection of Basic Statistical Data of Universities Directly under the Ministry of Education (2018–2022) and the official websites of universities. Among them, a small amount of data is artificially processed; Except for In (whether it is in Beijing) and First985 (whether it is in the first batch of 985), the statistics of all variables were processed using logarithms.

16.3.2 Research Model and Variable Description

Based on the agency theory and contingency theory, Pan Fei and Cheng Ming took the 2018–2022 budget data of Chinese listed companies as samples and found that organization size is one of the important variables to explain the relaxation of budget execution. Based on the aforementioned literature, this paper assumes that budget relaxation is related to organization size and budget emphasis, and establishes the following model:

$$Slack = \alpha + \beta i Xi + \varepsilon i = 1, 2, \ldots 7 \tag{16.1}$$

Dependent variable Slack is the degree of budget execution slack of universities. The higher the Slack value, the more slack the budget execution. As for the measurement of budget execution slack variables in colleges and universities, most of the existing studies have adopted questionnaire method or experimental method, so there are few measurement models for reference. According to the essence of budget relaxation, budget relaxation should be a comparison between budget implementation and budget. In this paper, budget relaxation is quantified by comparing the difference between actual expenditure in December and the average monthly expenditure of the previous 11 months with the average monthly expenditure of the previous November, namely: Slack implementation of budget expenditure = (Actual expenditure in December − average monthly expenditure in the previous 11 months)/ average monthly expenditure in the previous 11 months.

Explanatory variables in the model include: Student represents the number of students, which is calculated according to the number of ordinary undergraduate students in each school in 2018–2022; Staff represents the number of staff. Financial

Revenue is the educational appropriation revenue of each year; Area is the area of school buildings in each year; Equipment refers to the teaching and scientific research equipment of more than 400,000 yuan per year; In indicates whether it is a university in Beijing, is 1; otherwise, it is zero; First985 represents whether the first group of "985" institutions is 1, otherwise zero. The sample universities are independent of each other, and the model error obeys normal distribution.

16.3.3 Regression and Result Analysis Equations

Before the regression test, we first conducted descriptive statistics on the main variables involved in the model (see Table 16.1). The statistical results show that: ① there are differences in the scale of universities, especially in the amount of teaching and research Equipment (Equipment) above 400,000 yuan. ② The mean values of "In" and "First985" were 0.32 and 0.3867, respectively, indicating that universities in the selected sample accounted for 32% and the first group of "985" universities accounted for 38.67%. ③ The maximum and minimum values of Slack are 4.2108 and −1.1735 respectively, indicating that there is a large difference in the degree of deviation of budget execution slack among universities, some universities have poor balance of budget execution progress, and budget execution slack is prevalent in universities 85.

Based on the statistical data of 75 central colleges and universities from 2018 to 2022, this paper mainly studies the relationship between some characteristics of colleges and universities and the degree of slack in budget decision implementation. Through the above empirical analysis, it is found that: ① Slack in budget implementation is common in colleges and universities, and the balance of budget implementation schedule is poor. ② The relaxation of budget execution in colleges and universities is closely related to the number of students, the number of faculty

Table 16.1 Descriptive statistics

Variable	Observed number	Mean value	Median	Maximum value	Minimum value	Standard deviation
Student	229	9.6297	9.7067	10.6778	7.3038	0.6542
Staff	229	7.9369	8.0074	9.2243	5.9108	0.6313
Financial Revenue	229	11.4399	11.4351	12.6550	9.8916	0.5984
Area	229	13.7535	13.8564	15.0898	11.7777	0.6910
Asset	229	12.5010	12.5540	14.0701	10.9043	0.6686
Equipment	229	4.4236	5.0106	6.9985	0.0000	1.9436
In	229	0.3200	0.0000	1.0000	0.0000	0.4675
First985	229	0.3867	0.0000	1.0000	0.0000	0.4881
Slack	229	−0.0182	−0.2189	4.2108	−1.1735	0.7720

and staff, the area of school buildings, the amount of fixed assets and whether they are colleges and universities in Beijing, but has no significant correlation with the number of teaching and research equipment above 400,000 yuan, the number of educational funds and whether they are among the first group of "985" colleges and universities. ③ The relaxation of budget implementation in colleges and universities is significantly positively correlated with the number of students and staff, and significantly negatively correlated with the area of school buildings and the amount of fixed assets. It can be seen that the argument that "budget relaxation is positively correlated with organization size" in the existing literature has not been fully verified in colleges and universities. ④ Universities in Beijing have more slack budget execution than those outside Beijing. It can be seen that there is serious information asymmetry in colleges and universities in Beijing. The budget emphasizes that the management and control function in budget execution needs to be strengthened.

16.4 The Integration of Industry and Finance to Boost the Budget Performance of Colleges and Universities Refined Decision-Making Management Countermeasures

16.4.1 Timely Change of Consciousness

The most critical step for colleges and universities to carry out the refined decision-making management of budget performance under the integration of industry and finance is to change the backward concept and correctly understand that the integration of industry and finance is the current inevitable development trend. Therefore, it is necessary for financial personnel to establish the awareness of the integration of industry and finance in time and implement the refined decision-making management of budget performance [3]. At the same time, financial personnel should be engaged in post-supervision role positioning to the role of supervision and management before, during and after, strive to participate in the whole process of university budget performance work, constantly strengthen their overall awareness and macro awareness, through comprehensive consideration of the whole process of budget management, In order to give full play to their advantages in capital flow, capital approval, teacher attendance, teaching management and other aspects, they should not only have strong professional skills, but also have excellent business integration ability, so as to give advice for colleges and universities to achieve fine decision-making management of budget performance.

16.4.2 Transforming the Organizational Structure of Colleges and Universities

The integration of industry and finance is to realize the deep integration of business departments and financial departments. By implementing the integration of industry and finance, colleges and universities can realize the fine decision-making management of budget performance. Firstly, the internal organizational structure of colleges and universities should be properly adjusted, so that financial personnel can take the initiative to participate in the business department, analyze the business activities of the business department, and actively participate in other organizational activities of colleges and universities. Actively participate in the activities of the business operation team, and become the soul teacher to guide the business department to carry out the work. After fully understanding the information basis of promotion rewards and punishments, performance evaluation, teacher-student relationship, educational administration management, etc., I use my professional knowledge to give professional guidance to the work of the business department, and build a modern organizational structure. The original organizational structure can meet the needs of refined decision management after deep adjustment.

16.4.3 We Will Improve the Organization System for Fine-Grained Decision-Making and Management of Budget Performance

In the process of perfecting the fine decision-making management organization system of budget performance, colleges and universities must effectively apply the concept and model of the integration of industry and finance. First, it is necessary to prompt colleges and universities to change the management concept in time and improve the organizational system of budget performance management through continuous adjustment and optimization. In combination with the development trend, school-running direction and development scale of colleges and universities, a fine decision-making management committee for budget performance implementation is established, and reasonable Settings are made for supervisory organs, supporting institutions, fine decision-making management institutions and budget performance decision-making institutions, so as to form a multi-party joint management and multi-in-one organizational system [4]. At the same time, the staff responsible for budget performance management in the internal financial departments of colleges and universities also need to start from their own, establish the refined decision-making management thinking of budget performance, take the initiative to participate in various business activities, and improve the level of budget management through the use of budget performance management. Especially in the management of various expenses, it is more necessary to set the refined decision-making management process. To realize the fine decision-making management of the whole process from the formulation of budget performance to performance appraisal, expense reimbursement, capital expenditure, so as to strengthen the effective management of each link. Second, in the implementation of budget performance management, colleges and universities should constantly strengthen the effective connection and communication between business departments and budget performance management departments, comprehensively improve the precision level of budget performance, and ensure that business departments and budget performance management departments can count and measure performance indicators and financial budget indicators according to the financial resource plan and internal resource plan of colleges and universities. In this way, the financial department and business department can be deeply integrated to ensure the budget performance and finally realize the fine decision-making management.

16.4.4 Construct a Refined Decision-Making Management Model and Sort Out the Budget Performance Management Framework

First, for comprehensive budget performance management, budget performance refined decision management is its foundation, in which performance appraisal, performance evaluation, organizational objectives, resource allocation, business activities, etc. are the most basic elements of budget performance model. The construction of budget performance model under the background of the integration of industry and finance can cover the five elements and achieve dynamic planning. At the same time, it is helpful to realize the reasonable planning of objectives and the maximum optimal allocation of resources. In order to realize the fine decision management of budget performance, it is necessary to establish the budget performance management model, and only on this basis can we realize the fine management and comprehensive management of budget performance. Therefore, colleges and universities need to consider their own actual situation, combined with the theoretical framework of the integration of industry and finance, the internal business departments and financial departments of colleges and universities should participate in the preparation of the budget performance refined decision management model, so as to clarify the key points of financial links and business links, and improve the risk prevention ability by carrying out the budget performance refined decision management.

Secondly, financial departments of colleges and universities are encouraged to participate in the compilation of budget performance of major projects together with secondary colleges and functional departments. According to the four basic elements in the budget model, namely basic standard elements, business elements, resource elements and financial elements, the contingency requirements for implementing refined decision-making management in the budget performance of colleges and universities are followed. Try to build a budget performance model in line with the development trend of the internal finance of colleges and universities [5]. According to the requirements of the four basic elements in the budget model, the existing institutional structure, management and control organization structure, budget performance management system structure and so on are further optimized. Through a comprehensive review of the budget performance management framework of colleges and universities, to ensure that the internal business system of colleges and universities can achieve fine decision-making management [6].

Thirdly, in order to prevent the repeated occurrence of budget performance in the budget performance management model, more effective budget performance management methods should be incorporated into this model. At the same time, in the process of analyzing the expenditure status of budget performance, incremental budget law should be adopted to eliminate unreasonable expenditures in this way, so as to avoid the occurrence of repeated budget expenditures.

16.4.5 Establish a Sound Budget Performance Management and Evaluation Mechanism

University budget performance in the integration of business and finance to achieve fine decision-making management is undoubtedly put forward higher requirements [7]. Therefore, when colleges and universities develop performance management evaluation mechanism, they need to comprehensively consider key projects such as the reform of talent training mode, the construction of training bases and the reserve of technical talents in colleges and universities. In the process of building the performance management evaluation mechanism, colleges and universities need to keep close contact with each department, strictly in accordance with the combination of quantitative and qualitative and adhere to the scientific and reasonable principle, and formulate practical, scientific and reasonable evaluation system and budget indicators based on the development of various businesses in colleges and universities. After determining the budget index, it is also necessary to further analyze the completion of the budget index and the specific development of budget performance management according to the previous evaluation mechanism, so as to ensure that various business activities in colleges and universities can be deeply integrated with budget performance management and financial management [8]. Only in this way can the integration of industry and finance be implemented. To ensure that the university's established budget targets can be achieved to the maximum extent.

16.4.6 Improving IT Application

The implementation of budget performance fine decision-making management under the background of the integration of industry and finance requires university leaders to realize the importance of applying information technology to budget performance management [9]. Therefore, colleges and universities need to build a set of perfect accounting information system, in order to implement the integration of industry and finance and fine decision-making management to build a good information platform, through which information and data generated by various business activities in colleges and universities can be collected and analyzed, so as to provide real and effective data support for the implementation of budget performance management [10]. In addition, colleges and universities also need to improve the information module in this information platform, so that the financial management system can accommodate various performance budget indicators at the same time, through the application of information technology to budget performance management, can improve the intelligent level of budget performance management and information level [11]. In the process of management system construction, we should pay attention to the problems in the subject setting and project management, so that the subject and management at the same time into the elements of performance budget management, so as to collect accounting information and data more efficient, so as to help improve the precision level of budget performance management.

References

1. D. Fuping, Analysis of standardized and refined financial management of public institutions under comprehensive budget performance guidance [J]. Stand. China **16**, 129–132 (2022)
2. X. Hongying, L. Jingjing, Design of fine budget scheme based on unit budget performance management [J]. Financ. Superv. **16**, 46–51 (2022). ((in Chinese))
3. Q. Zhen, Research on financial performance appraisal to promote comprehensive budget fine decision management [J]. Mod. Bus. **12**, 169–171 (2022). doi: https://doi.org/10.14097/j.carolcarrollnki.5392/2022.12.043
4. D. Yuannan, Research on the fine decision management of budget performance in higher vocational colleges by the integration of industry and finance [J]. J. Hubei Open Vocat. Coll.E **35**(08), 34–35 (2022)
5. S. Jingjing, On the role of performance management in the fine decision management of university budget [J]. Adm. Assets Financ. **19**, 18–20 (2020)
6. D. Yuannan, Research on the transformation and development of budget performance management in higher vocational colleges promoted by the integration of industry and finance [J]. De Econ. **12**, 237–238 (2022)
7. W. Guoxiang, Research on the optimization of budget performance management in higher vocational education from the perspective of industry and finance integration [J]. Mech. Prof. Educ. **12**, 20–24 (2022). doi: https://doi.org/10.16309/j.carol carroll nki. ISSN 1007-1776.2022.12.005
8. S. He, Analysis of problems and countermeasures of comprehensive budget performance management in colleges and universities based on the integration of industry and finance [J]. Mod. Audit. Account. **11**, 34–36 (2022)

9. L. Xiaojuan, Z. Hua, L. Yilin, Industry rich fusion of college comprehensive budget performance management evaluation study [J]. J. Human Inst. Sci. Technol. LANCET **03**, 63–65 (2022). doi:https://doi.org/10.16336/j.carolcarrollnkicn43-1459/z.2022.03.017
10. D. Yuannan, Research on the fine management of budget performance in higher vocational colleges by the integration of industry and finance [J]. J. Hubei Open Vocat. Coll.E **35**(08), 34–35 (2022)
11. M. Yue, Y. Hongjing, Y. Danqi, Comprehensive budget performance management strategies of colleges and universities under the background of industry-finance integration [J]. Financ. Account. Learn. **32**, 61–62 (2021)

Chapter 17
Research on the Application of Activity-Based Costing in Strategic Decision of Cost Management in Communication Engineering Industry

Jiao Wang and Bo Ma

Abstract On the basis of sorting out the relevant theories of activity-based costing, this paper obtains the advantages and characteristics of activity-based costing through case analysis and empirical analysis, and then puts forward the corresponding suggestions for enterprise cost management.

Keywords Activity-based costing · Communication engineering industry · Cost management

17.1 Introduction

With the continuous transformation and development of China's economy to technology-intensive and high-tech industries, the proportion of direct costs in enterprise product costs is gradually reduced, but the proportion of product costs is gradually increased. Activity-based costing fills the limitation of traditional costing. On the one hand, activity-based costing uses the concept of activity to divide resources into product costs more scientifically and reasonably. On the other hand, activity-based costing can be used in commodity pricing, procurement forecasting analysis, customer profitability analysis, cost control and many other aspects.

Amid (2015) points out that activity-based costing is more accurate and fairer than traditional costing. It allocates customary consumption into costs according to module level, which has practical significance as a part of cost supervision [1].

Cidav Zuleyha (2020) proposed that activity-based costing can be used as a practical method to estimate resource use and cost of different implementation strategies and their components, which may reduce the burden of economic evaluation in implementation science [2]. Deng Yawen (2019) believes that ABC is the general trend of the development of cost accounting science, and it has important theoretical and

J. Wang (✉) · B. Ma
Haojing College of Shaanxi University of Science and Technology, Xi'an, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_17

practical significance to study and promote ABC in China [3]. Wang Biqiu (2022) believes that the application of actual cost method has strong practical significance for enterprise cost decision-making management [4].

Wu Lingjie and Huang Shengnan (2022) pointed out that ABC has obvious advantages in the logistics industry [5]. In a word, since the advent of ABC more than 60 years ago, the world's leading experts in the field of enterprise management and accounting have conducted a comprehensive analysis on the concept and application level of ABC, providing effective guidance for enterprises' practical activities.

Now, China's communication engineering industry has basically completed the system reform, has been gradually socialized. The competition between industries is becoming more and more intense, and the management level of communication engineering construction projects needs to be constantly improved. In short, it is to change from the traditional broad line management to the fine management. This paper takes Xi'an Rongting Network Technology Co., Ltd. as an example to explore the practical role of activity-based costing in the cost management of communication industry, in order to provide necessary suggestions for the healthy and sustainable development of the company. Compared with previous studies, the innovation point of this paper is to introduce the application of activity-based costing into different industries through actual case analysis, and finally optimize the cost management of enterprises.

17.2 Necessity and Feasibility Analysis of Activity-Based Costing Applied to Rong Ting Company

Xi'an Rong Ting Network Technology Co., LTD. (hereinafter referred to as "Rong Ting Company"), founded in 2014, is a small and micro enterprise in China, mainly serving the construction of some local communication engineering facilities and the production of communication equipment in Shaanxi Province. The company mainly provides products and technical services for the communications industry. Enterprises adhere to the principle of honesty and trustworthiness; business development is good. Rong Ting company mainly adopts the management mode of "production by sales", and takes sales as the central link of operation. The company has mapped out a detailed operational system from purchasing to manufacturing to selling goods. Its overall production and management process is shown in Fig. 17.1.

17.2.1 Necessity Analysis of Activity-Based Costing Applied by Rong Ting Company

The product cost structure of Rong Ting Company: In the product cost of Rong Ting Company, the production cost accounts for a large proportion, about 30% of the total

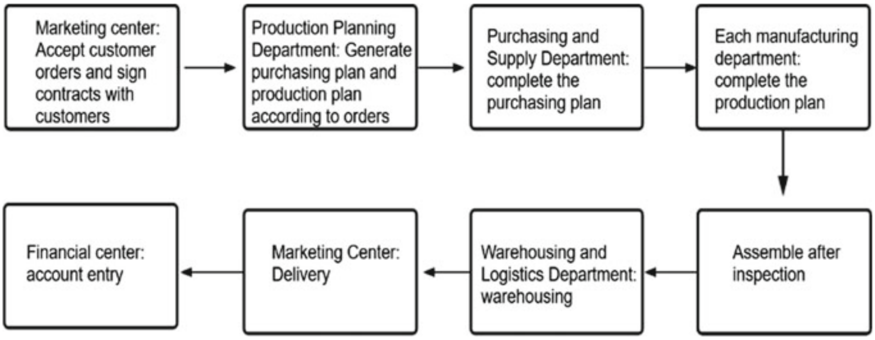


Fig. 17.1 Production and management process

cost. In the traditional cost method of calculation and distribution, the cost capital investment assets is larger, the gross profit rate is lower, the operating profit level in the second half is higher, the cost deviation is relatively large. This is probably due to the deviation of financial data collection or inaccurate calculation of cost. However, it can be seen from the side that the accuracy of cost information calculated by traditional cost method is not high when calculating cost. The calculation of Activity-based costing gives the accuracy of indirect cost and period cost, including the cost of non-productive links, so the product cost can be determined more reasonably. Standardized product cost is very important to the strategic decision of enterprise managers.

The range of products of Rong Ting Company is complex. Each product consumes a different proportion of resources. The traditional cost method only takes the working hour as the allocation standard, and cannot accurately measure the cost difference of different types and specifications, which may have a bad impact on the decision-making of managers. Making questionable management decisions in a competitive environment is very unfavorable to the company. Activity-based costing can effectively allocate resources required by different kinds of products and calculate the cost of each product effectively. Therefore, it is necessary for Rong Ting Company to introduce Activity-based costing.

17.2.2 Feasibility Analysis of Activity-Based Costing Applied by Rong Ting Company

In recent years, the communication industry has paid more and more attention to the influence of products, and vigorously advocated innovation for new technologies, improved technology research and development level, and strengthened the efficiency of internal control and management. Rong Ting company is a potential enterprise in the development of communication industry, in order to adapt to the industry environment, Rong Ting company needs to keep up with the pace of The Times.

In recent years of market competition, Rong Ting company clearly put forward the idea of production and processing quality management program, learning and training in application, and developing independent innovation in exploration. The implementation of Activity-based costing must be approved by the superior department, the collection of operational cost time, administrative logistics, technical team leader, frontline staff closely cooperate, actively give a variety of materials and data, and actively promote the smooth implementation of Activity-based costing in Rong Ting Company.

Rong Ting company to the information management method of independent innovation, according to the information management method, gradually refined operations. In order to implement Activity-based costing, the company has prepared the information software update in advance and made the relevant financial budget. After the information system is updated, Activity-based costing software will be applied to the newly added cost module. The informationization of software greatly reduces manual operation and makes operation more convenient.

17.3 Analysis of Cost Difference Between Traditional Cost System and Activity-Based Cost System in Order a of Rong Ting Company

Rong Ting Company takes the order accounting cost as the unit. The following takes an order from the manufacturing department as an example (hereinafter referred to as Order A) to compare the differences between the measurement system of traditional cost method and Activity-based costing. What is selected is the order of manufacturing department to produce two bare delivery cabinets, which will be finished and stored on June 18, 2019. Order A is calculated in the traditional costing method and Activity-based costing, as shown in Tables 17.1 and 17.2.

Table 17.1 Cost of order A under the traditional cost system. *Unit:* Ten thousand Yuan

Cost content	Amount (Yuan)
Direct material	136,757.2
Direct labor	20,307.1
Outsourcing cost	11,300
Manufacturing costs	64,412.27
Total cost	232,776.6

Table 17.2 Cost of order A under ABC cost system. *Unit:* Ten thousand Yuan

Job classification	Amount (Yuan)
Direct material	136,757.24
Direct labor	20,307.1
Outsourcing expenses	11,300
Production preparation work	1084.57
Production and processing operations	19,371.84
Equipment maintenance work	435.2
Quality inspection work	258.92
Warehouse logistics operations	569.53
Procurement operations	389.57
Marketing assignment	19,678.39
Total cost	210,151.46

17.3.1 Form Difference

Under the traditional costing system, the order cost consists of raw materials, outsourced processing fees, direct labor and manufacturing costs. All indirect costs recorded in the purchase order cost are recorded in the product cost, and the production department and production assistance department cannot separate the purchase order cost.

Under the ABC costing system, the total indirect cost caused by the order will be reflected in seven operation items. It can clearly reflect the cost of each department on this order.

17.3.2 B. Data Difference

Under the two accounting methods, the total cost data is different, as shown in Table 17.3.

As can be seen from Table 17.3, the traditional cost method overestimates the cost of the optical AC cabinet. The total overestimated cost is 22,625.1 yuan, with an overestimation rate of 9.7%. There are two factors contributing to the difference:

Table 17.3 Detailed cost of each operation of the Procurement Department. *Unit:* Ten thousand Yuan

	Cost of order A
Traditional cost method	232,776.6
Activity-based costing	210,151.5
Difference amount	−22,625.1
Variance rate	−9.70%

- The original costing system did not include most of the expenses of purchasing department and business department into product cost. Among them, the expenses of the purchasing department are included in the period expenses, and the expenses of the business department are included in the operating expenses.
- The product cost allocation of the original costing system is not quite standard. Some financial statements are calculated after adjustment, but ABC costing method is calculated according to the original cost. When allocating product cost, Activity-based costing uses several cost allocation drivers to carry out cost allocation of cost database data, establishes the correlation between cost allocation and commodity, and makes product cost more accurate after allocation. This has a great impact on the company's commodity pricing, sales work plan formulation, the company's long-term development trend.

17.4 Suggestions Put Forward by Rong Ting Company Using Activity-Based Costing

17.4.1 Improve Data Information and Reasonably Choose Operation Motivation

In activity-based costing system, it is the first task of an enterprise to collect and sort out resource drivers and operation drivers, and sort out and analyze data information. In addition, when ABC costing method is adopted, cost accounting should be combined and the principle of cost economic benefit should be followed. Therefore, the enterprise should standardize the entry way of original data, the use of electronic computers, network and other methods, not only to efficiently deal with the data information in the enterprise, but also to consider the cost needed in the implementation process.

17.4.2 Optimize the Ratio of Resource Allocation and Reasonably Connect Activity-Based Costing and Traditional Cost Method

The resource allocation of Rong Ting company is to allocate the same resources to different operations, and the resource allocation rate needs to be calculated. Therefore, when Rong Ting company applies Activity-based costing in the later period, it should make adjustments according to the actual situation. It should not only modify the proportion of resource allocation, but also pay attention to the working time organized at the present stage or adopt new countermeasures. At the present stage, due to the lack of a method that closely combines accounting cost measurement and testing standards with ABC cost measurement and testing standards, enterprises choose traditional cost method for external financial reports and Activity-based costing for internal cost management.

17.4.3 Strengthen Activity-Based Costing Concept and Focus on Professional Personnel Training

Activity-based costing is not only an excellent accounting tool, but also the basis of many enterprises' costs management method reform. In the process of implementing ABC costing method, it is not only necessary to reduce the exclusion between employees and the reform of ABC costing method, improve the basic theoretical knowledge reserve and specific operational skills of ABC costing method, but also to strengthen the training of mixed technical professionals, so as to make the relevant technical indicators more effective in the later stage.

17.5 Conclusion

According to the situation of Rong Ting company, the paper establishes the Activity-based costing framework suitable for communication enterprises. In the case application, it analyzes the defects of traditional cost method and the advantages of Activity-based costing, so as to better calculate the cost details of each product in the enterprise, which is more conducive to the development of the enterprise. However, Rong Ting Company does not blindly choose Activity-based costing, but based on the feasibility and necessity analysis of Activity-based costing, the activity cost management system scheme is designed.

This paper takes a specific communication company as an example, sorts out and applies the advantages and disadvantages of ABC costing method, and puts forward suggestions for the enterprise to plan the use of ABC costing method, which is a great breakthrough in related research fields. The disadvantage lies in the trial balance of operating costs of various departments in the study. Because unit records are not standardized, some data can only be amortized. At the same time, the selection of cost drivers, even with professional research, is highly subjective.

It still takes time for Activity-based costing to be promoted in Rong Ting Company. Activity-based costing has a lot of room for development from concept to practice. In the subsequent development, emphasis should be placed on the selection norms such as cost drivers. Activity-based costing is an excellent cost management method with broad application prospects. Besides communication manufacturing enterprises, there are also many researches on non-production manufacturing enterprises. Take bold steps in the service industry, for example.

References

1. A.E. Haroun, Maintenance cost estimation: Application of activity-based costing as a fair estimate method [J]. J. Qual. Maint. Eng. **21**(3), 258–270 (2015)
2. C. Zuleyha, M. David, P. Jeffrey, B. Rinad, C. Geoffrey, M. Steven, A pragmatic method for costing implementation strategies using time-driven activity-based costing. [J]. Implement. Sci. IS **15**(1), (2020)
3. B. Wang, Application and impact analysis of activity-based costing in enterprises [J]. Mod. Bus. **34**, 79–82 (2022)
4. L. Wu, S. Huang, Research on application of activity-based costing in Shun Feng express [J]. China Storage Transp. **06**, 170–171 (2022)
5. D. Yawen, L. Junjun, C. Yuzhen, Discussion on the difference between activity-based cost accounting and traditional historical cost accounting [J]. Bus. Inf. **16**, (2019)

Chapter 18
Construction of Low-Carbon Economic Model Based on Grey Clustering Algorithm and Big Data

Yongqiang Lin

Abstract Due to the influence of global climate, energy, economy and other factors, low-carbon economy has won the consensus of all countries, has risen to the height of national and regional development strategies. At present, China's low-carbon research is still in its infancy, so we should grasp its research status as a whole, so as to make a better in-depth study. Therefore, this paper further analyzes the low-carbon economy based on grey clustering algorithm and big data, and builds a model in this paper. In this paper, the low-carbon economy is analyzed based on the grey clustering algorithm and big data. Simulation results show that the algorithm in this paper has the highest accuracy rate, with the accuracy rate of 88.72%, followed by the GA (genetic algorithm) algorithm with the accuracy rate of 65.74%. Finally, the machine learning algorithm, the accuracy rate is 44.76%. Through the grey clustering algorithm, the concept of low carbon is established, the concept innovation is realized, the idea that "low carbon economy is an important way to implement scientific outlook on development" is earnestly implemented, and the concept, connotation and measures of low carbon economy and the importance and necessity of developing low carbon economy are widely publicized.

Keywords Grey clustering algorithm · Big data · Low-carbon economy

18.1 Introduction

Entering the industrial era, with the development of economy, the climate problem has become more and more serious. The substantial increase of population, the expansion of people's endless desire, the unrestrained production and lifestyle, and the increasingly serious carbon dioxide emissions have intensified the destruction of the ozone layer, resulting in an unprecedented crisis. Extreme weather occurs frequently

Y. Lin (✉)
School of EconomicsSouthwest University of Political Science & Law, Chongqing, China
e-mail: linyongqiang@swupl.edu.cn

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_18

all over the world, and natural disasters are intensifying. The human survival environment and life safety and health problems have been fatally threatened. Due to the influence of global climate, energy, economy and other factors, low-carbon economy has gained national consensus and has risen to the height of national and regional development strategies, which will lead to changes in the world's production mode, lifestyle, values and national rights and interests. At present, the issue of climate change has also become a new major constraint for sustainable development, a special background in the development process and a strategic issue that needs to be properly addressed [1, 2].

As a new research field, low-carbon research has not been statistically analyzed by scholars using knowledge maps. Moreover, China's low carbon research is still in its infancy, and it is urgent to grasp its research status as a whole to facilitate better in-depth research. Therefore, this paper further analyzes the low carbon economy based on gray clustering algorithm and big data, and constructs a model in this paper. The energy utilization of low-carbon economy will be diversified, efficient and clean. Realize a low-carbon economic model, diversify China's energy supply, and stop relying on fossil energy such as coal and oil. The optimization of energy structure reduces the potential risk of a single energy structure, and improves China's ability to cope with the energy crisis [3, 4]. To advocate a low-carbon economy, we should devote ourselves to make important contributions to the development of an environment-friendly society.

18.2 The Connotation and Far-Reaching Significance of Low-Carbon Economy

With the continuous growth of global population and economic scale, the global temperature rise caused by energy use has become a global problem, and the shortage of resources and environment has increasingly become the bottleneck of human sustainable development. A series of new concepts and policies have emerged as the times require, and we often hear about "low-carbon economy", "low-carbon lifestyle" and "low-carbon city". A series of legal, economic, administrative and technical means of low-carbon economic model will realize a large amount of energy conservation, optimization of energy structure, suppression of environmental pollution and improvement of adaptability in China, a substantial improvement of low-carbon scientific and technological development and research capability, an improvement of public awareness of climate change and a perfection of climate change management mechanism [5]. The key to developing low-carbon economy lies in the gradual decoupling of economic growth from carbon emissions caused by energy consumption. Since its industrial revolution, the main energy sources that the world economy depends on are coal, oil and natural gas. Up to now, these three fossil fuels still account for about 87% of the world's energy consumption structure.

After realizing the low-carbon economy and embarking on the road of low-carbon development, China will have more initiative in the international political arena and a wider range of activities on the stage of dealing with climate change. At the same time, China needs to take a more active part in the establishment of a new international emission order in the post-Kyoto era. Institutional innovation and technological innovation are the keys to low-carbon development. Our country should carry out the feasibility study of legislation, and when formulating and revising relevant laws and regulations, add relevant provisions to deal with climate change. The relevant provisions of climate impact assessment should be added to the technical fields of industrial planning, project audit and environmental assessment, and the ability of supervision and management should be strengthened to improve the adaptability and response ability of the government, enterprises and the public in environmental climate change, so as to gradually establish a legal system to deal with climate change [6, 7]. Therefore, with the realization of the low-carbon economy mode, the greenhouse gas emissions in China will gradually decrease, and the trend of exchanging energy and resource consumption for high-speed economic growth in China will change constantly, with the development quality as the primary goal of production. When the state adjusts its energy strategy and formulates its energy policy, it should increase the content of dealing with climate change, limit fossil energy consumption, and encourage energy conservation and clean energy use.

18.3 Necessity of Developing Big Data Low-Carbon Economy

At present, people should further master scientific theoretical knowledge and establish a sense of sustainable development. They must not pollute the environment in exchange for economic development, or even seek quick success and instant benefit. They should harm the interests of future generations with the immediate interests and development of the contemporary era. Development should become sustainable development. In the process of building a big data low-carbon economy, the environment will continue to be improved, which is conducive to the construction of a harmonious society and sustainable development [8]. Therefore, to develop a low-carbon economy, we need to change the economic development mode and reduce the resource cost and environmental cost of big data investment. In order to make the achievements of scientific and technological development better serve human beings or people, we can invest in natural resources, reasonably develop to restore and expand the resource stock, and use ecological principles to design new product processes and industrial processes to improve the efficiency of resource integration, Be targeted. The necessity of developing a low-carbon economy is mainly divided into three aspects, as shown in Fig. 18.1.

The high attention of the international community to the development of low carbon economy shows that human beings re-examine various economic and social

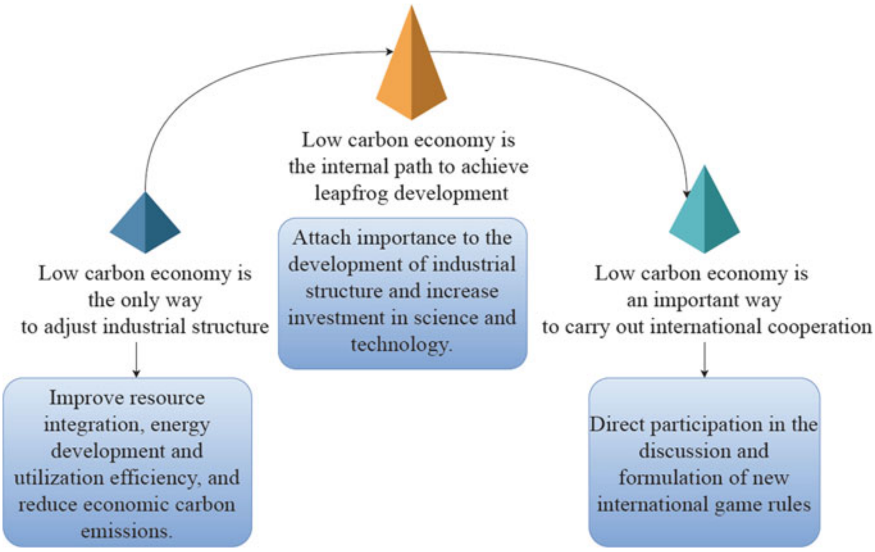


Fig. 18.1 Concept map of the necessity of developing a low carbon economy

activities from the root, which is conducive to controlling greenhouse gas emissions from the mechanism and system level, making the theory and model of low carbon economy a way to solve the problem of global climate change [9]. The low-carbon economic model under big data is a good medicine to reverse the extensive economic growth to intensive economic growth. The essence of low-carbon economy is to achieve efficient utilization of resources and low-carbon or carbon free development of energy while maintaining economic and social development [10]. Therefore, in production, efforts should be made to eliminate polluting processes, equipment and enterprises and improve the emission standards of various enterprises.

18.4 Research on Low-Carbon Economy Based on Grey Clustering Algorithm and Big Data

18.4.1 Construction of Low-Carbon Economic Model

As the largest developing country, China has both opportunities and challenges to develop a low-carbon economy. China's basic national condition is that there is a large population but little land, and the per capita resources are relatively insufficient. Establish low-carbon concept and realize concept innovation. Practically implement the idea that "low-carbon economy is an important way to implement

Scientific Outlook on Development", and widely publicize the concept, connotation, measures and the importance and necessity of developing low-carbon economy [11]. However, according to the microscopic analysis of provincial areas, different provinces have different low-carbon transformation performances. Therefore, all localities should formulate reasonable low-carbon transformation policies according to local conditions, so as to overcome their own shortcomings in low-carbon transformation, give full play to their comparative advantages in resource endowments and historical and geographical conditions, and realize smart growth. In urban planning, the concept of low carbon should be introduced into the design category, and the layout of urban functional areas should be rationally planned. Promote sustainable development through various incentive mechanisms, and formulate incentive mechanisms for the export of low-carbon technologies and products.

Institutional innovation and technological innovation are the keys to low-carbon development. Our country should carry out the feasibility study of legislation, and when formulating and revising relevant laws and regulations, add relevant provisions to deal with climate change. The relevant provisions of climate impact assessment should be added to the technical fields of industrial planning, project audit and environmental assessment, and the ability of supervision and management should be strengthened to improve the adaptability and response ability of the government, enterprises and the public in environmental climate change, so as to gradually establish a legal system to deal with climate change. In this paper, a grey clustering algorithm is proposed, and the basic method and theory of applying grey system can be adopted in the evaluation of grey clustering algorithm. On this basis, a low-carbon economic model is constructed. Firstly, the evaluation indexes of this model are divided into industrial pollution, resource utilization rate, noise pollution, environmental assessment and economic benefit. This model calculates the environmental efficiency score and environmental total factor productivity of low-carbon evaluation index to analyze four provinces. See Table 18.1.

The main idea of the low-carbon economy model is to eliminate the randomness and volatility as much as possible by accumulating the hash series in the time domain, and then obtain a curve close to the exponential function by fitting the envelope of

Table 18.1 Score of China's provincial environmental efficiency, super efficiency and group efficiency based on grey cluster estimation

Province	Environmental efficiency	Environmental super efficiency	Group membership	Environmental group efficiency
	Based on total output	Based on GDP		
Beijing	1	1	1.215	1
Tianjin	1	1	1.157	1
Shanghai	1	1	1.437	1
Zhejiang Province	1	0.756		1

the accumulated series obtained from the low-carbon economy. According to this exponential function, it can be extrapolated to the next cumulative sum. Finally, the original sequence prediction value of the low-carbon economy can be obtained through cumulative reduction. Set the initial sequence as:

$$\{x(k)\} = \{x(1), x(2) \ldots x(n)\} \tag{18.1}$$

where k represents the time of data sequence, the initial data is zero-time accumulated data, and the first-time accumulated sequence of the original data is defined as:

$$x(k) = \sum_{i=1}^{k} x(i) \tag{18.2}$$

n cumulative sequence is defined as:

$$x(k) = \sum_{i=1}^{k} x^{(n-1)}(i) \tag{18.3}$$

n represents the number of times of accumulation, and h represents the unknown parameters contained in the model.

The response function of the model can be obtained by discretizing the general solution of the first-order linear differential equation as follows:

$$x(k+1) = \left[x(1) - \frac{u}{a}\right] \tag{18.4}$$

Therefore, the prediction formula of the original data series is:

$$x(k) = (1-e)\left[x(1) - \frac{u}{a}\right]e \tag{18.5}$$

In the formula: a represents the development grey number, which reflects the development trend of series changes. But the amount of ash action, whose size reflects the changing relationship of data, is equivalent to the amount of action in the system.

Carry out a low-carbon economy in an all-round way, promote the transformation of development mode, the adjustment of economic structure and the upgrading of industrial level, and strive to build a resource-saving and environment-friendly society, so as to promote the sound and rapid development of China's economy and society.

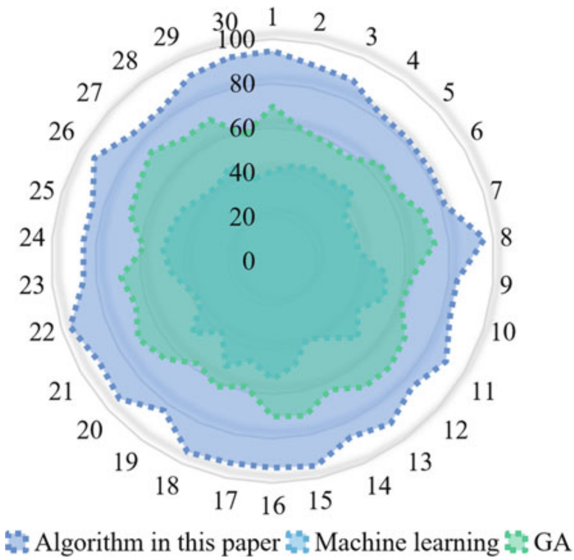


Fig. 18.2 Accuracy of low carbon economy assessment results

18.4.2 Simulation Data Analysis

In order to verify the effectiveness of this algorithm, this paper takes the low-carbon economy of big data as an example, and evaluates the low-carbon economy by using grey clustering algorithm, machine learning algorithm and GA. The results of accuracy and error rate are shown in Figs. 18.2 and 18.3.

From the experimental results in Fig. 18.2, we can see that among the three algorithms, the algorithm in this paper has the highest accuracy rate for low-carbon economy evaluation. The accuracy rate of the algorithm in this paper can be as high as 88.72%, and the accuracy rate of the GA algorithm is 65.74%. Finally, the machine learning algorithm has an accuracy of 44.76%. From the experimental results in Fig. 18.3, it can be found that the algorithm in this paper still performs best under the comparison of the error rates of the three algorithms, in which the error rate is the smallest, only 8.6%, followed by the error rate of GA, 22.5%. Finally, the error rate of machine learning algorithm is 29.2%.

It can be seen from Table 18.2 that research on low-carbon economy has absorbed more knowledge in environmental science, economics, management and other fields. However, for its own core journals, the proportion of citations is relatively low, indicating that research on low-carbon economy is still quite scattered.

Through the above analysis, it can be concluded that the innovation ability of low-carbon technology determines whether China can achieve low-carbon economic development, including the development of the substantial increase of population, the expansion of people’s endless desire, the unrestrained production and lifestyle, and the increasingly serious carbon dioxide emissions have intensified the destruction of the ozone layer, resulting in an unprecedented crisis. Extreme weather occurs

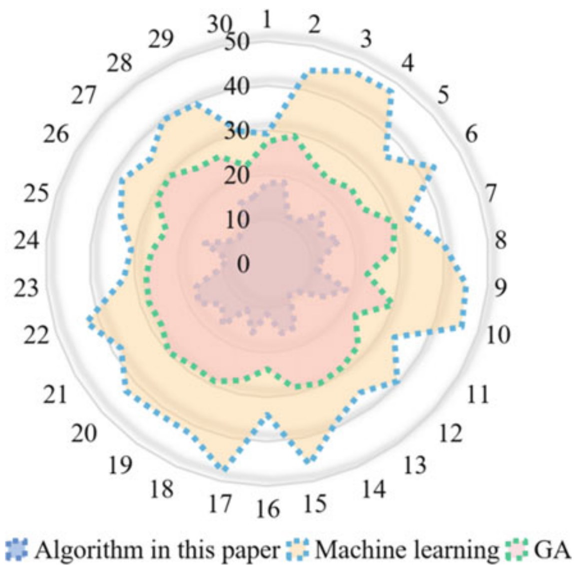


Fig. 18.3 Error rate of low-carbon economy evaluation results

Table 18.2 The first 10 cited literatures on low-carbon economy

Serial no.	Number of citations	Cited journals
1	115	China's population, resources and environment
2	62	Science press
3	59	Environmental protection
4	45	World environment

frequently all over the world, and natural disasters are intensifying industry, petrochemical industry, automobile and other sectors. Based on the grey clustering algorithm and big data, this paper studies the low-carbon economy, and the low-carbon economy shows a regular pattern of change. However, according to the microscopic analysis of provincial areas, different provinces have different low-carbon transformation performances. Therefore, all localities should formulate reasonable low-carbon transformation policies according to local conditions, so as to overcome their own shortcomings in low-carbon transformation, give full play to their comparative advantages in resource endowments and historical and geographical conditions, and realize smart growth. In urban planning, the concept of low carbon should be introduced into the design category, and the layout of urban functional areas should be rationally planned. Promote sustainable development through various incentive mechanisms, and formulate incentive mechanisms for the export of low-carbon technologies and products.

18.5 Conclusions

Research on low carbon economic and social development, regional economic development, industrial development, energy utilization, urban planning, low carbon technology, etc. of China's social and economic development level, economic structure and characteristics, and empirical research through the application of various quantitative models, provide a theoretical basis for the establishment of systems, policy formulation, mechanism and mode planning of China's low carbon economic development. This paper analyzes low-carbon economy based on grey clustering algorithm and big data, and simulation experiments show that the algorithm in this paper has the highest accuracy rate among them. The accuracy rate of the algorithm in this paper can reach 88.72%, and the accuracy rate of GA algorithm is 65.74%. Finally, the machine learning algorithm has an accuracy of 44.76%. Low carbon lifestyle is to avoid consuming goods and services that will lead to emissions as much as possible, so as to reduce the lifestyle generated by greenhouse gases, including clothing, diet, daily necessities, construction, transportation, behavior and other aspects, resist bad habits and luxury consumption, and guide the improvement of quality of life in the right direction. Therefore, it is necessary to implement effective supervision. In the process of implementing effective supervision based on the gray clustering algorithm, the government not only needs to give full play to the leading role of its supervision, but also needs to establish a practical self-discipline mechanism within the industry, and the whole society needs to pay more attention to the supervision of the CPA industry.

References

1. H. Yin, J. Zhao, X. Xi, et al., Evolution of regional low-carbon innovation systems with sustainable development: An empirical study with big-data. J. Clean. Prod. **209**(1), 1545–1563 (2019)
2. F. Li, R. Li, Z. Zhang et al., Big data analytics for flexible energy sharing: Accelerating a low-carbon future. IEEE Power Energ. Mag. **16**(3), 35–42 (2018)
3. L. Xin, Low carbon economic competitiveness statistic measure analysis under big data perspective. Basic Clin. Pharmacol. Toxicol. **28**(S1), 124–137 (2019)
4. Z. Zhang, J. Li, Big-data-driven low-carbon management—ScienceDirect. Big Data Min. Clim. Chang. **37**(19), 287–299 (2020)
5. D. Ma, J. Hu, F. Yao, Big data empowering low-carbon smart tourism study on low-carbon tourism O2O supply chain considering consumer behaviors and corporate altruistic preferences—ScienceDirect. Comput. Ind. Eng. **52**(20), 19–37 (2020)
6. A. Singh, S. Kumari, H. Malekpoor, et al., Big data cloud computing framework for low carbon supplier selection in the beef supply chain. J. Clean. Prod. **202**(20), 139–149 (2018)
7. P.H. Lyu, E. Ngai, P.Y. Wu, Scientific data-driven evaluation on academic articles of low-carbon economy. Energy Policy **125**(30), 358–367 (2019)
8. D. Zhu, Evaluation of insulation state based on improved grey clustering algorithm. Peak Data Sci. **28**(16), 28–49 (2017)

9. X.I.E. Naiming, S.U. Bentao, C.H.E.N. Nanlei, Construction mechanism of whitenization weight function and its application in grey clustering evaluation. Syst. Eng. Electron. Technol.: Engl. **30**(1) 11–22 (2019)
10. N. Xie, S.U. Bentao, N. Chen, Construction mechanism of whitenization weight function and its application in grey clustering evaluation. J. Syst. Eng. Electron. **30**(01), 125–135 (2019)
11. L.T. Ding, J.L. Fan, Y.X. Liu, Method of safety evaluation for system group based on grey clustering. Comput. Sci. **26**(10), 11–19 (2017)

Chapter 19
Optimal Trading Strategies Based on Time Series Analysis

Yifei Wang, Xiaofeng Zhao, Feng Zhang, Siyang Xie, and Zhihan Liu

Abstract Quantitative investment has been widely used in the field of foreign finance, especially the rapid development of international investment in the past decade. And financial activity is an important field of national economic activity. The frequency of financial transactions is an important indicator of the complexity of a country's economy, so it is of great significance to study the optimal investment strategy. This article uses daily price streams from past investments in gold, cash, and bitcoin to determine whether traders should buy, hold, or sell assets in their portfolios. The outlier data were processed by boxplot analysis, and the EM algorithm based on maximum likelihood estimation was used to visualize the case data. The ARIMA model and GARCH model are used to establish the portfolio optimization model and obtain the best portfolio scheme. The time series prediction model is used to conduct specific quantitative analysis on gold and Bitcoin and obtain the investment forecast of the initial $1000 in the future.

Keywords Time series analysis · EM algorithm · ARIMA model · GARCH model

19.1 Introduction

Trading strategy plays a very important role in financial asset trading. How to automatically select trading strategy in complex and dynamic financial markets is an important research direction of modern finance [1]. Market traders often buy and

These authors contributed equally to this work.

Y. Wang (✉) · X. Zhao · Z. Liu
Evergrande School of Management, Wuhan University of Science and Technology, Wuhan, China

F. Zhang
School of Finance, Jiangxi Normal University, Jiangxi, China

S. Xie
School of Information Science and Engineering, Wuhan University of Science and Technology, Wuhan, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_19

sell volatile assets with the aim of maximizing their total returns. There is usually a commission on every transaction. Two of those assets are gold and bitcoin. Investors usually use historical data for investment analysis [2]. According to the historical data, the prediction model of gold and bitcoin daily flow is established, and it is found that the daily fund flow is volatile whether it is gold or bitcoin.

In this paper, the outlier data are first processed by boxplot analysis, and then the data are visualized by EM algorithm based on maximum likelihood estimation, where the case data are sorted by date in a unified format. Then a stock is selected for qualitative analysis of relevant parameters, mainly analyzing the volatility trend and data distribution of gold and bitcoin. Visual trend analysis of gold bit volatility obtained by adding trend line.

Through ARIMA model and GARCH model, the portfolio optimization model is established to get the best portfolio scheme. Finally, based on the stock market price of USA from September 1, 2016 to September 1, 2021, the time series prediction model is used to conduct specific quantitative analysis and obtain the investment value of the initial $1000 in 5 years based on the best investment plan.

19.2 Model Preparation

19.2.1 Time Series Model Background

Time series analysis is a mature subject developed gradually on the basis of mathematical statistics, which is widely used in the economic field [3]. Time series, also known as dynamic series, refers to a numerical series that arranges the index values of a phenomenon in chronological order. Time series analysis can be roughly divided into three parts: describing the past, analyzing the law and predicting the future [7].

19.2.2 Visual Processing of Data

Because there are outliers in the case data and the data need to be cleaned, this paper mainly processed the outlier data through box graph analysis and completed the defective data. In order to fill the missing value data more accurately, this paper considered using the EM algorithm based on maximum likelihood estimation to fill the missing value.

The proposed algorithm can avoid the possible dragon lattice phenomenon of high-degree interpolation, maintain the smoothness and continuity of the data well, and reduce the loss of information quantity [8].

19.2.3 EM Algorithm Steps for Maximum Likelihood Estimation

Step 1: Missing value description, the analyst needs to take full account of the data, such as missing proportion, missing value distribution, missing value type (price type, usdpm), etc.

Step 2: Detect whether there is correlation between related variables. Missing value analysis is to use relevant variables to fill in missing values. For example, the padding of regression models in OLS estimation, and the correlation information between relevant variables (amos) in ML estimation.

Step 3: The correlation between variables can be linear or nonlinear. Then a scatter plot is used to describe the linear relationship between the variables. In general, regression model padding is recommended for linear relationships and EM for nonlinear methods [6].

Through the above data preprocessing steps, we model our portfolio using the preprocessed gold and bitcoin-related data.

19.2.4 The Qualitative Analysis

Firstly, a stock in the US market is selected for qualitative analysis of relevant parameters, mainly to analyze the volatility trend of gold and bitcoin and the distribution of data. By adding trend lines, the trend analysis of gold and Bitcoin volatility can be visualized. As shown in the Fig. 19.1.

19.3 ARIMA Bitcoin Prediction Model

(1) According to the case data, take Bitcoin as an example, model based on ARIMA model, and so on, each time series is modelled in this way. The time series diagram is as follows (Figs. 19.2 and 19.3).

(2) Descriptive statistics were performed for the daily yield rate of r (Table 19.1).

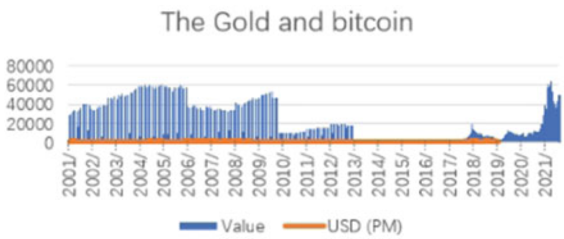


Fig. 19.1 Trend analysis diagram of the fluctuation visualization of gold and Bitcoin

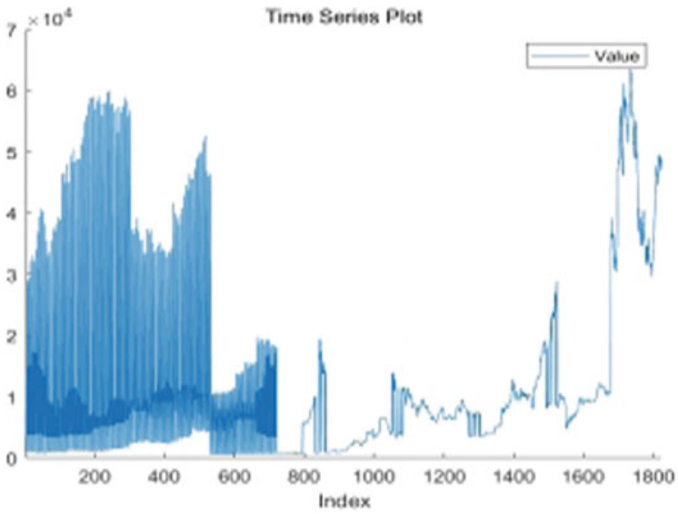


Fig. 19.2 Timing diagram of Bitcoin

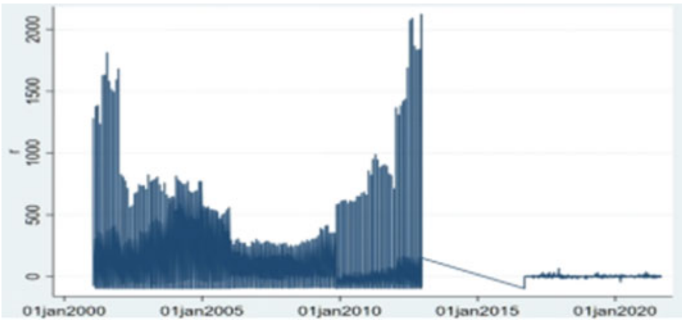


Fig. 19.3 Time series plot of the daily yield *r*

Table 19.1 Statistics of the daily yield *r*

Variable	Obs	Mean	Std. dev	Min	Max
r	1,825	72.76342	246.9307	−98.6593	2123.474

(3) ADF checkout. Test whether the yield sequence *r* is the root per unit (the original hypothesis: the unit root sequence, the alternative hypothesis: the smooth sequence) [9] (Table 19.2).

MacKinnon approximate *p*-value for $Z(t) = 0.0000$. A *p*-value of 0 means rejecting the null hypothesis, so we consider the *r* sequence stationary (Figs. 19.4 and 19.5).

Table 19.2 The ADF test table

	Test statistic	Dickey-Fuller-critical value		
		1%	5%	10%
$Z(t)$	−52.78	−3.43	−2.86	−2.57

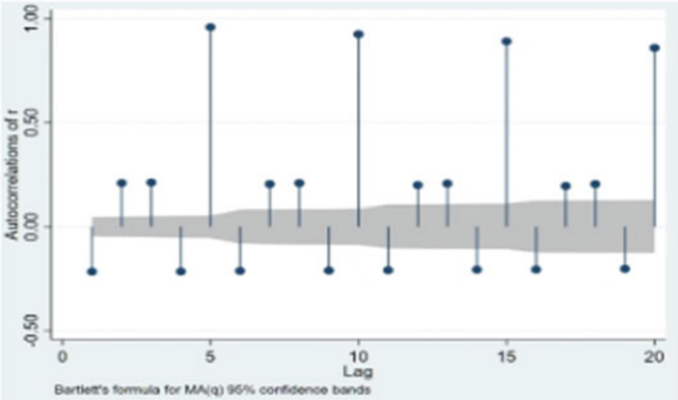


Fig. 19.4 ACF fig

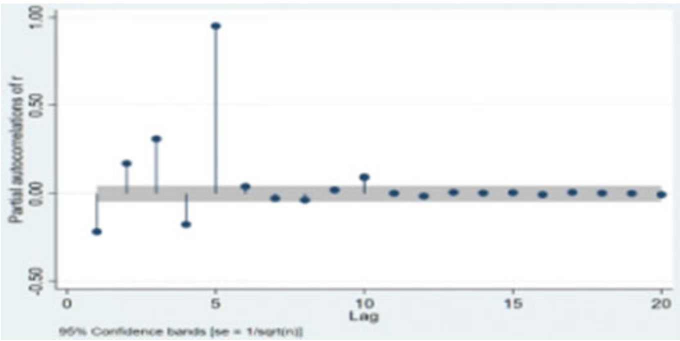


Fig. 19.5 The PACF fig

(4) Observe the ACF map (The figure below is left) and the PACF (Right of the figure below) graph, and judge the order of the AMRA model.
(5) Observe the ACF map (The figure below is left) and the PACF (Right of the figure below) graph, and judge the order of the AMRA model. The mathematical model is:

$$(1 - \phi_1 L - \cdots - \phi_6 L^6) y_t = c + (1 + \theta_1 L)\varepsilon_t \tag{19.1}$$

Table 19.3 AIC and BIC values for ARIMA mode

Model	AIC	BIC
ARIMA(1,0,6)	23,328.09	23,377.68
ARIMA(6,0,1)	20,337.78	20,387.36
ARIMA(6,0,1)	25,192.67	25,214.71
ARIMA(6,0,6) 0	20,325.33	20,402.46

(6) They were simulated separately with four alternative ARIMA models.
In preliminary judgment, four alternative ARIMA models were used to fit the results. Since both AIC and BIC are minor selection principles, the average of AIC and BIC values of ARIMA (6,0,1) models were the smallest, so the ARIMA (6,0,1) model was selected for fit (Table 19.3). Below we use this model for estimation to obtain the predictive value of the residuals and generate a histogram of the residue distribution as shown in Fig. 19.6 below:

(7) Q-test.Check whether the residuals are white noise sequence.
The residual sequence was subjected by white noise test to generate the square of the residues, and the Q test to generate the residual square sequence ressq (Table 19.4).
White noise test was performed on the residual squared sequence ressq (Table 19.5):

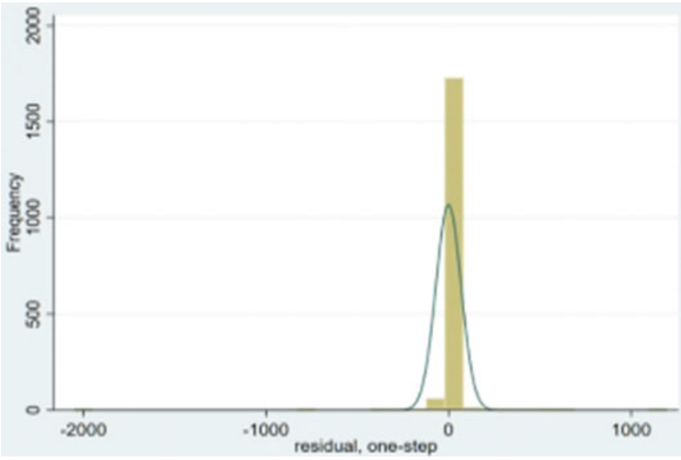


Fig. 19.6 Histogram of the residue distribution

Table 19.4 The White Noise Inspection Table

Portmanteau (Q) statistic	6.5230
Prob > chi2(12)	0.8875

Table 19.5 Portmanteau test for white noise

Portmanteau (Q) statistic	1.4778
Prob > chi2(12)	0.9999

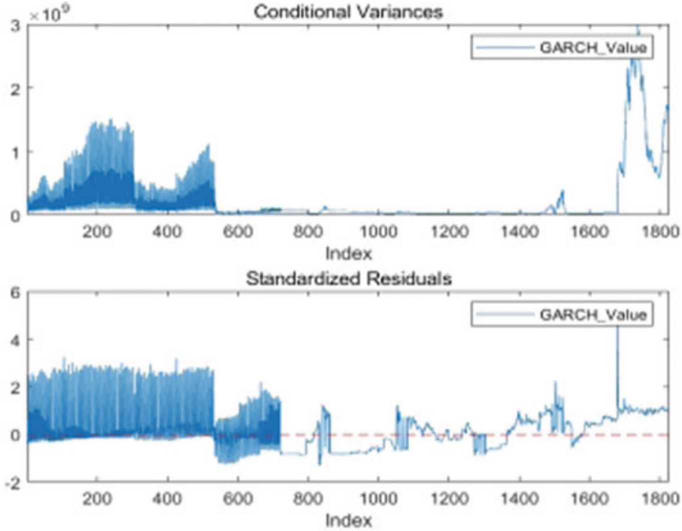


Fig. 19.7 Result of conditional variances and standard residual value for GARCH model

(8) LM test.Test for ARCH error. The residual squared terms were regressively fitted to their lag terms [10]. The output LM statistic is 1.490736; the calculated p-value is 0.91413639 (Figs. 19.7 and 19.8).

(9) Select appropriate models using the AIC and BIC minimum principles for estimation.

19.4 GARCH Model

19.4.1 Bitcoin Prediction Model GARCH (2,2)

Set up a set of equations as follows [5]:

$$
\begin{aligned}
y_t &= \mu + \varepsilon_t \\
\varepsilon_t &= \sigma_t z_t \\
(1 - \gamma_1 L - \gamma_2 L^2)\sigma_t^2 &= (\alpha_1 L + \alpha_2 L^2)\varepsilon_t^2
\end{aligned}
\tag{19.2}
$$

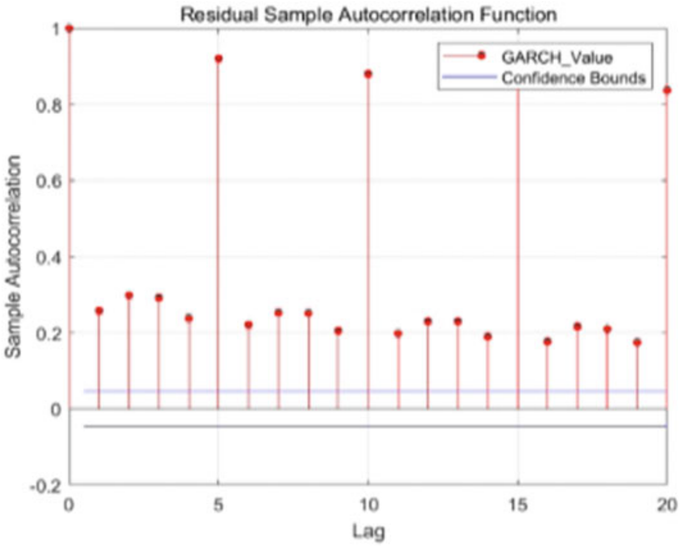


Fig. 19.8 Residual sample autocorrelation function

19.4.2 The ARMIA Gold Prediction Mode

$$y = 9485.9039/(1 + -13,051.9510 * \exp(-0.1255 * x)) \tag{19.3}$$

The above ARIMA model is used to forecast gold. Firstly, each time series is modeled based on stock market related data. Then, descriptive statistics of the daily output of r were carried out. Then, the ADF test was conducted to obtain the MacKinnon approximate p-value with $Z(t) = 0.0000$. A p-value of 0 indicates rejection of the null hypothesis, so the R-series is considered stationary.

By observing ACF and PACF images, a mathematical model was established:

$$(1 - \phi_1 L - \cdots - \phi_8 L^8)(1 - L)y_t = c + (1 + \theta_1 L + \theta_2 L^2 + \theta_3 L^3)\varepsilon_t \tag{19.4}$$

Four alternative ARIMA models were used for simulation (Table 19.6):

The average AIC and BIC values of the ARIMA (8,0,3) model are the smallest, so the ARIMA (8,0,3) model is suitable. Then Q test. Check if the residuals are white

Table 19.6 AIC and BIC values for ARIMA model for gold prediction mode

Model	AIC	BIC
ARIMA(3,0,8)	9298.079	9364.822
ARIMA(8,0,8)	9359.234	9425.977
ARIMA(3,0,3)	9384.29	9425.363
ARIMA(8,0,3)	9276.672	9369.086

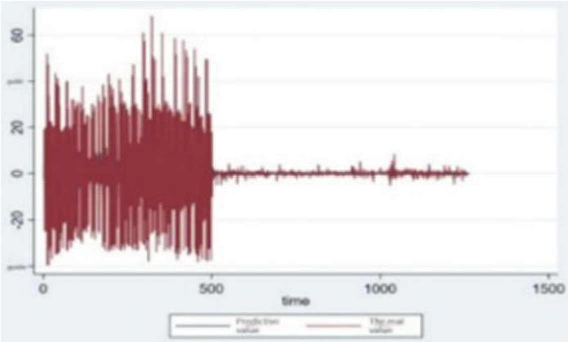


Fig. 19.9 Result using AIC model

noise sequences. Finally, the *p*-value of 7.409e-38 was obtained by LM test. The appropriate model was selected using the minimum principles of AIC and BIC, as shown below (Figs. 19.9 and 19.10).

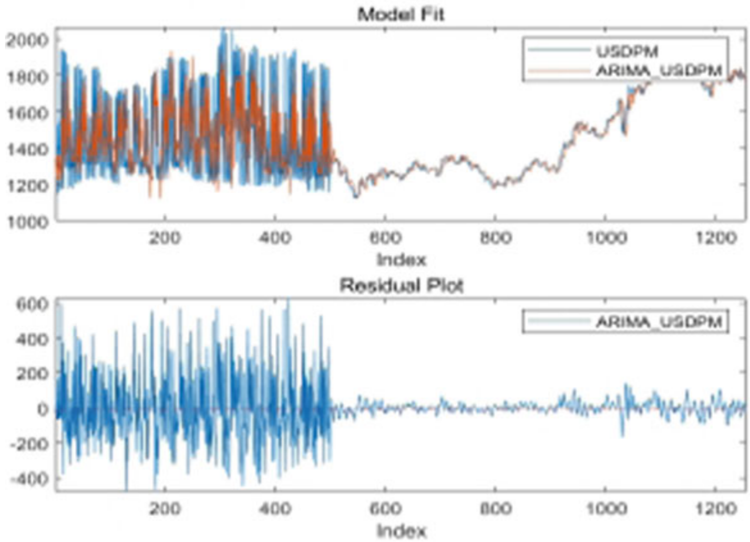


Fig. 19.10 Result using BIC model

19.5 Results Analysis of the Single-Target Investment Decision Model

Establish mathematical models of ARIMA and GARCH according to time series analysis with the following regression equations:

The model regression is ideal and the obtained data have strong reliability. Next, we present quantitative value results for the initial $1000 investment harvest on September 1, 2021. The data was calculated using MATLAB, and the final result was calculated by adding the gold and Bitcoin predictions, which was about $7,645.

19.6 Conclusions

With the continuous expansion of the stock market, more and more people become stock investors. Quantitative investment method has gradually received the favor and pursuit of investors. Under the condition of ensuring asset returns, how to combine stock investment so as to reduce the overall risk has also become a hot research [4].

Based on the daily price flows of gold and Bitcoin over the past five years, this paper builds prediction models to provide the best trading strategies for each day. In this paper, the outlier data are processed by box plot analysis, and the EM algorithm is used to fill in the missing values. Then, ARIMA model and GARCH model are established to study the stock return rate. In the Bitcoin prediction model, it is found that ARIMA (6,0,1) model has the best fitting effect by combining the autocorrelation coefficient, the number of bias relations and AIC criterion. Among the prediction models for gold, ARIMA (8,0,3) model has the best fitting effect.

Finally, based on time series analysis, mathematical models of ARIMA and GARCH were established, and the data were substituted to obtain the investment value of the initial $1000 investment income and the final harvest was $7645. The portfolio investment strategy based on ARIMA model and GARCH model in this paper can effectively reduce the risk of portfolio investment, which has positive significance for investors to optimize financial decisions.

References

1. X. Jie, Z. Yukun, X. Chunxiao, Research on financial transaction algorithm based on deep reinforcement learning [J]. Comput. Eng. Appl. **58**(07), 276–285 (2022)
2. L. Yang Zhuo, P.Z. Na, Application of EM algorithm in investment portfolio [J]. J. Tianjin Coll.E Commer. **03**, 45–47 (2007)
3. Z. Xin, Research and Application of time series analysis in economic investment [D]. Shenyang University of Technology, (2013)
4. N. Xinmi, Research on Shanghai Stock Index forecast and portfolio investment based on ARIMA and GARCH model [D]. Hunan University, (2020)
5. X. Feng, A GARCH model for stock price forecasting [J]. Stat. Decis. Mak. **18**, 107–109 (2006)

6. D. Qing, A new fast EM algorithm for adaptive estimation of Gaussian mixture model order[J]. J. Lanzhou Inst. Technol. **24**(1), 59–63 (2017)
7. Z. Yaojun, Time series analysis[J]. Shanxi Metall. **35**(6), 56–58 (2012)
8. S. Zilin, G. Lei, Z. Tianpeng, Comparison of cognitive diagnostic deficit data processing methods: Zero replacement, multiple interpolation and great likelihood estimation[J]. J. Psychol. **54**(4), 426–440 (2022), post-interpolation 1-post-interpolation 4
9. M. Daron, Modeling time series using ADF test[J]. Time Financ. **4**, 46–48 (2010)
10. H.-P. Li, J.-M. Guo, S.-C. Kang, LM test for heteroskedasticity of one-class linear regression models[J]. J. Tianshui Norm. Coll.E **32**(2), 8–9 (2012)

Chapter 20
Analysis and Prediction of E-Bank Suspicious Accounts Based on Ensemble Learning Under Imbalance Data

Song Jiang and Zhang Fengli

Abstract Due to its convenience, the bank transaction payment system has become the most common channel of money laundering transactions, and has become the forward and main battlefield of anti-money laundering transactions. The current anti-money laundering abnormal transaction identification rules of the domestic banking industry are mainly designed around the abnormal transaction standards issued by regulatory agencies. With the advancement and diversification of payment technology and electronic banking (E-Bank) business, various new abnormal transaction methods emerge in endlessly. The banking business is facing great challenges. In the massive transactions of commercial banks, the proportion of abnormal transactions is very small, and there is a serious sample imbalance problem. In order to improve the identification accuracy of abnormal transactions in massive E-Banks a mixed sampling method is proposed to solve the problem of centralized category of imbalance in the E-Bank transaction flow data set, while using the integrated learning method to build a commercial bank E-Bank account abnormal transaction identification model (SADA model). After data verification, the SADA model can effectively identify abnormal accounts in commercial bank E-Bank accounts.

Keywords Imbalanced samples · Correlation coefficient · Ensemble learning · Abnormal account identification · SADA model

S. Jiang (✉) · Z. Fengli
School of Information and Software Engineering, University of Electronic Science and Technology of China, Chengdu, China
e-mail: Songjiang_uestc@163.com

S. Jiang
Information Technology Center, Sichuan Rural Credit Union, Chengdu, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_20

20.1 Introduction

The threat of anti-money laundering to financial institutions and national security cannot be ignored. According to the statistics of the International Monetary Fund (IMF), the annual amount of illegal and abnormal transactions in the world accounts for about 2–5% of the world's GDP, and the annual amount is $100 billion keep growing. At the same time, only 1.1% of abnormal money laundering transactions are effectively identified. Although the abnormal transaction standards for money laundering proposed by regulatory agencies provide a unified and reliable reference for financial institutions to formulate abnormal transaction rules [1–3]. However, because E-Bank transactions are not limited by time and space, the investigation of abnormal transactions in E-Bank accounts lags behind. With the widespread application of technologies such as machine learning, NLP, and knowledge graphs in the field of financial risk control, researchers have conducted a lot of research on how to identify abnormal transactions in the massive transaction data of commercial banks. Mao et al. [4] compared the realization principles of artificial intelligence identification methods such as decision trees, neural networks, support vector machines, and clustering, and the application scenarios in the identification of suspicious anti-money laundering transactions,, and proposed for the construction of an intelligent anti-money laundering systems for domestic commercial banks. Liu et al. [5] systematically reviewed the application value and trend of new technologies represented by machine learning in the field of anti-money laundering in commercial banks. However, judging from the perspective of actual transaction data accumulated by commercial banks, the proportion of abnormal account data in all accounts of commercial banks is extremely small, and the sample is seriously imbalanced; at the same time, due to system construction of commercial banks, the inconsistent data standards between various systems lead to data quality problems. Problems such as poor performance affect the application effect of artificial intelligence or machine learning methods. With the online and complicated business of commercial banks, the flow of funds has become faster and more complicated, and the above problems have become more prominent. Therefore, it is necessary to improve the accuracy and efficiency of the identification of unusual transactions in commercial banks through innovative technical means.

20.2 Related Work

20.2.1 Suspicious Account Monitoring Model for E-Bank

The identification process of abnormal accounts in traditional commercial banks is as follows: when commercial banks make batches at the end of the day, the risk identification system automatically synchronizes transaction log data of each channel on that day, and extracts transaction elements according to transaction features, and

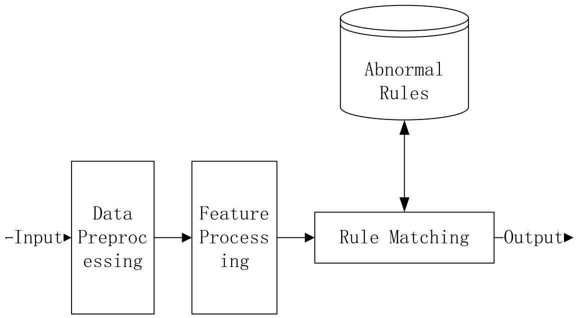


Fig. 20.1 Abnormal transaction identification model based on rule matching

compares them with the abnormal transaction detection feature library to determine whether the current transaction and account are abnormal. The rule-based detection model is shown in Fig. 20.1 [6].

This method judges abnormal transactions based on specific rules. It has a high identification rate for abnormal transactions that conform to the rule model settings. However, there are also problems with high rates of false positives and false negatives, resulting in economic losses or more serious consequences, and even the possibility of rule failure.

20.2.2 Methods for Processing Imbalanced Data

The class imbalance problem refers to the fact that the number of samples of a certain class in a data set is much larger than that of other classes, and it is divided into majority and minority classes according to the number of samples [7]. For example, in real E-Bank transaction data, the number of samples of normal transactions and accounts is far more than the number of samples for abnormal transactions and accounts. If the traditional classification model is directly applied to real transaction samples without any handling of the imbalance in classes, good classification results cannot be obtained. Currently, research on sample imbalance has been conducted at the data level, feature level, and algorithm level [8–10]. At the data level, resampling is mainly used to reduce the inclination of data. Commonly used methods include oversampling and under sampling. Currently, the Synthetic Minority Oversampling Technique (SMOTE), which is widely used, reduces the However, due to the lack of consideration of the distribution of samples, it is easy to overlap samples in specific areas, resulting in problems such as low quality of synthetic samples [11–13]. At the algorithm level, the main method is to introduce a penalty mechanism to compensate for the imbalanced problems in the algorithm [14, 15]. At the feature level, it is mainly to solve the problem of category imbalance in the data set by optimizing the feature selection method [16].

20.3 Building Method

20.3.1 Processing Imbalanced Sample Data

In order to improve the accuracy of the suspicious account identification model, a mixed sampling strategy is designed in this section based on the features of E-Bank transaction data. The core point of this mixed strategy is to use over-sampling for the minority class and under-sampling for the majority class. During the oversampling of the minority class, the distance between the majority class samples and the minority class samples in the minority class k-neighbors is calculated first, and the data is divided. Important samples are then selected for synthesis [17]. The specific steps are as follows:

Assume that the entire training set is D, where $C_i = \{c_1, c_2, \ldots, c_n\}$ and $P_i = \{p_1, p_2, \ldots, p_n\}$ are sets of minority and majority class samples, respectively, and there are three sets: noise, border, and safe.

(a) For each minority sample in the training set, first calculate the average distance between it andsimilar samples, as in (20.1)

$$dist(x_i\_C) = \frac{\sum_{i,j} dist(x_i, c_j)}{|C| - 1} \tag{20.1}$$

(b) Using the K-nearest neighbor algorithm, find its m neighbors and calculate the average distance between them and the majority class and the average distance between them and the minority class, using the Euclidean distance formula, are as shown in (20.2) and (20.3)

$$dist(mc) = \sqrt{\sum_{j=1}^{n} (x_i - c_i)^2} \tag{20.2}$$

$$dist(mp) = \sqrt{\sum_{j=1}^{n} (x_i - p_i)^2} \tag{20.3}$$

Dividing its m neighbors into three sets according to the following rules, as in (20.4)

$$partition(p_i)\begin{cases} dist(mc) \geq dist(mp), dist(mc) \geq dist(x_i\_C), p_i \in border \\ dist(mc) < dist(mp), p_i \in noise \\ dist(mc) > dist(mp), dist(mc) < dist(x_i\_C), p_i \in safe \end{cases} \tag{20.4}$$

Synthesize the samples in the border into new samples through the SMOTE algorithm, and combine them with the original dataset.

By comparing the average distance between the sample points and the same type of sample clusters and the distance between the center points of different types of clustering result, the abnormal sample points with a larger distribution are excluded.

In oversampling, according to the particularity of the research data set, oversampling is mainly carried out by clustering methods and business rules features. Through the above-mixed sampling strategy, the problem of sample imbalance can be solved to a certain extent [18].

20.3.2 Suspicious Account Detection Algorithm for E-Bank Based on Imbalanced Classification

(1) Selection Method of Base Classifiers

In ensemble learning, base classifiers are usually chosen from a pool of weak classifiers, such as LR, CART, SVM, and decision trees. When choosing specific base classifiers, it is necessary to ensure that they have both a certain level of "accuracy" and differences between them. In this study, the Pearson correlation coefficient is used to measure the correlation of the results of the base classifier to ensure that the selected base classifier has a large difference under the condition of having a high-performance evaluation index. The specific definition is as follows:

Given a dataset $D = \{(x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots, (x_m, y_m)\}$, for a binary classification task $y_i \in \{-1, +1\}$, the prediction results of classifiers A and B are listed in a table as shown in Table 20.1.

Where a represents the number of samples for which both h_i and h_j are predicted as a positive class; b, c, d have similar meanings, $a + b + c + d = m$. The measure of their correlation is calculated as in (20.5):

$$\rho_{\text{ij}} = \frac{ab - bc}{\sqrt{(a+b)(a+c)(c+b)(b+d)}} \tag{20.5}$$

The ρ_{ij} value range is $[-1, 1]$. If A and B are independent, the value is 0; if A and B are positively correlated, the value is positive, otherwise it is negative.

In terms of base classifier evaluation indexes, if the accuracy rate is used directly as the evaluation index, the classification model can simply classify all samples as positive samples, and a higher accuracy rate can be obtained, but it has no meaning

Table 20.1 Classification results table

	$h_i = +1$	$h_i = -1$
$h_j = +1$	a	b
$h_j = -1$	c	d

in practical applications. Area under receiver operating characteristic curve (AUC) is used as the area under the ROC curve of the base classifier evaluation index, which reflects the classification ability of the classifier to sort samples, and can objectively identify good classifiers even in imbalanced categories Therefore, combined with the features of the sample data, AUC is selected as the performance evaluation index of the base model for detecting suspicious accounts in E-Bank with imbalanced data, the following steps are followed:

(a) Determine m base classifiers $h_1, h_2, h_3 \ldots h_m$, where m is the number of base classifiers.
(b) Divide the sample into m parts, under the premise of controlling the sampling ratio, perform random under sampling on the majority class samples and minority class samples in the m training set, and then perform mixed sampling for each training subset. The validation set prediction results and corresponding performance metric values of the m base classifiers are $P_1, P_2, P_3 \ldots P_m$ $AUC_1, AUC_2, AUC_3 \ldots AUC_m$ respectively. Where $P_i = \{ p_{i1}, p_{i2}, p_{i3} \ldots p_{il} \}$ is the prediction result of a single classifier and m is the total number of samples in the test set, $i \in (1, m)$.
(c) *Sort* the performance indicators $AUC^i_{(1)}, AUC^j_{(2)}, AUC^k_{(3)}, \ldots, AUC^p_{(m)}$ from largest to smallest, resulting in a corresponding predicted result list of $P^i_{(1)}, P^j_{(2)}, P^k_{(3)}, \ldots, P^p_{(m)},\ i, j, k, p \in (1, l)$. Calculate the correlation coefficients between each $P^i_{(1)}$ and $P^j_{(2)}, P^k_{(3)} \ldots P^p_{(m)}$, respectively, resulting in $|\rho^j_{(2)}|, |\rho^k_{(3)}| \ldots |\rho^p_{(m)}|$.
(d) Firstly, add the base classifiers with AUC (area under the receiver operating characteristic curve) to the set G. Calculate the average AUC of the remaining m-1 base classifiers and add the base classifiers with AUC above the average to G.
(e) *Sort* the base classifiers in set G by the absolute values of the correlation coefficients, and select the base classifier with the minimum absolute value of the correlation coefficient (not equal to 1) and add it to the set G. Remove this base classifier from set G.
(f) Repeat step (5) until no base classifiers can be selected. The base classifiers in set G form a diverse set of base classifiers for the ensemble learning model.
(2) Class Imbalance Abnormal Transaction Detection Algorithm

Ensemble learning is a pattern mechanism for learning by combining multiple classifiers, It can absorb the advantages of each classifier and improve the classification performance. The ensemble learning model has high generalization ability and accuracy. This paper uses a variety of classifiers to form a heterogeneous ensemble learning model to identify abnormalities in E-Bank abnormal accounts. Commonly used integration techniques for transaction behavior include methods such as Bagging and Stacking [19]. In this study, the Bagging method is used to ensemble. In the ensemble learning methods, the key issue is to make the base classifiers good and diverse, that is, to improve the accuracy and diversity of the base classifiers Fig. 20.2.

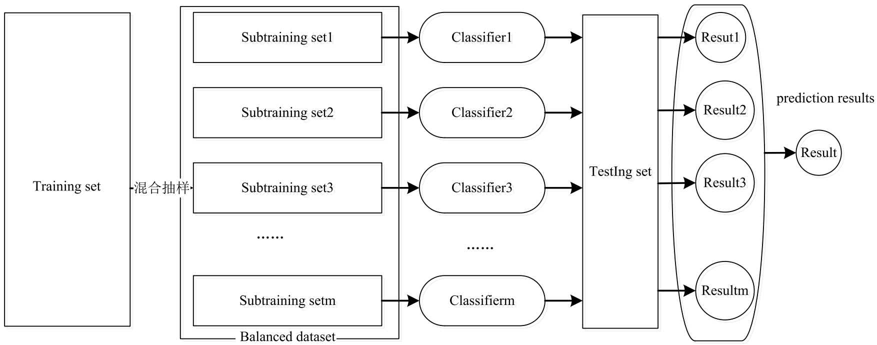


Fig. 20.2 Framework of Category Imbalance Abnormal Transaction Monitoring Algorithm

20.4 Experiment and Results Analysis

20.4.1 Data Source

The experimental data in this paper uses the anonymized transaction data provided by a commercial bank as the research object. The sample transaction data totals 1,151,475, of which there are 483 suspected abnormal transaction data, with an imbalanced ratio of 1:2384, which belongs to the severely imbalanced category. And the above-mentioned abnormal transactions are all abnormal transactions that cannot be identified based on the rule model. The sample labels are labeled with 0 and 1, where 0 represents normal transactions and 1 represents abnormal transactions.

20.4.2 Feature Engineering

Due to the features of diversity, complexity, specificity, and cross-regional nature of abnormal transactions in E-Bankaccounts, it is necessary to consider the identification ability and sample coverage of features when constructing features. The construction of feature engineering in this paper mainly adopts the method of building feature engineering based on business meaning, summarizes and refines multiple abnormal transaction cases from customer basic information, capital circulation, transaction mode, use age channels, regional factors, etc., and finally derives 115 features with clear business meanings of E-Bank suspicious account capital transactions. They can be divided into three categories: basic features, general features, and typical features. Basic features are used to distinguish normal accounts from abnormal transaction accounts, which only reflect fund changes, usually the most basic information such as account balance, transaction amount, and transaction times. This kind of feature has a large coverage and does not have the directionality of abnormal transaction types. General features have a clear directionality of abnormal transactions, but they can cover multiple abnormal transactions, such as whether the account has the features of "scattered transfers in and centralized transfers out" within a short period. Typical features have strong directionality and can be used to identify special abnormal transaction types, which are key features for improving model performance. Specifically, basic features include "the number of cash transactions in an account within 30 days", "abnormal amount of personal customer transfer transactions", "abnormal number of personal fund transactions", etc. Abnormal", etc., typical features include "the area where the counterparty of the transfer belongs" and so on. and typical features include "abnormal trade frequency between related accounts" and "abnormal transaction amount between related accounts". In the process of feature engineering, the relevant features of E-Bank abnormal transactions are selected and transformed based on the features of E-Bank abnormal transactions and the needs of model construction, and the feature selection method is used to select the optimal feature set to improve the model's performance and robustness.

20.4.3 Algorithm Evaluation Indicators

(3) *Evaluation Indicators Based on Confusion Matrix*

The results of a binary classification problem can be represented by the confusion matrix shown in Table 20.2.

TP: The model predicts that the transaction is abnormal and it is actually an abnormal transaction.

FP: The model predicts that the transaction is abnormal, but it is actually a normal transaction.

TN: The model predicts that the transaction is normal and it is actually a normal transaction.

FN: The model predicts that the transaction is normal, but it is actually an abnormal transaction.

Based on the confusion matrix, define the model evaluation indicators in the case of class imbalance in this paper: precision, recall, and $F1$ value. Their definitions are as shown in (20.6) and (20.7):

$$\text{precision} = \frac{\text{TP}}{\text{TP} + \text{FP}} \tag{20.6}$$

Table 20.2 Confusion matrix for predicting classification Actual result

Actual result	Predicting result	
	1	0
1	TP	FN
0	FP	TN

$$\text{recall} = \frac{TP}{TP + FN} \tag{20.7}$$

Precision refers to the proportion of truly abnormal transactions among all predicted abnormal transactions; recall refers to the proportion of correctly predicted abnormal transaction samples among all abnormal transaction samples.

(4) KS

The Kolmogorov–Smirnov (KS) statistic measures the maximum difference between the cumulative distribution of abnormal transactions and normal transactions samples[20]. The larger the difference between the two distributions, the larger the KS indicator, indicating a stronger distinguishability of the model.

(5) AUC

AUC reflects the ability of a classifier to sort samples, and is commonly used to reflect the performance of a model and can objectively identify better classifiers [21], even in the case of class imbalance.

20.4.4 Experiment Process and Analysis

(6) Data Processing and Imbalanced Sample.

Using the unbalanced data mixed sampling method constructed in Sect. 2.1, the sample imbalanced processing was carried out, and the results of the data before and after processing are shown in the following Table 20.3.

(7) Selection of Base Classifiers.

By using SVM, DT, GaussianNB, NB, MLP, KNN, and LR models as the base classifiers, the base classifiers were trained on the training set, with the results shown in Table 20.4.

According to the results in Table 20.4, SVM, DT, and GaussianNB were selected as the base classifiers of the ensemble learning model, based on the base classifier selection method in Sect. 2.2.3, and the ensemble learning model was constructed based on the Bagging method. To verify the effectiveness of the ensemble learning model builtin this paper on the E-Bank transaction dataset, XGBoost, RandomForest, GBM, and LightGBM models were run on the validation set as a comparison and their prediction results were used as a comparison.

Table 20.3 Comparison before and after mixed sampling treatment

	Normal	Abnormal	IR
Before processing	1,150,992	483	2383.01
After processing	22,410	11,205	2

Table 20.4 Results of base classifier training

Model	AUC
SVM	0.7541
Decision Tree	0.74
GaussianNB	0.7319
NaiveBayes	0.7153
MLP	0.7077
KNN	0.6658
LR	0.6367

Table 20.5 Results of different ensemble models

Model types	Precision	Recall	AUC	KS
XGBoost	0.0049	0.0741	0.8383	0.5776
RandomForest	0.0022	0.6296	0.8596	0.5801
GBM	0.0012	0.4117	0.857	0.596
LightGBM	0.4	0.0333	0.869	0.651
SADAModel	**0.2353**	**0.0741**	**0.9175**	**0.6532**

(8) Experimental Results and Analysis

To verify the effectiveness of the ensemble model builtin this paper, the four performance evaluation indicators of precision,, recall, AUC, and KSwere compared. The results are shown in the following Table 20.5.

As shown in Table 20.5, the overall effect of the model in this paper is better with the four evaluation indicators of precision, recall rate, AUC and KS. The highest AUC is 0.9175, which is 5.6% higher than the best single-model LightGBM, and the highest KS is 0.6532. On the other hand, compared with rule models that cannot predict abnormal transaction samples, the model built in this paper is more effective at capturing the mapping relationship between abnormal transaction features and labels and has been validated to be effective on the real data set.

20.5 Conclusion and Future Work

In conclusion, the E-Bank account abnormal transaction detection model (SADA model) established in this paper solves the problem of failure of the rule model to a certain extent. The experimental results on the real dataset show that the imbalanced sample processing method, and the SADA model based on ensemble learning proposed in this paper have obvious performance improvement compared with traditional rule models and single model methods, which proves the effectiveness and feasibility of this method in the current complex E-Bank account abnormal transaction detection field. In the next step, the research mainly focuses on the relationship features between customers and the risk of abnormal transaction on the relationship network, based on complex network technology, graph neural network modeling and other methods to conduct verification and follow-up research on more data sets.

References

1. J. Xiao, L. Xie, C. He, X. Jiang, Dynamic classifier ensemble model for customer classification with imbalanced class distribution. Expert. Syst. Appl. 3 (2011)
2. Z. Zhengyi, G. A. Satten, M. Caroline, H. Y. Juan. Constraining PERMANOVA and LDM to within-set comparisons by projection improves the efficiency of analyses of matched sets of microbiome data. Microbiome 1 (2021)
3. Li Xingqiu, Jiang Hongkai,Liu Shaowei,Zhang Jianjun,Xu Jun. A unified framework incorporating predictive generative denoising autoencoder and deep Coral network for rolling bearing fault diagnosis with unbalanced data [J] . Measurement . 2021
4. L. Jinglun, Y. Guoliang, G. Jianwen, H. Qifan, Z. Shaohui. Reducing false-positives in lung nodules detection using balanced Datasets&#13. Front. Public Health (2021)
5. L. Yueting. Imbalanced dataset classification algorithm based on NDSVM. J. Phys.: Conf. Ser. 1 (2021)
6. P. Hemalatha, G. Mary Amalanathan. FG-SMOTE: Fuzzy-based Gaussian synthetic minority oversampling with deep belief networks classifier for skewed class distribution. Int. J. Intell. Comput. Cybern. 2 (2021)
7. L. Kyungsu, K. J. Young, L. M. Hwan, C. ChangHyuk, H. J. Youn. Imbalanced loss-integrated deep-learning-based ultrasound image analysis for diagnosis of rotator-cuff tear. Sensors 6 (2021)
8. W. Jie, Li., De-yu, W. Su-ge, TSF feature selection method for imbalanced text sentiment classification. Comput. Sci. **43**(10), 206–210 (2016)
9. Li., Ke-wen, Y. Lei, L. Wen-ying, Lu., Liu, L. Hong-tai, Classification method of imbalanced data based on RSBoost. Comput. Sci. **42**(9), 249–252 (2015)
10. H. Xiao-sheng, Z. Run-Jing, Z. Yong. Two-tier clustering for mining imbalanced datasets. Comput. Sci. 40(11), 271–275 (2013)
11. R. Akbani, S. Kwek, N. Japkowicz. Applying support vector machines to imbalanced datasets. In: Proc of the 15th European Conference on Machine Learning. Pisa, Italy, (2004), pp. 39–50
12. Z. Dong-wen, X. Hua, S. Zeng-Cai, et a1. Chinese comments sentiment classification based on word2vecandSVM perf. ExpertSystems Appl. 42(4), 1857–1863 (2015)
13. N.V. Chawla, N. Japkowicz, A. Kotcz, Editorial: Special issue on learning from imbalanced data sets. SIGKDD Explor. Newsl. **6**(1), 1–6 (2004)
14. W. Su-ge, L. De-Yu, Z. Li-Dong, et al. Sample cutting method for in balanced text sentiment classification based on BRC. Knowl.-Based Syst. 37, 451–461 (2013)
15. H. Masnadi-Shirazi, N. Vasconcelos, Cost-sensitive boosting EJ~. IEEE Trans. Pattern Anal. Machine Intelli-Gence **33**(2), 294–309 (2010)
16. P. A. Domingos. Unified bias-variance decomposition. Proceedings of 17th International Conference on Machine Learning (2000), pp. 231–238
17. Z. H. Zhou. Ensemble methods: foundations and algorithms. Chapman and Hall/CRC (2012)
18. K. A. Spackman. Signal detection theory: valuable tools for evaluating inductive learning. Proceedings of the sixth international workshop on Machine learning. Morgan Kaufmann, 1989, pp. 160–163
19. T. Fawcett, An introduction to ROC analysis. Pattern Recogn. Lett. **27**(8), 861–874 (2006)

20. J. Benesty, J. Chen, Y. Huang et al., *Pearson correlation coefficient//Noise reduction in speech processing* (Springer, Berlin, Heidelberg, 2009), pp.1–4
21. E.W. Steyerberg, M.J.C. Eijkemans, J.D.F. Habbema, Stepwise selection in small data sets: a simulation study of bias in logistic regression analysis. J. Clin. Epidemiol. **52**(10), 935–942 (1999)
22. T. Chen, C. Guestrin, Xgboost: A scalable tree boosting system. In: Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining. ACM 785–794 (2016)

Chapter 21
Design and Research of Credit Bank System Based on Blockchain Oracle

Zhiyuan Wang, Gehao Lu, Yulian Gao, and Mingan Gao

Abstract At present, all kinds of credit banks in China mainly rely on credit bank management center. The centralized management mode of credit bank in the process of learning achievement certification and conversion will produce a series of problems, mainly as follows: Inefficient certification and transfer of learning outcomes; The certification quality of learning achievements is difficult to guarantee; The management mode of credit bank, which is characterized by fuzzy and centralizing the main body of credit bank identification, is not only unfavorable to the formation of high credibility certification results, but also hinders the credit transfer and system integration among different fields and institutions. To solve these problems, this paper constructs a credit bank system based on blockchain oracle. The system relies on Hyperledger Fabric platform, uses Go language to develop chain code, and designs user intelligent contract and oracle intelligent contract according to functional requirements. The user intelligent contract initiates a data request to the oracle intelligent contract, the external data source sends data to the oracle intelligent contract, and the oracle intelligent contract feeds back the data to the user intelligent contract. And then use the related API provided by Fabric-SDK-Go to realize the installation and instantiation of the chain code. The experimental results show that the blockchain oracle technology can not only ensure the degree of decentralization, but also enhance the credibility of data, ensure the security of data, reduce communication overhead and improve the security of data in the process of on-chain.

Keywords Blockchain · Hyperledger · Oracles · Credit bank · Smart contracts · Decentralization

---

Z. Wang · G. Lu (✉) · Y. Gao · M. Gao
School of Information Science and Engineering, Yunnan University, Kunming, China
e-mail: gma1072809689@live.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_21

21.1 Introduction

China's vocational education system belongs to a centralized model, which is characterized by high social commitment and low enterprise participation. Vocational education has always been a closed field, with monopoly, it is difficult for external resources to enter, even if it is cooperation, it also faces the problem of difficult to divide responsibility, power and benefit. Internal mechanism ossification is the difficulty of vocational education reform. Due to the lack of contact between vocational colleges and enterprises, there is no information "transmission" mechanism between enterprises 'needs and vocational colleges. It creates information asymmetry. At the same time, vocational schools are not flexible enough to change, and the demand-driven mechanism has lost its role. Inevitably lead to supply lag, inaccurate, ineffective supply and other problems. The centralized credit bank management mode is not only unfavorable to the formation of high credibility certification results, but also hinders the credit transfer and system integration between different fields and institutions [2]. Considering the great value and potential of blockchain prophecy technology for credit bank, in order to build a lifelong learning "overpass" covering all levels and types of education, different educational institutions can be combined to build a centerless credit bank through blockchain technology. As long as all educational institutions voluntarily participate, learning ach ievement certification and conversion can be carried out [3]. The "credit bank" based on blockchain oracle technology is based on automatic distribution technology, not to confirm the right by the center. Every node in the system has the opportunity to change business value. Thus, it can quickly respond to social needs. That is to say. Vocational schools, training institutions, and indus try organizations can be written into the blockchain as long as they can make effective and high-quality responses to needs, increasing the flexibility of the entire system. In this context, the core value created by the nodes of education and training institutions is different, that is to say, vocational colleges, training institutions, enterprise training departments, etc. create value in one or several businesses of the whole system, but not all values. This requires each institution subsystem to carry out value chain precipitation, that is, to locate the links that add value and appreciation to the business in the whole system. Only through high-level design can each subsystem distribute more high-value-added "credit coins" and enhance the value of services [4]. The oracle is used to solve the problem that the uploaded data may be tampered with when the smart contract specifies the data source, thus making up for the lack of network effect and scalability of the smart contract platform. Oracle is essentially a kind of data call and access middleware, which solves "yes or no" and "how much data" problems respectively, thus realizing the call of intelligent contract to external data. It can get data from the native chain, or it can get data from the chain through crawlers or trusted third-party organizations [5].

21.2 Related Work

Hyperledger Fabric is an open-source, enterprise-grade licensed distributed ledger technology (platform) designed for use in enterprise environments. With a highly modular and configurable architecture, Fabric provides innovation, diversity, and optimization for businesses across a wide range of industries, including banking, finance, insurance, healthcare, human resources, supply chain, and even digital music distribution. Fabric is the first distributed ledger platform that supports writing smart contracts in general-purpose programming languages such as Java, Go, and Node.js, independent of domain-specific languages. One of the most important differentiators of the platform is its support for pluggable consensus protocols, allowing the platform to be more effectively customized to suit specific business scenarios and trust models [6].

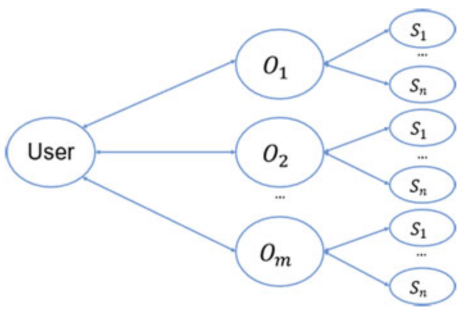
According to the classification of business organization forms, oracles can be centralized single oracle mechanisms (such as Oraclize)–centralized oracles, and also decentralized multiple prophetic mechanisms (such as Chainlink, DOS Network, etc.)–decentralized oracles. This system adopts the decentralized oracle chainlink, the decentralized oracle is jointly provided by multiple oracles to obtain data services, the use of erasure encoding technology to achieve answer redundancy, enhance the fault tolerance of the entire oracle system. When all the answers submitted by the oracle within the specified time have been summarized (the methods of aggregation include weighted average, median, or mode, depending on the data called), the summarized answers are fed back to the requester [7].

The relational model of the decentralized oracle chainlink is shown in Figs. 21.2–21.1, where S1, S2 to Sn, etc. represent the data source, O1, O2 to Om, etc. represent the prophets participating in providing services, n, m $> = 1$.

Schnorr aggregate signatures, sometimes called group signatures, are as follows:

There is a set of public keys involved in the signature, assuming N, after signing, you will get N signatures, and this N signatures can be added to finally get a signature. The verification of this signature means that N verifies all the signatures of the public key, in other words, aggregates multiple signatures into one signature [8].

Fig. 21.1 Chainlink relationship model



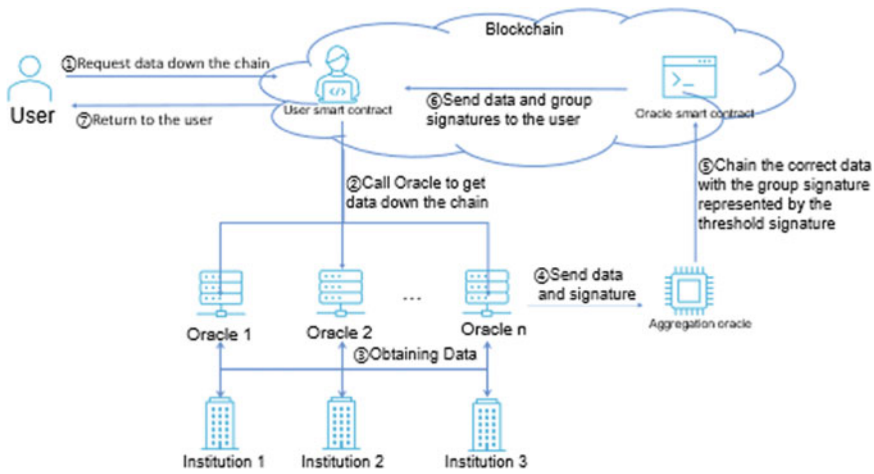


Fig. 21.2 Data transmission model

Symbol definition:

Private key: x_1, x_2.

Public key: $P_1 = x_1 * G, P_2 = x_2 * G$.

Random numbers: k_1, k_2, and $R_1 = k_1 * G, R_2 = k_2 * G$.

Group public key: $P = P_1 + P_2$.

Then there are:

The signatures of the private key sum are: $(R_1, s_1), (R_2, s_2)$.

Add the two signatures together to get the group signature: (R, s). where: $R = R_1 + R_2$, $s = s_1 + s_2$.

The group public key here is the value of N adding the public key, also known as the aggregation key. It should be noted that participants need to exchange public keys and R values with each other, then sign each other, and finally aggregate.

21.3 System Model

21.3.1 System Process Analysis

The whole process of this system can be divided into three stages: select identity login → transaction information on the chain → query transaction information. Among them, the transaction information on the chain includes the smart contract initiating a request to the user, and then sending the transaction information to the oracle smart contract, which then sends the data to the user smart contract. In the process of on-chain, the oracle adopts threshold signature technology, allowing other nodes to check whether the prophet providing the service has misbehaved and whether the transaction is reasonable, and at least more than half of the available nodes must implement signatures off-chain to implement the transaction. The biggest feature of Schnorr is that it can perform public key and signature aggregation (aggregate). Multiple signatures can be aggregated into a single signature, thus greatly saving the byte space of multi-signatures. This aggregation is not only the signature aggregation between different singers of the same input, but also the signature aggregation between different inputs [9].

21.3.2 System Architecture

1. *Operation Layer*: The in terms of operation layer, the decentralized oracle adds a multi-signature mechanism and an external adapter on the basis of the centralized oracle.

Decentralized oracles do not need the endorsement of trusted third-party institutions to prove their innocence, but they need to rely on a multi-signature mechanism to allow oracles that meet more than the minimum number of honest nodes to sign the corresponding nodes at the same time.

More importantly, the external API adapter setup allows the oracle to split the complex data call requirements into multiple subtasks, and participate multiple oracles in the service process in a cooperative manner. Similar to distributed storage, external adapters happen to be a distributed system, and the more nodes that require multi-step complex requests, the more predictors will be involved, so that the more people who serve the request, the faster the feedback will be obtained, and the shorter the time to complete the service [10].

2. *Operation Layer*:The decentralized oracle system adds a reputation contract and a summary contract on the basis of the centralized oracle system.

In terms of reputation contracts, because the decentralized oracle system is essentially a service network composed of multiple oracles, it is necessary to count the historical service of each oracle by calling the reputation contract, and deduct the reputation score and staked from the prophet who has improper behavior (such as free-riding to copy the hash value of the answer provided by other prophets, mirror attack, witch attack, etc.) [11].

In terms of aggregate contracts, since a decentralized oracle is a data service network with multiple oracles, in most cases, there are multiple oracles responding to the same service request at the same time within a specified time [12].

At this point, the oracle network summarizes the answers provided by all prophets by calling the summary contract by weighted average or median [13] (Fig. 21.3).

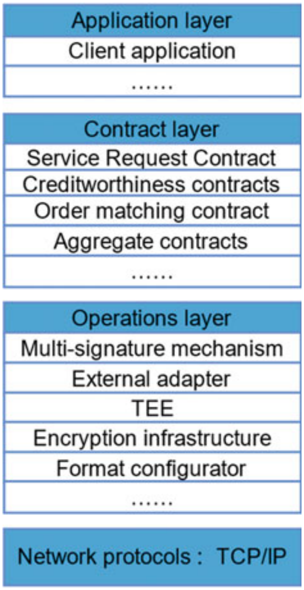


Fig. 21.3 Network architecture

21.4 System Testing and Analysis

21.4.1 Functional Testing

The test platform is ubuntu-20.04.4 pre-installed in the VMware Workstation Pro virtual machine, the virtual machine is 1 6G memory, hard disk 80G configuration, Hyperledger Fabric is version 2.2 The deployment method is deployed with a single machine and multiple (Figs. 21.4, 21.5, 21.6, 21.7, and 21.8).

21.4.2 Performance Testing

The throughput of a blockchain system reflects its performance, and this article uses TAPE to test the throughput of the system. The main function of this system is to load and query the results of the chain, so the throughput is tested according to the functions–CreateProducts and ReadProducts. The throughput calculation formula is as follows:

$$TPS = \frac{Number\ of\ Transactions}{Response\ Time} \tag{21.1}$$

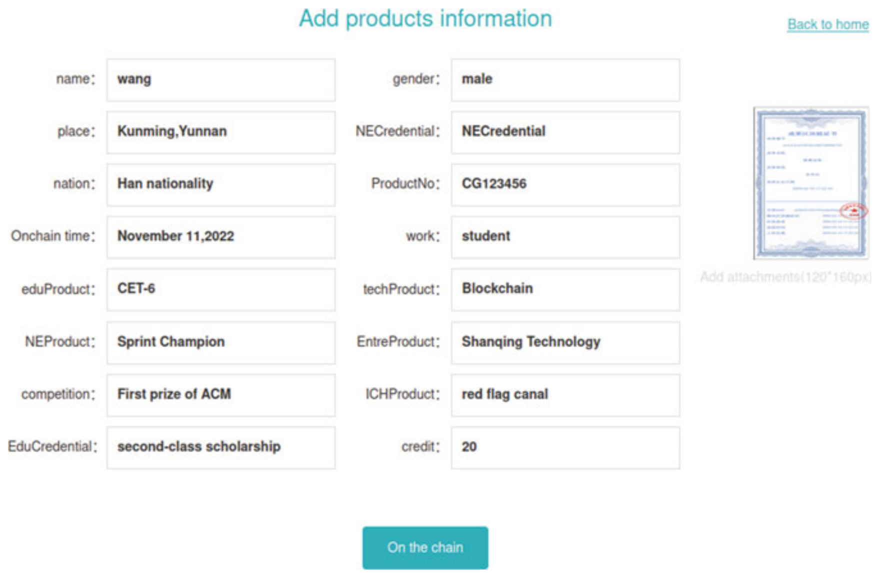


Fig. 21.4 Fill in the chain information

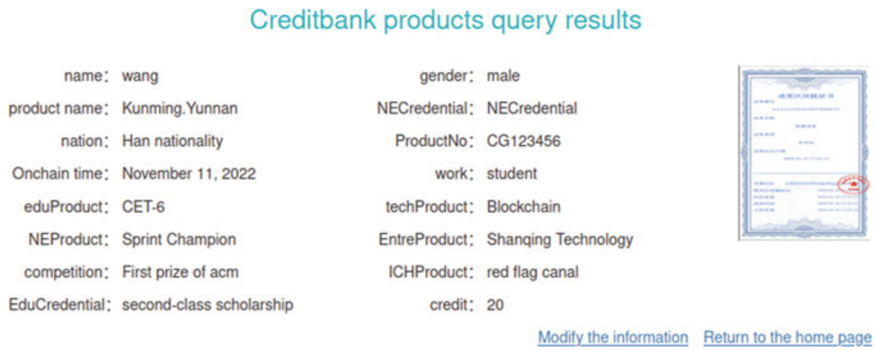


Fig. 21.5 On chain query results

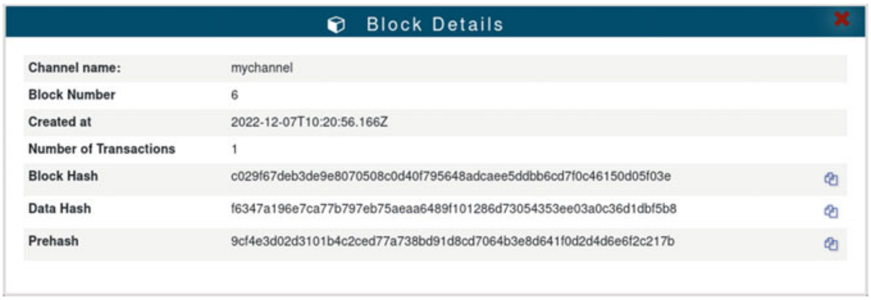


Fig. 21.6 Block details

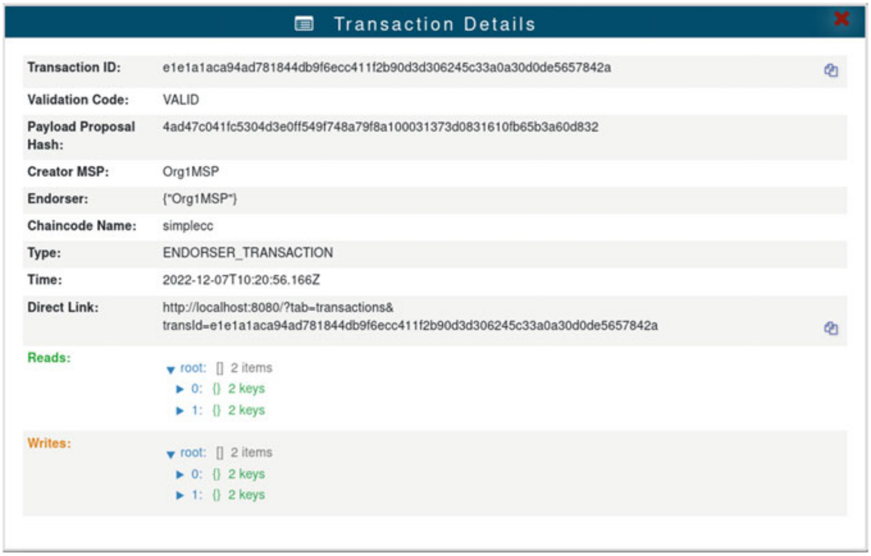


Fig. 21.7 Transaction details

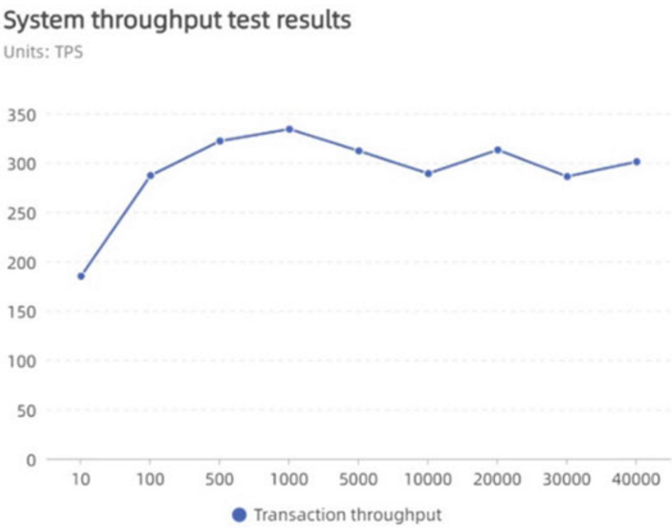


Fig. 21.8 System throughput test results

21.5 Conclusion

This paper studies the decentralized oracle and hyperledger technology, uses the highly modular platform of hyperledger, supports users' highly controllable advantages of performance, scalability and security, and designs and realizes the application model based on consortium blockchain and decentralized oracle on credit bank, and the performance of the system is considerable. It effectively solves the problems of low information credibility and difficult traceability of traditional credit bank achievement platform. The oracle simply solves the risk that the data may be tampered with during transmission, thereby establishing a trusted mechanism between the oracle and the user, so that the untrusted two parties can achieve value exchange. However, once there is a problem with the data source itself, the data fed back to the user is also distorted, and the experiment can be gradually improved in the next research.

Acknowledgements This paper is financially supported by the project of Research and Application demonstration of key Technologies of Yunnan Autonomous controllable Block chain basic Service platform. (Grant no, 202102AD080006).

References

1. H. Lin, Intelligent teaching system of vocational education based on a new generation of information technology, in *6GN for future wireless networks. 6gn 2021. lecture notes of the institute for computer sciences, social informatics and telecommunications engineering*, vol. 439, ed. by S. Shi, R. Ma, W. Lu (Springer, Cham, 2022). https://doi.org/10.1007/978-3-031-04245-4_53
2. K. Wang, System Structure of school-enterprise cooperative education service platform in higher vocational education based on blockchain technology, in *The 2021 international conference on machine learning and big data analytics for IoT security and privacy. SPIoT 2021. Lecture notes on data engineering and communications technologies,* vol. 97, ed. by J. Macintyre, J. Zhao, X. Ma (Springer, Cham, 2020). https://doi.org/10.1007/978-3-030-89508-2_129
3. J. Chen, X. Su, W. Wen, H.-T. Wu, Credit platform construction of vocational education group based on blockchain, in *2020 16th international conference on computational intelligence and security (CIS)* (2020), pp. 313–317. https://doi.org/10.1109/CIS52066.2020.00073
4. N. Yan, Application of blockchain in academic credit bank system. in *Technology in education. Innovations for online teaching and learning. ICTE 2020. Communications in computer and information science,* vol. 1302, ed. by L.K. Lee, L.H. U, F.L. Wang, S.K.S. Cheung, O. Au, K.C. Li (Springer, Singapore, 2020). https://doi.org/10.1007/978-981-33-4594-2_28.
5. F. Yang, L. Lei, L. Chen, Method of Interaction between Blockchain and the World outside the Chain based on Oracle Machine, in *2022 IEEE 8th Intl conference on big data security on cloud (BigDataSecurity), IEEE Intl conference on high performance and smart computing, (HPSC) and IEEE Intl conference on intelligent data and security (IDS)* (2022), pp. 101–106. https://doi.org/10.1109/BigDataSecurityHPSCIDS54978.2022.00028. J. Clerk Maxwell, *A treatise on electricity and magnetism*, 3rd ed., vol. 2 (Oxford, Clarendon, 1892), pp.68–73.

6. M. Dabbagh, M. Kakavand, M. Tahir, A. Amphawan, Performance analysis of blockchain platforms: empirical evaluation of hyperledger fabric and ethereum, in *2020 IEEE 2nd International conference on artificial intelligence in engineering and technology (IICAIET)* (2020), pp. 1–6. https://doi.org/10.1109/IICAIET49801.2020.9257811
7. K.B. Jyothilakshmi, V. Robins, A.S. Mahesh, A comparative analysis between hyperledger fabric and ethereum in medical sector: a systematic review, in *Sustainable communication networks and application. Lecture notes on data engineering and communications technologies*, vol 93, ed. by P. Karrupusamy, V.E. Balas, Y. Shi (Springer, Singapore, 2022). https://doi.org/10.1007/978-981-16-6605-6_5
8. M. Kaleem, W. Shi, Demystifying pythia: A survey of chainlink oracles usage on ethereum. in *Financial Cryptography and data security. FC 2021 International workshops. FC 2021. Lecture notes in computer science*(), vol. 12676, et al. (Springer, Berlin, Heidelberg, 2021). https://doi.org/10.1007/978-3-662-63958-0_10Y. M. Yorozu, K. Hirano, Oka, Y. Tagawa, Electron spectroscopy studies on magneto-optical media and plastic substrate interface, IEEE Transl. J. Magn. Japan, **2**, 740–741. August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
9. J. Na, H.-Y. Kim, N. Park, B. Seo, Comparative analysis of schnorr digital signature and ecdsa for efficiency using private ethereum network. IEIE Trans. Smart Process. & Comput. **11**(3), 231–239 (2022)
10. M. Beunardeau, A. Connolly, H. Ferradi, R. Géraud, D. Naccache, D. Vergnaud, Reusing Nonces in Schnorr Signatures, in *Computer Security–ESORICS 2017. ESORICS 2017. Lecture Notes in Computer Science* (), vol. 10492, ed. by S. Foley, D. Gollmann, E. Snekkenes (Springer, Cham, 2017). https://doi.org/10.1007/978-3-319-66402-6_14
11. Y. Zhao, X. Kang, T. Li, C.-K. Chu, H. Wang, Toward trustworthy defi oracles: past, present, and future. IEEE Access **10**, 60914–60928 (2022). https://doi.org/10.1109/ACCESS.2022.3179374
12. S. Goswami, S. M. Danish, K. Zhang, Towards a middleware design for efficient blockchain oracles selection, in *2022 Fourth international conference on blockchain computing and applications (BCCA)* (2022), pp. 55-62. https://doi.org/10.1109/BCCA55292.2022.9922433
13. S. Schmeelk, B. Rosado, P.E. Black, Blockchain smart contracts static analysis for software assurance. in *Intelligent computing. Lecture notes in networks and systems*, vol. 284, ed. by K. Arai (Springer, Cham, 2021). https://doi.org/10.1007/978-3-030-80126-7_62

Chapter 22
A Deep Learning Network Using CNN_GRU with GRU Residual for Stock Prediction

Jingxi Zhu, Xugong Qin, and Peng Zhang

Abstract Stock prediction is a hot research issue in the field of time series prediction and AI. Among all the classical models, the GRU deep learning model without an encoder-decoder structure performs best for the stock market one-step prediction problem. In recent years, researchers have adopted many methods to improve the performance of traditional GRU. However, a comprehensive comparison is seldomly explored. This paper explores several different variants and presents a deep learning network using CNN to enhance input and GRU residual to enhance output for stock prediction:CNN_GRU with GRU Residual (CGGR). CGGR achieved the outstanding performance on the Microsoft stock data set getting from Quandl. In addition, this paper compares the performance of the attention mechanism with that of the above two mechanisms in terms of enhancing input and enhancing output of GRU. It is found that the attention mechanism does improve traditional GRU, but it is still not as effective as those of CNN and GRU residual.

Keywords Stockprediction · GRU · CNN · Attentionmechanism

J. Zhu
School of Materials Science and Engineering, Tsinghua University, Beijing, China

X. Qin
School of Cyberspace Security, Nanjing University of Science and Technology, Nanjing, China

P. Zhang (✉)
Institute of Information Engineering, Chinese Academy of Sciences, Beijing 100093, China
e-mail: pengzhang@iie.ac.cn

School of Cyber Security, University of Chinese Academy of Sciences, Beijing 100049, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_22

22.1 Introduction

Stock prediction has been a hot research issue in the field of data mining for many years for its practicality and high profits. However, it is not an easy work because of its complexity and randomness. For these reasons, this issue has attracted extensive attention from academia and industry[1, 2].

At the same time, the stock prediction problem has a high demand for forecasting accuracy and timeliness, prompting people to constantly explore this field, and a variety of methods and models have been introduced to this problem. Statistical methods such as autoregressive integrated moving average (ARIMA) and linear regressions[3, 4] are applied in this area. However, the model mentioned above is defective. It is hard for them to fit non-linear characters, and the lack of robustness of these models also needs to be addressed. Therefore, the performance of these models is overstepped by machine learning methods like Artificial Neural Networks (ANNs) and Support Vector Machines (SVM) [5, 6]. And Krollner et al. [7] provides a review of these methods. However, machine learning models are affected by feature selection, which often requires feature engineering on input features to achieve superior results.

Recent papers have focused on the application of deep learning in stock market forecasting. The deep neural network uses a large number of neurons to form a computing layer, such as CNN, RNN, etc., to extract the information of the input sequence in the progress of transferring features between layers. The deep learning model is popular because of its high precision, generalization, and robustness. Among the deep learning models mentioned above, CNN has extensive applications in the fields of computer vision and image processing, with the advantage of effectively extracting local information. However, its design objectives and structure determine that it is not suitable for being used alone to solve time series problems that require consideration of dependencies between multiple time steps. Compared with CNN, Recurrent Neural Networks (RNN), which was put forward in 1982 by [8], performed better in dealing with sequence problems since it was proposed. However, because of the long-term dependence of sequences, RNNs are often prone to gradient disappearance and gradient explosion when the complexity of the model has to increase to fit fine features. Besides, limited by its relatively simple recurrent unit, the fitting ability of the RNN model itself is also insufficient.

LSTM and GRU were proposed in 1997 [9] and 2014 [10] respectively. As two variants of RNN, once they were proposed, their powerful performance in dealing with time series problems has attracted wide attention. Their benefit is that their unique recurrent units, consisting of several gates, enable them to solve the original problems of the RNN models. Compared with RNN models, these two variants perform much better while facing long-term dependence of sequences, showing less gradient disappearance and gradient explosion [10]. However, the input of GRU and LSTM models is often data from a single time step, which limits their ability to fit the local context of the input sequence. As for the difference between these two models, LSTM uses three gates in its recurrent unit, while GRU only uses two. Fewer parameters make training faster and convergence easier. But on the whole, there is not much difference between their performances[11]. This conclusion is also confirmed by our experiments. Therefore, we use GRU to represent RNN-based models in this paper.

To enable more accurate stock prediction, and improve the performance of GRU for this problem, we proposed a novel deep neural network named CNN_GRU with GRU Residual. It uses CNN layer to enhance the input data of GRU, and uses GRU residual mechanism to optimize the output feature, in other words, enhancing output, of GRU. Besides, we also conduct experiments on whether attention mechanism can replace CNN/GRU residual to enhance the input and output of GRU.

The contributions of this work are summarized as follows:

- We propose a novel deep neural network named CNN_GRU with GRU Residual (CGGR) for stock prediction. CGGR uses covariates to help predict the closing price of a stock for the next day. On the MSFT dataset, compared to traditional GRU, CGGR reduces the loss by 42.97%, achieving a good performance.
- We compared various methods, including CNN, attention mechanism, and GRU residual, to enhance the input and output of traditional GRU, proved that attention mechanism performs worse than CNN and GRU_residual mechanism mentioned above.

22.2 Related Works

These years, researchers have made a lot of achievements in stock forecasting using deep neural networks. As early as 1998, researchers started to use RNN to predict the stock market [12]. Models based on RNN are also taken [13]. To overcome the limit of RNN, like hard to deal with long-term patterns, researchers started to use its variants. LSTM-based models perform well in this area in [14, 15], and Chen et al. [16] used GRU in encoder-decoder structure for multi-step stock prediction. [11] indicates that there is not much difference between GRU and LSTM in the performance of stock market forecasting.

In recent years, in the field of deep learning of stock market forecasting, more and more papers have emerged to improve the performance of models by many ways. In [17], CNN layers are introduced to enhance the local context of the input sequence. Jaiswal et al. [18] uses LSTM and GRU at the same time to forecast the short-term and medium-term stock market behavior respectively. In 2017, due to the publication of [19], the attention mechanism attracted many researchers' interest. Qiuet al. [20] uses the attention mechanism to integrate the hidden state of the LSTM model at each time step.

Generally speaking, many methods have been proposed to improve GRU performance, but none of them mention whether modules used to enhance GRU performance will perform well when replaced by attentions. In addition, the GRU residual mechanism proposed in this paper is also novel.

22.3 Preliminaries

In this section, we introduced several mechanisms which are utilized in models mentioned in this paper: the GRU model, the CNN model, and attention mechanism.

22.3.1 Gru

As the variants of RNN, GRU, and LSTM are commonly used to deal with sequence data in natural language processing [21], and stock prediction [16] for their outstanding performance. For an input sequence $x_1, x_2, \cdots x_t$, an RNN defines a recurrent function F with hidden state h. h is updated at each time step t, by function F.

$$h_t = F(h_{t-1}, x_t) \tag{22.1}$$

Recurrent function F of the variants of RNN are different from each other according to how their RNN unit is designed. The recurrent unit of GRU is defined by the following equations:

$$r_t = \sigma(W_{xr}x_t + b_{xr} + W_{hr}h_{t-1} + b_{hr}) \tag{22.2}$$

$$z_t = \sigma(W_{xz}x_t + b_{xz} + W_{hz}h_{t-1} + b_{hz}) \tag{22.3}$$

$$n_t = \tan h(W_{xr}x_t + b_{xn} + r_t\Theta(W_{hn}h_{t-1} + b_{hn}) \tag{22.4}$$

$$h_t = (1 - z_t)\Theta n_t + z_t\Theta h_{t-1} \tag{22.5}$$

where r_t, z_t, n_t are the reset, update and new gates, σ and tanh are sigmoid and tanh activate function, and Θ is Hadamard product.

22.3.2 Cnn

CNN is a kind of neural network proposed to extract grid-like topologies of data. It was first proposed by Lecun et al. in 1998 [22]. This design is widely used in computer vision in the past years [23]. However, in recent years, its application in the field of time series problems, such as stock market forecasting, has also been widely concerned, because it can effectively enhance local context information [17]. Its mechanism is letting a discrete convolution operator slides several convolution kernel K over the input matrix (or sequence) X to generate a feature map. In our work, we use 1D CNN to slide on the input window to generate the high-dimension feature map of input features, and two hyper-parameters including stride and padding are used to maintain the length of input data.

$$out(C_{out_j}) = bias(C_{out_j}) + \sum_{k=0}^{C_{in}-1} weight(C_{out_j}, k)\Delta input(k) \tag{22.6}$$

where C_{in_j}, C_{out_j} is the output of a 1D CNN layer, C denotes the number of channels, L is the length of input sequence.

22.3.3 Attention Mechanism

The attention mechanism is inspired by the attention pattern of the human brain. This mechanism assumes that human have a kind of "query" in their mind, and they will pay more attention to information(key) which are more similar to these queries, and this result will decide human behavior(value). Query, key, and value are three inputs as well as basic conceptions in the attention mechanism. This mechanism is widely used in nowadays deep learning models. To be brief, it computes the similarity of Query and Key, and the result (attention weight) will be multiplied by Value after a SoftMax function.

$$Attn(q, (k_1, \mathrm{v}_1), \cdots (k_m, \mathrm{v}_m)) = \sum_{i=1}^{m} w(q, k_i)\mathrm{v}_i \tag{22.7}$$

$$w(q, k_i) = softmax(a(q, k_i)) = \frac{exp(a(q, k_i))}{\sum_{j=1}^{m} exp(a(q, k_j))} \tag{22.8}$$

where $w(q, k_i)$ refers to attention weight computed by formula (22.8) for q and k_i, $a(q, k_i)$ refers to the scoring function which will be mentioned below.

Two kinds of attention scoring functions are used in our experiments: additive attention and dot-product attention, among which one that performs best is taken in the current model. Their difference is that each of them has its own score function $a(q, k)$, and formulas to calculate these functions are shown below:

Additive:

$$a(q, k) = \mathrm{w}_v^t \tanh(\mathrm{w}_q q + \mathrm{w}_k k) \tag{22.9}$$

Dot Product:

$$a(q, k) = q^T k / \sqrt{d} \tag{22.10}$$

Noted that w_v^t, w_q, w_k in additive attention is parameters which can be trained, d is the variance of the dot-product of two vectors. $\sqrt{d}$ is divided in dot product attention to keep the result scaled.

22.4 Models

In order to improve the performance of GRU, we leverage mechanisms mentioned above to build 4 variants of GRU. In terms of enhancing input data of GRU, we use CNN and self-attention mechanism to build CNN-GRU and self-attention GRU. In terms of optimizing the output feature of GRU, CNN-GRU with GRU Residual (CGGR) and Attention Connected CNN-GRU and GRU (ACGG) are proposed. Performance of the 5 models is tested on the dataset mentioned in Sect. 22.5, and their details are described in subsections and Fig. 22.1.

22.4.1 Gru

The traditional GRU, which is mentioned in [10], is used as a benchmark to verify the performance of other models. Its output is passed into a batch norm layer and a dense layer, and its output is the prediction of stock prices at the t + 1 time step. The batch norm layer is used to avoid overfitting. Experiments show that the batch norm layer greatly improves GRU's performance.

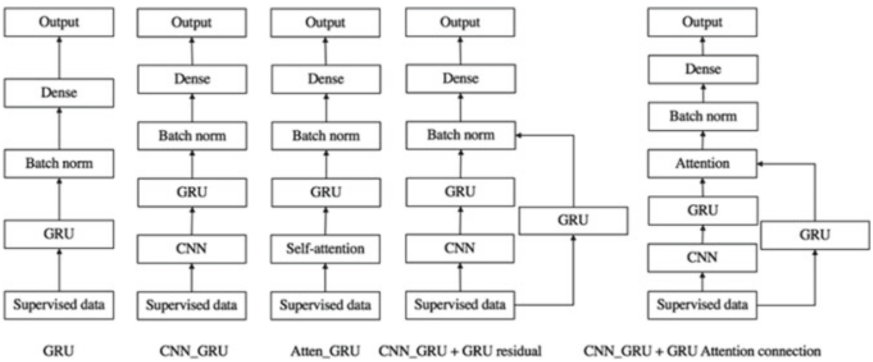


Fig. 22.1 Structures of different models

22.4.2 Cnn-Gru

CNN-GRU model is used as a way to enhance the input data of GRU. In traditional GRU, all variables are directly input to GRU for learning in days. However, some events, such as the sharp fall of stock price, usually last for several days. In other words, hidden features of stock price may be highly related to time steps around it, but traditional GRUs that only focus on a single time step cannot pay attention to this context information. We follow [17] to utilize CNN layers to enhance the local context of the input data.

22.4.3 Attention-GRU

Self-attention is also used to enhance the data input to GRU. Our design here is based on the similarity assumption that prior to the occurrence of two similar stock events, the information such as the daily trading volume must also be similar. The traditional deep learning model cannot pay attention to the correlation of vectors between different time steps, and the self-attention mechanism solves this problem well. The self-attention mechanism makes the deep learning model pay attention to the correlation in the model by calculating the similarity between variables at different times, so as to enhance the input data.

22.4.4 CNN-GRU with GRU Residual (CGGR)

Experiments in Table 22.1. indicated that the CNN-GRU model where the input sequence is pretreated by the CNN layer can significantly improve the performance of traditional GRU. We start to consider "output enhancement", which means optimizing the output feature of GRU based models. In the CNN-GRU with GRU Residual (CGGR) model, we use the output of the traditional GRU model as the base and that of the CNN-GRU model as the residual of the GRU model. In this structure, GRU is mainly used for the long-term mode implied in the time step change, and CNN-GRU is mainly used to learn the local pattern implied in the local context.

22.4.5 Attention Connected CNN-GRU and GRU (ACGG)

In this model, the last hidden layer of CNN-GRU and GRU are inputted to an attention layer for similarity calculation, and the results are transferred to the batch norm layer and dense layer for final prediction. We assume that both CNN-GRU focusing on

Table 22.1 Performance of different models

Model	MAE	RMSE
GRU	6.772	6.937
CNN-GRU	5.305	5.519
Attention-GRU	5.653	6.182
CGGR	3.825	3.956
ACGG	5.372	6.127

local context and traditional GRU make their own votes on the prediction, and the parts that reach consensus between them, in other words, the parts with high similarity in the hidden layer will be closer to the ground truth.

22.5 Experiment

22.5.1 Data Setup

The data used in our work is the Microsoft (MSFT) stock information getting from Quandl [24], including five variates including open price, high and low price, close price, and exchanging volume from 2013–03-27 to 2018–03-27, with an interval of one day. The close price of each day is the prediction target data, and other 4 variants are used as exogenous variables (covariates) to help the model to predict.

As for data preprocessing, we use a sliding window as shown in Fig. 22.2 to turn stock market prediction into a supervised deep learning problem. we use fivefold cross-validation to increase the amount of data, and the dataset is divided to train, valid and test datasets.

Hyper-parameter. As for hyper-parameters, we conduct a random search to find the best hyper-parameter. The hidden dim of GRU in all of the models is selected from {8, 16, 32}, stacking layers of GRU is selected from {1, 2}, and the kernel num

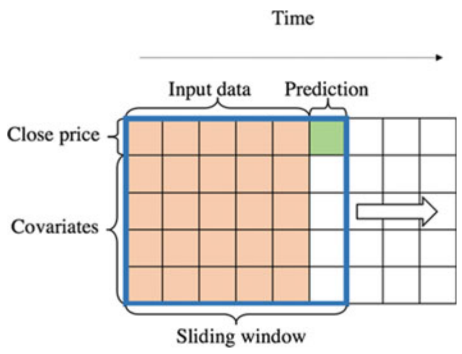


Fig. 22.2 Sliding window to get supervised data

of CNN is selected from {8, 12}. Batch size is selected from {64, 128}, learning rate is set as {0.001}, and the drop prob is set as {0.2} to avoid overfitting. As for attention, both of dot-product attention and additive attention are tried in attention related models, the hidden layer of additive attention is set as half of GRU hidden dim. Each model runs for 500 epochs to reach stability.

22.5.2 Evaluation

Mean Absolute Error (MAE) and root mean square error (RMSE) is used to evaluate the final performance of the model with formulas below.

$$MAE = \frac{1}{n}\sum |y_t - \tilde{y}_t| \tag{22.11}$$

$$RMSE = \sqrt{\frac{\sum (y_t - \tilde{y}_t)^2}{N}} \tag{22.12}$$

22.5.3 Result

It can be seen in Table 22.1 that the traditional simple GRU has the highest MAE and RMSE, indicating that all of the methods used in this experiment have improved the performance of traditional GRU. However, different mechanisms have different performances on the GRU model. In the two models of input enhancement, CNN-GRU's MAE is 5.305, and RMSE is 5.519, which is less than those of Attention-GRU. It shows that the CNN layer has a better lifting performance than the attention layer. In output enhancement, the performance of CNN-GRU and GRU connected by attention mechanism is not better than that of CNN-GRU alone, but the performance of directly connecting CNN-GRU and GRU by GRU Residual is far better than those of all other models.

22.5.4 Discussion

(a) Why attention cannot be all we need?

The attention mechanism is good at dealing with complex sequences. In Transformer [19], about 25,000 source tokens and 25,000 target tokens are given to self-attention in each training batch. When a such large amount of data is given, the attention mechanism extracts the features of complex sequences and performs well. However, in our work, input length and num of variables are limited, therefore limiting the features hidden in each input batch. This mechanism cannot be made full use of such data.

To be exact, in terms of input enhancement, the maximum length of network signals traveling paths can be reduced to a close distance (theoretical shortest O(1)) by self-attention[25], which provides strong long-range alignment ability. However, its ability to enhance local context is not as good as CNN. On the other hand, as for enhancing output, dot-product Attention actually calculated the similarity of hidden dim of long-term forecasting (GRU) and local context forecasting (CNN-GRU). However, limited by dimensions, its ability to fit subtle features is not as good as CNN-GRU with GRU Residual.

(b) Why not encoder-decoder structure?

Encoder-decoder structure [26] is not adopted in our work though it is one of the mechanisms which are most widely used these years to deal with series information. There are two reasons for that. First, the stock price 1 day later is predicted in our work, thus there's no need to control the length of the output sequence, which is the aim for which the encoder-decoder mechanism is initially designed. Second, in short sequence time-series forecasting problems, the performance of the encoder-decoder is not better than in traditional RNN-based models. We implemented an encoder-decoder structure of GRU and conducted experiments on the MSFT dataset using the same hyperparameters as in the Model 4.1 experiment. We calculated the RMSE between the predicted values and the true values using formula (22.12), which was 6.9698, while the RMSE of traditional GRU was 6.937, indicating that its performance is worse than simple GRU.

22.6 Conclusions

In this paper, we propose CNN_GRU with GRU Residual model (CGGR), a GRU-based deep learning model, using CNN to enhance input and GRU Residual to enhance output of GRU. Compared with four models including traditional GRU, CNN_GRU, self-attention GRU, and Attention Connected CNN-GRU and GRU, their performance on the Microsoft stock dataset getting from Quandl shows that two mechanisms taken in CGGR (the CNN block to enhance the local context and GRU residual mechanism to enhance the output features) significantly improve the performance of the GRU model on stock prediction, decreasing the RMSE loss by 42.97%. In addition, the attention mechanism has been shown to be not as good as CNN and GRU residuals in enhancing GRU input and output. We believe that the CGGR model structure and the study of the effect of attention mechanism on this problem can promote the further development of deep learning in the field of stock prediction.

References

1. J.A. Ou, S.H. Penman, Financial statement analysis and the prediction of stock returns. J. Account. Econ. **11**(4), 295–329 (1989)
2. N. Pahwa, N. Khalfay, V. Soni et al., Stock prediction using machine learning a review paper. Int. J. Comput. Appl. **163**(5), 36–43 (2017)
3. A.A. Ariyo, A.O. Adewumi, C.K. Ayo, Stock price prediction using the ARIMA model, in *2014 UKSim-AMSS 16th international conference on computer modelling and simulation* (IEEE, 2014), pp. 106–112
4. Y.E. Cakra, B.D. Trisedya, Stock price prediction using linear regression based on sentiment analysis. in *2015 international conference on advanced computer science and information systems (ICACSIS)* (IEEE, 2015), pp. 147–154
5. Z. Guo, H. Wang, Q. Liu, J. Yang, A feature fusion based forecasting model for financial time series. PLoS ONE **9**(6), 172–200 (2014)
6. Y. Lin, H. Guo, J. Hu, An SVM-based approach for stock market trend prediction, in *The 2013 international joint conference on neural networks (IJCNN)* (IEEE, 2013), pp. 1-7
7. B. Krollner, B. Vanstone, G. Finnie, *Financial time series forecasting with machine learning techniques: A survey*, (2010)
8. J.J. Hopfield, Neural network sand physical systems with emergentcol-lective computational abilities. Proc. Natl. Acad. Sci. **79**(8), 2554–2558 (1982)
9. S. Hochreiter, J. Schmidhuber, Long short-term memory. Neural Comput. **9**(8), 1735–1780 (1997)
10. J. Chung, C. Gulcehre, K.H. Cho et al., Empirical evaluation of gated recurrent neural networks on sequence modelling, (2014). arXiv preprint arXiv:1412.3555
11. Y. Gao, R. Wang, E. Zhou, Stock prediction based on optimized LSTM and GRU Models. Sci. Program., **2021**, 2021
12. E.W. Saad, D.V. Prokhorov, D.C. Wunsch, Comparative study of stock trend prediction using time delay recurrent and probabilistic neural networks. Neural Netw. IEEE Trans. On **9**(6), 1456–1470 (1998)
13. A.M. Rather, A. Agarwal, V.N. Sastry,Recurrent neural network and a hybrid model for prediction of stock returns. Expert. Syst. Appl. **42**(6), 3234–3241 (2015)
14. C.Y. Lai, R.C. Chen, R.E. Caraka, Prediction stock price based on different index factors using LSTM, in *2019 International conference on machine learning and cybernetics (ICMLC)* (IEEE, 2019), pp. 1–6
15. K. Chen, Y. Zhou, F. Dai, A LSTM-based method for stock returns prediction: A case study of China stock market. IEEE Int. Conf. Big Data (Big Data) **2015**, 2823–2824 (2015). https://doi.org/10.1109/BigData.2015.7364089
16. U. Gupta, V. Bhattacharjee, P.S. Bishnu, StockNet—GRU based stock index prediction. Expert Syst. Appl. **207**, 117986 (2022)
17. R. Jaiswal, B. Singh, A hybrid convolutional recurrent (CNN-GRU) model for stock price prediction, in *2022 IEEE 11th International conference on communication systems and network technologies (CSNT)* (IEEE, 2022), pp. 299–304
18. Y. Touzani, K. Douzi, An LSTM and GRU based trading strategy adapted to the Moroccan market. J. Big Data **8**(1), 1–16 (2021)
19. A. Vaswani, N. Shazeer, N. Parmar et al., Attention is all you need. Adv. Neural Inf. Process. Syst., **30**, 2017
20. J. Qiu, B. Wang, C. Zhou, Forecasting stock prices with long-short term memory neural network based on attention mechanism. PLoS ONE **15**(1), e0227222 (2020)
21. W. Yin, K. Kann, M. Yu, et al., Comparative study of CNN and RNN for natural language processing. arXiv preprint arXiv:1702.01923, 2017
22. Y. Lecun, L. Bottou, Y. Bengio, P. Haffner, Gradient-based learning applied to document recognition. Proc. IEEE **86**(11), 2278–2324 (1998)
23. A. Krizhevsky, I. Sutskever, G.E. Hinton, ImageNet classification with deep convolutional neural networks. Commun. ACM **60**(6), 84–90 (2017)

24. Quandl Stock Index. http://www.quandl.com/stocks
25. H. Zhou, S. Zhang, J. Peng et al., Informer: Beyond efficient transformer for long sequence time-series forecasting,in *Proceedings of the AAAI conference on artificial intelligence*, vol. 35, No. 12 (2021), pp. 11106–11115
26. K. Cho, B. van Merrienboer, C. Gulcehre, F. Bougares, H. Schwenk, Y. Bengio, Learning phrase representations using rnn encoder-decoder for statistical machine translation, in *Conference on Empirical Methods in Natural Language Processing (EMNLP 2014)* (2014)

Chapter 23
Exploring Stock Price Prediction Based on Deep Learning

Jingwen Yu

Abstract The stock market is an essential part of the financial market. Stock price prediction becomes difficult due to the complication of the stock market. Stock prices are predicted based on Recurrent Neural Network (RNN), Long Short-Term Memory Model (LSTM), and Gate Recurrent Unit (GRU) in deep learning. Eventually, we obtained the prediction curves of stock prices and three evaluation indexes of Mean-absolute error (MAE), Mean-square error (MSE), and Root-mean-square error (RMSE). The empirical surveys illustrate that the GRU model outperforms the RNN and LSTM models in respect of the accuracy of stock prediction.

Keywords Stock price prediction · Long short-term memory model · Gate recurrent unit · Machine learning · Recurrent neural network · Deep learning

23.1 Introduction

The stock market is an essential part of the financial market. Due to the non-linear and multivariate influences of the stock market, the stock price of a particular company may depend on that company's financial situation, economic situation, political situation, and other factors, making it difficult to forecast the trend of the stock price.

There are two main approaches to stock price prediction: fundamental analysis and technical analysis [7]. Fundamental analysis is a manual judgment of the future movement of a company's stock based on factors such as its past performance and earnings forecast. The technical analysis predicts the future movement of its price based on historical market data. Moreover, technical analysis has become more popular with more powerful computer technology.

J. Yu (✉)
Guangdong University of Foreign Studies, 178 Waihuan Rd E, Guangzhou 510006, Guangdong, China
e-mail: 18102810324@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_23

The research domain of artificial intelligence has further expanded with the progress and development of science. Machine learning has continued to develop and grow as a branch of artificial intelligence. The previous technical analysis included the autoregressive model, differential autoregressive moving average model, and autoregressive moving average model [2]. Techniques such as support vector machines, random forests, genetic algorithms, and deep learning have better handled the nonlinear data in the stock market by valuable mining information in the data.

Deep learning (artificial neural networks) in machine learning learns by simulating the human brain. The LSTM model in deep learning is an improved version of the RNN model, which adds cell states and gate structure, and it is easier to remember past data and better solve the gradient disappearance problem in RNN. The GRU model is a lightweight version of the LSTM model, which merges the memory and cell states and reduces the gate structure [10]. Its parameters are also reduced, making the training more concise and effectively solving the risk of overfitting in the LSTM.

Most of the previous studies constructed new models based on RNN, LSTM and GRU, and other models to predict the stock price trend and compared the price prediction effect of the newly constructed models with the neural network models such as RNN, LSTM or GRU, and obtained the conclusion that the new models have better prediction effect, but no study analyzed and compared the stock prediction effect of these three models separately. This paper predicts Guizhou Maotai stock price based on RNN, LSTM, and GRU models and compares which model has the best prediction effect from the prediction results to provide suggestions for the selection of stock prediction models.

In this paper, three neural network models, RNN, LSTM, and GRU are used to forecast Guizhou Maotai stock prices. We obtain the evaluation indexes of these three models and the trend graphs of stock prediction results and actual values, which are visually compared. The experimental surveys show that the RNN is only a network structure with repeated iterations along the time sequence. This temporal dependence will disappear, making the RNN model suffer from a gradient disappearance problem. Its prediction result accuracy is the worst among the three models. The Gate Recurrent Unit Model significantly reduces the complexity of training and is a lightweight version of the Long Short-Term Memory Model, effectively mitigating the risk of overfitting the LSTM model. In comparison with that of the LSTM, the precision of the GRU model prediction values is significantly improved [9]. The comparison concludes that the GRU model outperforms the RNN and LSTM models in stock price prediction.

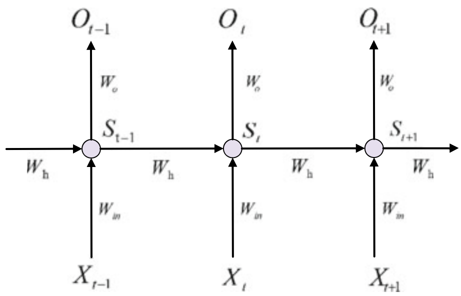


Fig. 23.1 Flow chart of RNN recurrent neural network

23.2 RNN, LSTM and GRU Models Construction

23.2.1 RNN Model

Recurrent neural networks (RNN) focus on the continuous growth and progression of each neuron in the hidden layer on time series on the basis of the convolutional neural network model and repeatedly record each neuron with timely updates to establish temporal correlations. RNNs use error back propagation and gradient descent to update the weights. However, the target subsequence will suffer from "gradient disappearance" and "gradient explosion" during training when the dependencies span an extended period. The solution is to make the window of the RNN correspondingly wider to capture these dependencies across a long time, large samples [13] (Fig. 23.1).

Its formula is:

$$h_t = f(W_{in}X + W_h h_{t-1} + b) \tag{23.1}$$

The states of the hidden layers are h_t and h_{t-1}. The moments of the hidden layer's states are t and t–1. W_h and W_{in} are both weight matrices. W_h is the weight matrix between different layers, W_{in} is the weight matrix of the input layer, X is the input layer, and b is the bias term.

23.2.2 LSTM Model

The LSTM model improves the RNN model, remembers past data more efficiently, and better solves the problem of gradient disappearance which is mentioned above for the RNN model. The LSTM adds the cell state c_t and three "gates", namely "the forgetting gate", "input gate" and "output gate. These three "gate" structures edit the information of cell states throughout them as a function of the input value x_t at the current moment and the hidden layer state h_{t-1} at the previous moment (Fig. 23.2).

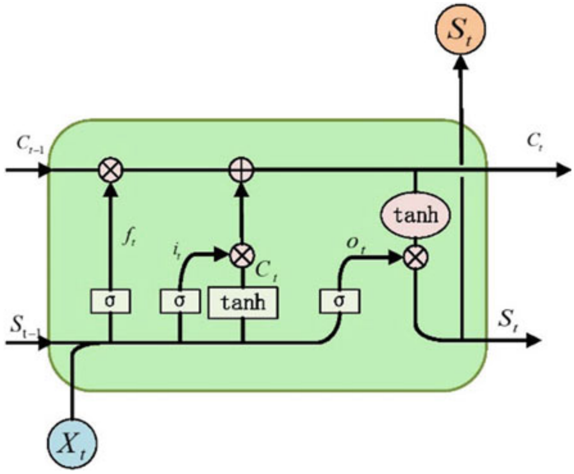


Fig. 23.2 Flow chart of long and short-term memory model

The oblivion gate f_t receives the cell state c_{t-1} output from the previous cell module, retains important features and ignores irrelevant information. The equation is as follows:

$$f_t = \sigma(W_f \cdot [h_{t-1}, x_t] + b_f) \tag{23.2}$$

The input gate i_t not only filters the information in input x_t of the present network but also retains some critical information about the cell state c_t [1]. The formula is as follows:

$$i_t = \sigma(W_i \cdot [h_{t-1}, x_t] + b_i) \tag{23.3}$$

The output gate o_t determines the value h_t of the following hidden state based on the cell state, which contains part of the previous input values. The equation is as follows:

$$O_t = \sigma(W_o \cdot [h_{t-1}, x_t] + b_o) \tag{23.4}$$

σ is the activation function sigmoid, taking values between 0 and 1. W_f, W_i, W_o are the matrices of parameters to be trained. b_f, b_i and b_o are the bias terms to be trained.

The cell state represents long-term memory. These cells' states are equal to the information retained by the forgetting gates multiplied by the long-term memory of the last moment add to the input gate information multiplied by the new knowledge generalized at the current moment. The calculation formula is as follows:

$$c_t = f_t * c_{t-1} + i_t * g_t \tag{23.5}$$

The formula for the new knowledge inducted at the current moment is as follows:

$$g_t = \tanh\left(W_g[h_{t-1}, x_t] + b_g\right) \tag{23.6}$$

W_g is the matrix of parameters to be trained, and b_g is the bias term to be trained. The activation function tanh takes values between –1 and 1 and serves to sort out and summarize what happened in the two days.

The memory is the result of activating the cell state c_t with the tanh function. After that, we multiply it with the output gate, i.e., the output gate mentioned before determines the value of the following hidden state h_t based on the cell state. Its calculation is given by:

$$h_t = o_t * \tanh(c_t) \tag{23.7}$$

Compared with RNN, LSTM introduces more parameter matrices, but the gradient descent method is still available to update the weights.

23.2.3 GRU Model

Gate Recurrent Unit Model is a lightweight version of Long Short-Term Memory Model. Gate Recurrent Unit Model does not have a separate unit state but still has a gating mechanism that controls the flow of information within the unit in contrast to the LSTM model [9]. The LSTM model merges the input gate i_t and the forgetting gate f_t into one gating mechanism named update gate z_t. The calculation formula is:

$$z_t = \sigma(W_Z \cdot [h_{t-1}, x_t]) \tag{23.8}$$

Moreover, the reset gate r_t in the GRU replaces the output gate o_t in the LSTM. The reset gate r_t mainly affects the probability of inputting the state details of the former unit into this model. This calculation formula is:

$$r_t = \sigma(W_r \cdot [h_{t-1}, x_t]) \tag{23.9}$$

σ is the activation function sigmoid, taking values between 0 and 1. W_z and W_r are the matrixes of parameters to be trained.

The GRU model merges the memory h_t and the cell state c_t of the LSTM in the form of memory. The calculation formula is:

$$h_t = (1 - z_t) * h_{t-1} + z_t * \tilde{h}_t \tag{23.10}$$

1–z_t and z_t have a function that can selectively remember, and h_t is the candidate hidden layer, i.e., the new content come into being by the current state. Its formula is (Fig. 23.3).

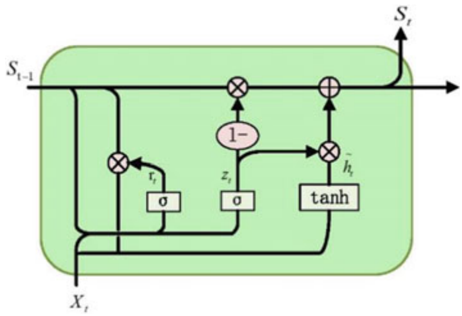


Fig. 23.3 Flow chart of GRU model

$$\tilde{h}_t = \tanh(W \cdot [r_t * h_{t-1}, x_t]) \tag{23.11}$$

23.3 Experiment and Analysis

23.3.1 Data Acquisition and Pre-Processing

The opening price of Guizhou Maotai (stock code: 600,519. SH) from Jan. 1, 2012, to Aug. 13, 2021, was selected for modeling, and the data were obtained from Tushare.

The read data are divided into a training set and a test set, with the opening prices in the first 2126 days of data as the training set and the opening prices in the last 300 days of data as the test set. In order to prevent the different units and magnitudes of the original data from causing large deviations in the data prediction results, this paper uses the Min–Max Normalization method to normalize the data so that the data distribution is between 0 and 1. Its formula is.

$$x_t' = \frac{x_t - x_{\min}}{x_{\max} - x_{\min}}, \ t = 1, 2, \ldots, n \tag{23.12}$$

x_t is the initial data, $x_{\min}$ is the minimum value in the initial data, $x_{\max}$ is the maximum value in the initial data, and x_t' is the normalized data.

The minimum–maximum normalization method is the initial data x_t minus the minimum value $x_{\min}$, divided by the distance between the maximum value $x_{\max}$ and the minimum value $x_{\min}$ to obtain the normalized data x_t'.

23.3.2 Comparative Experiments

The three neural network model experiments based on RNN, LSTM, and GRU all create empty lists for receiving the input features and labels of the training and test

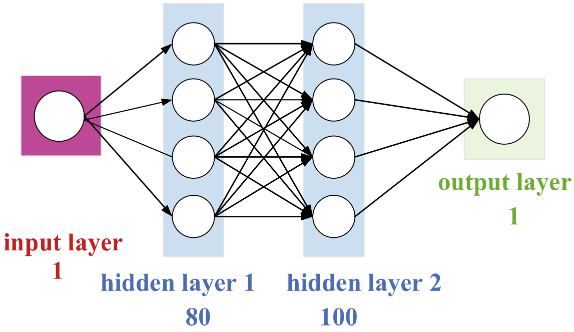


Fig. 23.4 Double-loop internal structure

sets first. Then, the entire training data is iterated every 60 consecutive days of data as the input features and the 61st day of data as the corresponding labels, generating a total of 2066 sets of training data and then disrupting the order of the training data. Similarly, we traverse the entire test data to generate 240 test data sets. The test set does not need to be disordered because it needs to be in chronological order to get the correct prediction values.

The Sequential model is used to build the neural network. The first layer of recurrent computational memory is set to 80, and each time step pushes the hidden layer state h_t to the next layer. Dropout is set to 0.2, which effectively alleviates the overfitting phenomenon. The second recurrent computation layer sets the memory to 100, and only the last time step pushes the hidden layer state h_t to the next layer, also using a Dropout of 0.2 (Fig. 23.4).

Since the output value is the opening price, which is only one number, the fully connected Dense is set to 1. The optimizer of the method of configuring the training set is the Adam with both error backpropagation and gradient descent using the mean square error loss function to update the weights.

Next, we perform the stock prediction using the test set data and transform the predicted and actual values from normalized values to actual values. Finally, the stock price curves predicted by RNN, LSTM, and GRU models are drawn and compared.

In this paper, we choose Root-mean-square error (RMSE), Mean-square error (MSE), and Mean-absolute error (MAE) as the evaluation indexes. The calculation formula for each index is as follows:

$$MSE = \frac{1}{\mathrm{n}} \sum_{t-1}^{n} (forecast(t) - actual(t))^2 \tag{23.13}$$

$$RMSE = \sqrt{\frac{1}{\mathrm{n}} \sum_{t-1}^{n} (forecast(t) - actual(t))^2} \tag{23.14}$$

$$MAE = \frac{1}{\mathrm{n}} \sum_{t-1}^{n} |forecast(t) - actual(t)| \tag{23.15}$$

The forecast(t) is the predicted opening price of Maotai stock on a particular day, the actual(t) is the actual opening price of Maotai stock on a particular day, and n is the number of test data sets. Comparing the evaluation indexes of models. The assessment criteria to evaluate the accuracy of the model predictions are whether the three indicators are small [1].

23.3.3 Experimental Results and Analysis

Figures 23.5, 23.6, and 23.7 show the trend plots of the anticipation results of the GRU, LSTM, and RNN models for the Guizhou Maotai's stock price. These red lines represents the actual value of Guizhou Maotai stock price, and these blue lines indicates these forecasted values of the stock price by the three models. We will analyze each trend graph in turn below.

Figure 23.5 shows the stock price forecast curve for Guizhou Maotai by the RNN model from January 1, 2012, to August 13, 2021. The RNN model's predicted curve fits poorly with the actual value, while the predicted price curve is always in the range of 1600 RMB per share with slight fluctuation. The highest value of the actual value curve is close to 2600RMB per share, and the lowest value is relative to 1600RMB per share, and the stock price fluctuates significantly during this period.

Figure 23.6 shows the stock price forecast curve of Guizhou Maotai from January 1, 2012, to August 13, 2021, by the LSTM model. The trend of the stock price forecast curve is consistent with the actual value curve. The forecasted value curve fits well with the real value curve, but the stock predicted prices are all slightly smaller than the actual values in general. When there is a substantial change in the stock price,

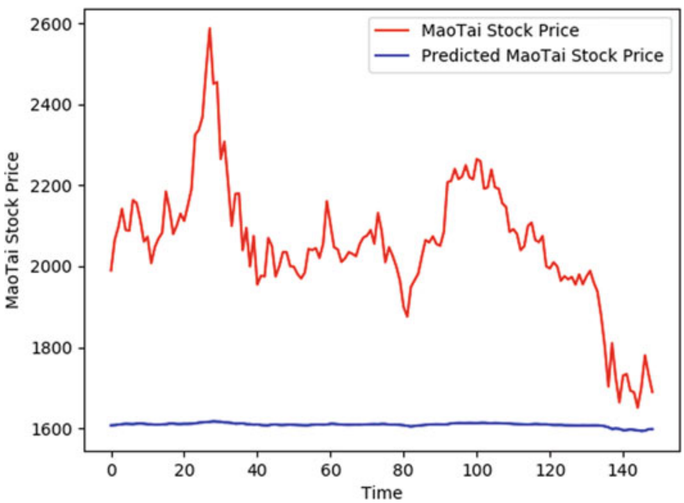


Fig. 23.5 RNN model stock price prediction

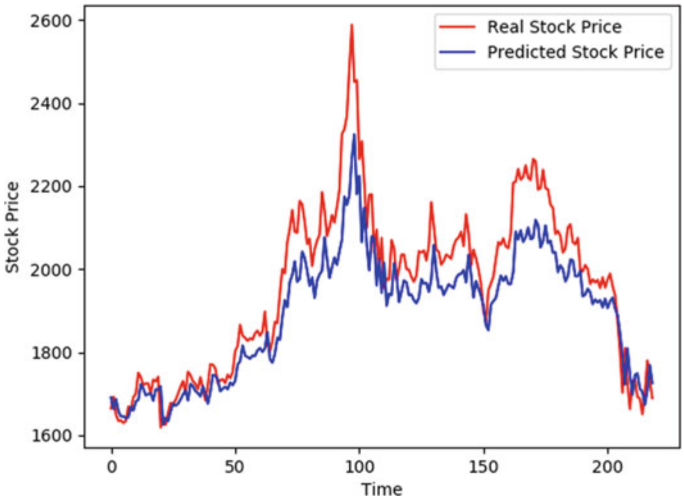


Fig. 23.6 LSTM model stock price prediction

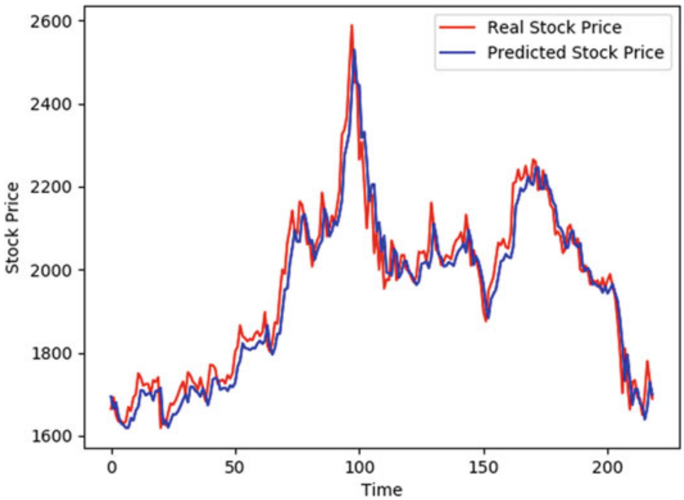


Fig. 23.7 GRU model stock price prediction

the model prediction results are less accurate, and the fitting effect is weaker. When the stock price is relatively stable, the model is more accurate, and the fit is better.

Figure 23.7 shows the GRU model's stock price prediction curves for Guizhou Maotai from January 1, 2012, to August 13, 2021. It is clearly observed that the prediction curve is consistent with the actual value curve, and the stock prediction price almost overlaps with the actual price. Based on the LSTM model, the fitting

Table 23.1 Model evaluation indexes

Evaluation indicators	Neural network models		
	RNN model	LSTM model	GRU model
MSE	222,516.991700	8425.330799	2876.887127
RMSE	471.717067	91.789601	53.636621
MAE	446.237016	72.250376	39.775545

effect of the GRU model predicted the stock price curve with the real value curve is further improved.

In this paper, we used Root-mean-square error (RMSE), Mean-square error (MSE), and Mean-absolute error (MAE) as loss functions to evaluate the accuracy of the results of the three models. These three error indexes have been used in previous studies and can be effective in assessing the accuracy of the results.

We compared the actual values of the three models with the predicted values. As shown in Table 23.1, we obtained three evaluation indexes for each model's predicted results. By comparing the evaluation indexes, we can find that the three indexes of the RNN model are much larger than the other two models. The MSE index of the RNN model is about 26 times that of the LSTM model and about 77 times that of the GRU model; the RMSE index of the RNN model is approximately five times that of the RMSE index estimated by the LSTM model and around nine times that of the RMSE index calculated by the GRU model; the MAE metric of the RNN model is approximately six times that of the MAE metric estimated by the LSTM model and around 11 times that of the MAE metric calculated by the GRU model. This stock prediction performance of the RNN model is the worst among the three models.

The GRU model stock forecasting results are the best among the three models. The GRU, as a lightweight version of LSTM, has significantly improved prediction accuracy.

23.4 Conclusion

In this paper, three neural network models, GRU, LSTM, and RNN are used to forecast the stock price of Guizhou Maotai, the trend graphs of the stock prediction results and the actual values, as well as the evaluation indexes of the three models, are visually compared. The RNN model is a network structure with repeated iterations along the time series. This temporal dependence vanishes, making the RNN model suffer from gradient disappearance. The Gate Recurrent Unit Model reduces the complexity of training and is a lightweight version of the long and short-term memory model, effectively mitigating the risk of overfitting the LSTM model. The experimental surveys clearly explain that the anticipation result accuracy of RNN is the worst among the three models. From the trend graphs of stock prediction results and actual values, the RNN prediction results fit the actual values very poorly.

In contrast, the anticipation results of Gate Recurrent Unit Model and Long Short-Term Memory Model fit the actual values better, where the stock price curves predicted by the GRU model overlap with the real value curves. Comparing the three models' evaluation indexes, we can see that the GRU model has the minor evaluation indexes and the best anticipation accuracy among these three models. Therefore, Gate Recurrent Unit Model (GRU) outperforms the RNN and LSTM models in stock price prediction.

References

1. C. Zhao, J. Liu, M. Wu, X. Chang, Research on stock price prediction based on LSTM with numerical and text features. J. Shanxi Univ. (Nat. Sci. Ed.), (2022)
2. D. Wang, H. Ma, Y. Liang, *Stock price prediction based on ATLG hybrid model*. CODEN CSAOBN.
3. F. Wu, C. Xie, C. Xie, A stock price prediction algorithm based on GRU gradient of differential mutation. Mod. Comput. **28**(10), 1007–1423 (2022)
4. L. Su, *Research on the application of ICA-GRU model in stock price prediction*. thesis.
5. P. Buczkowski, *Predicting stock trends based on expert recommendations using GRU/LSTM neural networks. Lecture notes in computer science* (2017), pp. 708–717
6. S. Gao, *Research on stock price forecasting model based on LSTM* (CMFD, 2022)
7. S. Vatsal, *Machine learning techniques for stock prediction*. Thesis
8. W. Bai, *Research and application of recurrent nerual network in stock index forecasting model* (CMFD, 2018)
9. S. Sun, J. Chen, J. Sun, Traffiffiffic congestion prediction based on GPS trajectory data. Int. J. Distrib. Sens. Netw., (2019)
10. X.R. Zu, R.X. Song, Short-term wind power prediction method based on wavelet packet decomposition and improved GRU. J Phys: Conf Ser, (2018)
11. X. Wang, J. Xu, W. Shi, J. Liu, OGRU: An optimized gated recurrent unit neural network. J. Phys.: Conf. Ser., (2019)
12. L. Zheng, X. Cao, F. Chen, Main steam temperature prediction modeling based on autoencoder and GRU. J. Phys.: Conf. Ser., 2020A. Sherstinsky, Fundamentals of Recurrent Neural Network (RNN) and long short-term memory (LSTM) network, Phys. D: Nonlinear Phenom.,**404**, 132306 (2020)
13. R. Fu, Z. Zhang, L. Li, Using LSTM and GRU neural network methods for traffic flow prediction. in *2016 31st Youth academic annual conference of Chinese association of automation (YAC)*, (2016)

Chapter 24
Using Generative Adversarial Network to Forecast Stock Price

Tong Wang, Menghan Yu, and Panji Wang

Abstract Stock price forecasting is one of the hottest research fields in recent years because it can help policymakers and investors make appropriate decisions. The method of deep learning can make the prediction more accurate. Therefore, in this paper, a Generative Adversarial Network (GAN)model is proposed for the prediction of stock price. In this model, the Gated Recurrent Units (GRU) are used as the generator to predict the future stock price by training historical data. Convolutional neural networks (CNN) are used as discriminators to distinguish real data from predicted data. We selected Apple's stock price as the research object, extracted the highest price, lowest price, opening price, S&P 500 index, and other indicators as characteristics, and added the feature of the news index into the research, which can increase the accuracy of the forecast. Finally, the accuracy of the prediction results was determined by calculating the value of RMSE.

Keywords Generative adversarial network · Stock price forecasting · Deep learning

24.1 Introduction

In recent years, the financial market has been changing with the popularity of artificial intelligence and big data technologies. The following will introduce how big data and artificial intelligence technologies are applied to the financial sector and the changes and breakthroughs they have brought. Big data technologies mainly use

T. Wang · M. Yu (✉) · P. Wang
College of Science and Technology, Wenzhou-Kean University, Wenzhou, Zhejiang, China
e-mail: yume@kean.edu

T. Wang
e-mail: wangto@kean.edu

P. Wang
e-mail: wangpa@kean.edu

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_24

techniques such as data mining, statistical analysis, and machine learning to analyze and process large amounts of data, which can better support decision-making in the financial industry [12]. For example, the adoption of technologies such as big data in the financial industry can better collect customer information to select the best financial solutions with more market value [9]. The application of artificial intelligence technologies in the financial market is also becoming more popular. In the stock industry, AI and neural network technologies are used to simulate stock market movements, thus helping investors to make sound investment decisions [16]. Above all, big data and artificial intelligence play an important role in helping the financial market develop and progress. The popularity of these technologies has provided new ideas for decision-making in the financial industry, while also leading to more efficient markets and more accurate investment decisions.

The application of generative adversarial networks (GANs) to predict stock prices has greatly interested researchers because of their ability to capture nonlinear and complex relationships between data points. In recent years, researchers have explored the use of deep learning algorithms and GANs to predict stock prices. Deep learning architectures such as convolutional neural networks (CNNs) and long and short-term memory networks (LSTMs) have been widely used to predict stock prices because of their ability to capture and store long-term dependencies between a large number of input parameters [1]. GANs have recently been explored as an alternative approach to predicting stock prices. They are a powerful tool for capturing large numbers of signals and complex nonlinear relationships between them [4].

In general, GANs were found to be more effective than traditional machine learning techniques for stock price prediction. the ability of GANs to capture more complex patterns and trends in the data allows them to achieve better performance than other methods. In addition, GANs can learn from data faster than traditional methods, which makes them suitable for stock price prediction in rapidly changing stock markets. In summary, generative adversarial networks (GANs) have shown great potential for stock price prediction. CGANs and GAIL have been effectively used to predict stocks by capturing long-term and complex patterns in data. Although further research is needed in this area, GANs can provide a great opportunity to better understand the data and accurately predict stock prices in a rapidly changing market.

24.2 Related Work

According to “Deep generative models: GAN” [17], generative adversarial networks (GAN) are deep learning models that consist of two games of a random selection of potential spaces to develop a variety of complex things such as images, audio, text, and video, thus compensating for traditional machine learning methods [7]. One model called an adversarial training model, is learning to generate similar content, while the other one mainly distinguishes between real and fake content [7]. First, the detection model learns from the real input and then provides a feedback signal to the generative model, which is used to improve its ability to generate specific content [7].

GANs have been widely used in various applications, not limited to image generation. GANs have been used in music applications to generate new melodies and drum patterns [5]. In natural language processing, GANs can be used to generate new sentences and stories [13, 14]. GANs have also been used in healthcare applications, such as monitoring patient vitals and the detection of anomalies [3]. GANs are composed of two main parts—a generator and a discriminator. The generator is responsible for generating new data based on a given input, while the discriminator assesses whether the data is real or generated. The generator and discriminator interact to differentiate between real and generated data.

To begin with, the generator generates a data sample from a random vector. This data sample is then fed into the discriminator. The discriminator then evaluates the sample and assigns a probability of the sample being real or generated [15]. If the probability is deemed to be low, it means the discriminator is not sure that the data is real. In this case, the generator is trained to modify the sample so that it is more similar to real data. This process is repeated for each new data sample generated by the generator. As the generator and discriminator become better at their respective tasks, the generated data become increasingly realistic. This is due to the generator being trained to minimize the accuracy of the discriminator. In other words, the generator is trained to generate data that the discriminator can't distinguish from real data. In this way, GANs can be used to generate realistic data, which can be used in various applications. Overall, GANs are a powerful tool for data generation and analysis. They continue to evolve and become increasingly popular in numerous application domains. As GANs become even more powerful, they will continue to make significant contributions in various fields, such as image generation and computer vision [6].

Different types of GANs have been explored for stock price prediction. One example of such GANs is conditional generative adversarial networks (CGANs) [2]. CGANs generate samples from a given conditional input and output pair. In the case of stock price prediction, the conditional input can be past stock prices, financial news, or economic events, while the corresponding output is the predicted stock price. In Bahng et al. [2], the authors show how CGANs can be used to predict the stock price of a company, given its past stock price. The results show that the GAN model outperforms existing methods by capturing potential nonlinear, long-term dependencies between the data. Another GAN for stock price prediction is Generative Adversarial Imitative Learning (GAIL) [13, 14]. the goal of GAIL is to learn a policy from expert policies in an unsupervised manner. In their study, the authors applied GAIL to predict the Dow Jones Industrial Average (DJIA), using expert policies as guidance. The results again show that GAN models can capture the underlying patterns better than existing methods and achieve higher accuracy than existing models.

Despite the wide range of applications of GAN models, its use in financial markets and stock markets has also received extensive attention. Many researchers have tried to use GAN models to understand financial markets, for example, GAN-based models can identify the drivers of changes that occur [11]. In addition, unsupervised GAN models have been used to identify non-deterministic elements in the stock market, which can also provide insights into the area of market behavior [8]. Recently, some researchers have also used GAN models to learn and generate stock market data to replicate the historical movements of the CSI 300 [10].

24.3 Method

The predictive capabilities of Generative Adversarial Networks (GANs) are widely employed in various real-life applications. GAN is a novel framework for training two models via a zero-sum game, as described by Mohammad Diqi (s418). The generator produces simulated data during the training process, while the discriminator distinguishes between the generated data and real data. The generator aims to continuously optimize the generated data to fool the discriminator, while the discriminator tries to improve its ability to differentiate between real and fake data. Eventually, the GAN model reaches an equilibrium where the discriminator cannot distinguish between the generated and real data. Based on this principle, we will employ the GAN model to forecast stock prices.

24.3.1 The Generator

We have employed the GRU technology as the generator in our model. Being a variant of the LSTM model, it possesses powerful time series data processing capabilities, along with simple architecture and easier convergence. Our dataset comprises ten years of stock price information, from July 1, 2010, to June 30, 2020, including 36 data characteristics such as 'Open', 'High', 'Low', 'Close', 'Volume', 'NASDAQ', 'NYSE', 'S&P 500', 'FTSE100', 'NIKKI225', 'BSE SENSEX', 'RUSSELL2000', 'HENG SENG', 'SSE', 'Crude Oil', 'Gold', 'VIX', 'USD index', 'Amazon', 'Google', 'Microsoft', 'MA7', 'MA21', 'MACD', '20SD', 'upper_band', 'lower_band', 'EMA', 'log momentum', 'absolute of 3 comps', 'angle of 3 comps', 'absolute of 6 comps', 'angle of 6 comps', 'absolute of 9 comps', 'angle of 9 comps', and 'News'. The generator comprises three layers of GRU with 1024, 512, and 256 neurons, respectively. To avoid overfitting, we have set a 20% dropout rate for each layer. Finally, we added two dense layers and one dense layer with the same number of neurons as the output step we aim to predict. The generator takes three-dimensional data consisting of input dimension, output dimension, and feature size as input and generates the stock price for the next day, which is then passed to the discriminator for further processing.

24.3.2 The Discriminator

To differentiate between input data, we have selected a Convolutional Neural Network (CNN) as the discriminator for the GAN model. The CNN outputs 0 when fed with fake data and 1 when presented with true data. The discriminator comprises three Convolutional Layers with 32, 64, and 128 neurons, respectively, and three dense layers with 220, 220, and 1 neuron. The LeakyReLU function serves as the inter-layer activation function, while the sigmoid activation function is used for the output layer to determine whether the input is generated data or real data. The discriminator sorts the data into 0 s and 1 s, calculates the loss for the real and generated distributions separately, and passes it to the generator, which updates the weights to generate data that more closely resembles real data.

24.3.3 The Architecture of GAN

The generator (G) and discriminator (D) described above make up the GAN model structure we use. Interference variable $p_{z(z)}$ needs to be input to learn the distribution p of the generator on data x [17]. The mapping to the data space is then expressed as a cap,where G is a differentiable function represented by the multilayer perceptron of the parameter. And define the multilayer perceptron $x; \theta_d)$ to output a single scalar. D(x) is the probability that x comes from data instead of. We train D and G, and the optimization function V (G, D) of defined values is as follows:

$$\begin{aligned} &min_G max_D V(G,\ D) \\ &= E_{x\sim p_{data(x)}}[logD(x)] \\ &+E_{z\sim p_{z(z)}}\left[\log(1 - D(G(z)))\right] \end{aligned} \tag{24.1}$$

The above formula using GAN said the optimal choice of classifying data, including are selected from real data and by G to minimize and can through training G to maximize the.

24.3.4 Technical Indicators

In the following sections, we will discuss the technical indicators used in the experiment in Fig. 24.1.

1. Moving Averages (MA): MA is an average of stock prices over a certain period and a line connecting the averages over different periods. Here, we calculated the average value of the stock price in the past 7 days and 21 days respectively,

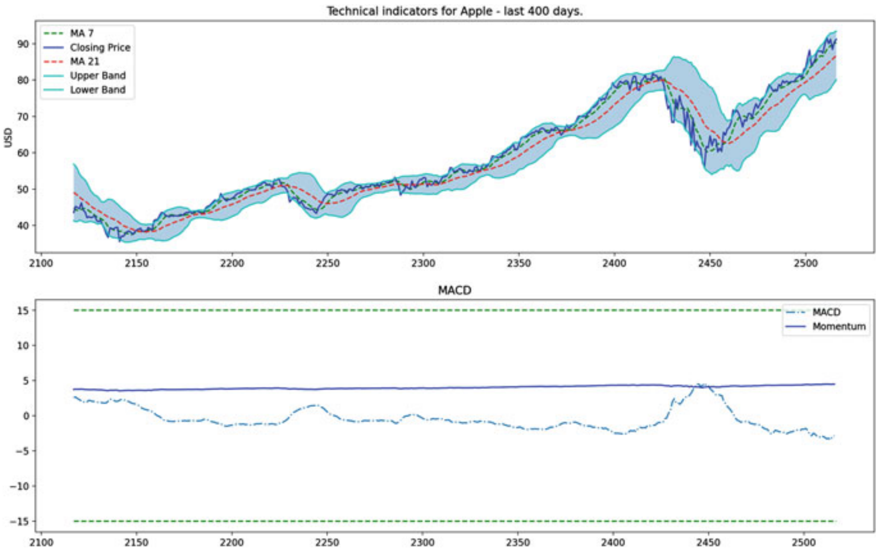


Fig. 24.1 The technical indicators for apple

and made the corresponding MA curve, which can well reflect the past price and help confirm the overall trend of the stock price.

2. Bollinger Bands (BB): The Bollinger Band consists of a moving average and an upper and lower band. The upper and lower bands are set above and below the moving average and show the volatility of the price. Usually, the upper and lower bands are the numbers with the moving average plus or minus 2 standard deviations.
3. Moving Average Convergence Divergence (MACD): The convergent/divergent moving average is used mainly for trading trends and is the difference between exponential moving averages (12) and exponential moving averages (26).
4. Fourier transforms: In this experiment, the Fourier transforms of 3,6 and 9 components of closing prices are calculated respectively.

24.4 Experiments

24.4.1 Dataset

We use 30-day data to predict the closing price of the stock the next day. Price forecasts are made by entering historical closing prices and 36 characteristics that are likely to have an impact on prices. The data set selects the stock price data and stock index data of Apple Inc. from 2010 to 2020. A total of 2,494 sets of data and

Table 24.1 Partial sample data

Date	Open	High	Low	Close	Crude oil
2010–07–01	9.08	9.10	8.69	8.87	72.95
2010–07–02	8.95	8.96	8.69	8.82	72.14
2010–07–06	8.96	9.03	8.79	8.88	71.98
2010–07–07	8.95	9.24	8.92	9.24	74.07
2010–07-08	9.37	9.39	9.10	9.22	75.44

36 variables are used, of which 70% is the training set and the remaining 30% is the test set. Some data are shown in Table 24.1.

24.4.2 Data Processing

For our experiment, we selected 1746 data points from the ten-year dataset as the training set and used these data to train the GAN model. However, the stock price values are often very large, which can lead to significant errors in the prediction process. To mitigate this issue, we normalized the data before training by scaling the stock prices to the same order of magnitude and limiting their range to [0, 1]. We used the extreme value method to perform the normalization, which is accomplished using the following formula.

$$x\prime = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{24.2}$$

24.4.3 Training the Model

Our experiment aimed to use historical data from the past 30 days to predict the closing price of a stock for the following day. To accomplish this, we selected 36 factors that can affect stock prices, such as opening price, closing price, highest price, and lowest price, and trained them using the GAN model. During the training process, we divided the dataset into a training set and a test set, with the training set containing 1746 data points (70%) and the test set containing 748 data points (30%). By training on this data, the GAN model was able to make more accurate predictions of stock prices.

Figure 24.2 shows the losses incurred during the training process, indicating a strong confrontation between the generator and discriminator. As they optimized each other's performance, the generator and discriminator were able to improve the overall accuracy of the GAN model's predictions.

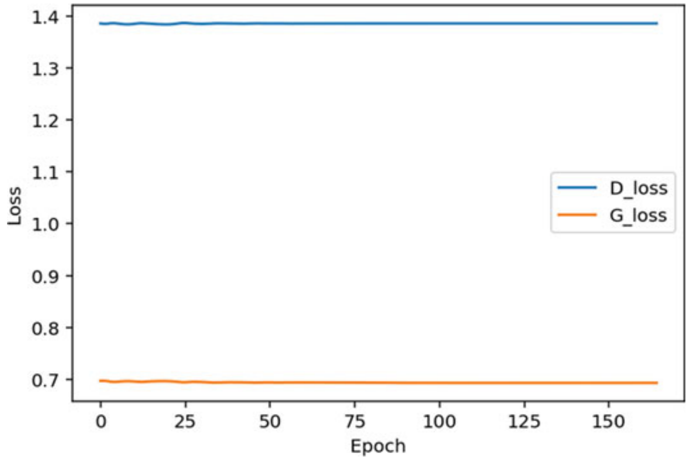


Fig. 24.2 Losses generated by generators and discriminators during training

24.4.4 Result

As can be seen from Fig. 24.3, the real price curve is very close to the predicted price curve, with some relatively obvious errors in 2016, but generally accurate.

In addition to comparing the two curves, we alsoused Root Mean Square Error (RMSE) to determine the accuracy of the algorithm. Root mean square error is the square root of the ratio of the square of the deviation between the predicted value and the real value and the number of observations n, which is used to represent the deviation between the predicted closing price and the real closing price in this

Fig. 24.3 Predicted values and real values

paper. The smaller the error between the true value and the predicted value, the more accurate the result. The formula for RMSE is as follows,

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\widehat{y_i} - y_i\right)^2} \tag{24.3}$$

where y represents the predicted value, *that* represents the real value, and n represents the amount of data. The smaller the RMSE, the higher the measurement accuracy.

In this experiment, RMSE is chosen because compared with Mean Absolute Error (MAE), when the number of times is higher, the calculation result is related to the larger value, while the smaller value is ignored, and the outlier will be more sensitive. In addition, compared with Mean Square Error (MSE), the calculated values of RMSE are all positive, which avoids the occurrence of negative values and leads to the average error of 0, thus obtaining the wrong conclusion. Here the value of RMSE is 0.589328, which is less than 1. It can be seen that GAN, the prediction model we used, performs well.

24.5 Conclusion

In conclusion, this paper demonstrates the use of the GAN model with a CNN discriminator and GRU generator for predicting stock prices. The model is trained using 36 input variables and tested on the closing price of Apple. Despite the challenges of stock price prediction due to various external factors, our experimental results show that the GAN model can still achieve good prediction accuracy. We acknowledge that there is still room for improvement and look forward to future research on more effective data processing methods and models for predicting stock prices with greater accuracy.

References

1. L. Alzubaidi, J. Zhang, A.J. Humaidi, A. Al-Dujaili, Y. Duan, O. Al-Shamma, J. Santamaría, M.A. Fadhel, M. Al-Amidie, L. Farhan, Review of deep learning: concepts, CNN architectures, challenges, applications, future directions. J. Big Data, **8**(1), (2021). https://doi.org/10.1186/s40537-021-00444-8
2. S. Bahng, I. Oh, J.G. Kim, G.K. Choo, Stock price prediction using conditional generative adversarial networks. Proc. G-IoT **2018**, 13–17 (2018)
3. H. Banaee, M. Ahmed, A. Loutfi, Data Mining for wearable sensors in health monitoring systems: a review of recent trends and challenges. Sensors **13**(12), 17472–17500 (2013). https://doi.org/10.3390/s131217472
4. Y. Cho, B. Choi, Neural network architecture for predicting stock price index by combining chart pattern recognition and fundamental analysis, in *Proceedings of the 25th KIPS computer society conference* (2018)
5. H.-W. Dong, W.-Y. Hsiao, L-C. Yang, Y.-H. Yang, MuseGAN: Multi-track sequential generative adversarial networks for symbolic music generation and accompaniment. in *Proceedings of the*

AAAI Conference on Artificial Intelligence, vol. 32, issue no 1 (2018). https://doi.org/10.1609/aaai.v32i1.11312
6. A. Esteva, K. Chou, S. Yeung, N. Naik, A. Madani, A. Mottaghi, Y. Liu, E. Topol, J. Dean, R. Socher, Deep learning-enabled medical computer vision. Npj Digit. Med., **4**(1), (2021). https://doi.org/10.1038/s41746-020-00376-2
7. I. Goodfellow, J. Pouget-Abadie, M. Mirza, B. Xu, D. Warde-Farley, S. Ozair, A.C. Courville, Y. Bengio, Generative adversarial nets. in *Advances in neural information processing systems* (2014), pp. 2672–2680
8. S. Kiranyaz, T. Ince, G. Turan, A. Weitzenfeld, S. Ince, M. Gabbouj, Stock market analysis using generative adversarial networks for fuzzy time series. Inf. Sci. **515**, 214–227 (2020)
9. W. Li, Q. Zhang, J. Deng, Q. Tang, Utilize big data mining and machine learning methods to detect bank loan fraud based on illegal transactions. Int. Conf. Big Data Smart Comput., 125–129 (2019)
10. L. Liu, Generative adversarial network for stock price prediction. L. (2020). arXiv Preprint arXiv:2001.04548
11. S. Otomo, G. Kawabe, Y. Sayama, H. Asama, M. Hatanaka, K. Tsuda, T. Kagawa, Explaining the distributional changes in Japan's coastal fishing villages causing price variation of fish. PLoS ONE **15**(5), 1–18 (2020)
12. K. Sun, Y. Yuan, S. Ji, H. An, The application of big data technology in data-driven decision-making in financial systems. Sci. Rep. **7**(1), 10556 (2017)
13. W. Y. Wang, S. Singh, J. Li, Deep Adversarial learning for NLP. ACLWeb. Association for Computational Linguistics, (2019) https://doi.org/10.18653/v1/N19-5001
14. G. Wang, T. Wang, Y. Wen, Y. Gu, Y. Chang, Deep learning-based stock price prediction: a generative adversarial imitation learning approach. Sci. China Inf. Sci., 1–15 (2019)
15. Z. Zheng, L. Zheng, Y. Yang, *Unlabeled samples generated by GAN improve the person re-identification baseline in vitro* (2017). Openaccess.thecvf.com. https://openaccess.thecvf.com/content_iccv_2017/html/Zheng_Unlabeled_Samples_Generated_ICCV_2017_paper.html
16. H.T. Zhu, J.F. Yang, K. Zhao, X. Xie, An artificial intelligence-based stock investment decision support system. J. Ambient. Intell. Humaniz. Comput. **9**(4), 1029–1038 (2018)
17. I. Goodfellow, J. Pouget-Abadie, M. Mirza, B. Xu, D. Warde-Farley, S. Ozair, Y. Bengio, Generative adversarial networks. Commun. ACM **63**(11), 139–144 (2020)

Chapter 25
Research on the Risk Contagion Effect in China's Interbank Market from the Perspective of Debt

Yuqing Cui

Abstract The global financial crisis caused by the US subprime mortgage crisis in 2007 shows that the banking crisis has obvious negative externality and infectivity. This paper argues that the creditor and debt relationship formed by actual business association between banks becomes the basis of direct risk contagion, and the network structure of Chinese banks is the medium of risk contagion. In this paper, a scale-free network model was established, and the risk transmission threshold was determined by SIS and SIR Models. Secondly, a matrix is established based on the creditor's debt relationship between banks to determine the conditions of risk contagion. The balance sheet data and interbank data of 19 sample banks are used to simulate and empirically analyze the effects of risk contagion between banks under external shocks. The results show that: first, the banks with obvious risk contagion effect are usually state-owned banks, and the failure of small and medium-sized banks has little impact on the market; Second, the overall risk contagion effect of China's interbank market is small. Although it may lead to asset losses within the system, the number of failed banks is small and will not cause large-scale contagion.

Keywords Inter-bank market no scale network · Credit shock · Default loss rate · Risk contagion effect

25.1 Introduction

The current research on the measure of risk contagion and spillover effect focuses on the ① matrix method: Toivanen [1] estimated the risk of crisis contagion using the maximum entropy method to estimate the risk, and used the Finnish interbank market data from 2005 to 2007 as a sample for simulation and demonstration. Mistrulli and Casolaro [2] used the maximum entropy method to establish a matrix of the actual

Y. Cui (✉)
School of Economics, Sichuan University, Wangjiang Road 29, Chengdu 610065, Sichuan, China
e-mail: CuiYuqing606@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_25

data of the assets and liabilities in the Italian interbank market, which exposed the disadvantages of the maximum entropy method, which was reflected in the deviation from the actual situation. ② Network analysis: Gai et al. [16] to build a simple financial system involving interrelated entities and simulate the probability and spread of infectious defaults after an unexpected impact, the model provides a clear feature of the balance sheet, clear direction of claims and obligations of financial institutions. Castro [4] In the GIPSI network structure of Greece, Ireland, Portugal, Spain and Italy, using between the first quarter of 1997 and the third quarter of 2011, we found that the bank credit risk was significantly affected by the macroeconomic environment. ③ VaR method: Bollerslev [5] Based on the ARCH model, it proposes the GARCH model which is more suitable for the VaR model and introduces volatility estimation. From a micro perspective, the paper uses the risk position data exposed by listed banks and policy banks in China's interbank market to simulate the contagion process of China interbank market under the combined impact of credit risk, credit risk and liquidity risk and analyzes the contagion effect of interbank market risk.

25.2 Overview of Scale-Free Network and Characteristics of Chinese Interbank Networks

Scale-free network is a network whose degree distribution conforms to the power law distribution. Its typical characteristics are that a large number of connections are concentrated in a few nodes, while the other nodes have only very few connections. Scale-free network was proposed by Albert and Barabasi in 1999. When Albert and Barabasi calculate the number of world Wide web pages with exactly k connections, they found that the connection distribution of web pages follows the "power law", that is, the probability of any node connecting with other k nodes is proportional to $k^{-\alpha}(p(k) = Ck^{-\alpha})$.

With the continuous deep analysis of Albert and Barabasi, two scholars found the reason why scale-free networks obey the power law. Later studies found that scale-free networks not only obey the "power law" but also the power exponential α in the $k^{-\alpha}$ term of the power law, usually between 2 and 3.

No scale network has serious heterogeneity, namely the connection of different nodes in the scale network (degree) serious imbalance: a few network called Hub points (distribution nodes) nodes has a large number of connections, and most nodes are only a small number of connections, therefore, a few Hub points for scale network plays a leading role. Meanwhile, the scale-free network is also robustness and fragile.

In China's inter-bank market, large state-owned commercial banks and joint-stock banks have a leading position both in terms of asset scale and inter-bank asset scale, and are in the "central" position in the bank network structure. Even if the upper banks belong to different types, thus forming a complete market structure. The lower banks have a loan relationship with the upper banks, but the lower banks borrow little to each other. In the same logic, it is assumed that there is no loan relationship between some banks. According to the previous analysis of the network structure of banks of China, the network of banks of China can be divided into the core layer and the peripheral layer. It is assumed that the core layers have a loan relationship, and the peripheral layer has a loan relationship with the core layer, but there is no loan relationship between the peripheral layers.

Therefore, There are only a few banks with many other connections, Most banks have relatively few associated banks, therefore, If the banks in the interbank market are seen as a node in the network, The banks in the interbank market constitute a large network with many members, Then this network exactly fits the characteristics of a scale-free network, therefore, In this paper, the interbank structure in the interbank market can be regarded as a scale-free network structure, Giving each bank in the market amounts to a node in the network structure, When the two banks are associated, There is an edge connection between two nodes. Risk contagion between two banks is considered to be virus infection between two nodes in a scale-free network.

25.3 Interbank Market Risk Contagion Threshold

Because of the large interbank market, the banks have many members. In general, the closer the correlation between banks in the interbank lending market, the greater the influence between each other. Therefore, once a bank in the market defaults, the association between the banks is bound to affect the associated other banks in the market. Therefore, the contagion of interbank risk in the lending market is similar to the spread of a virus on a computer network. There are many models for virus transmission in the network, but the most accepted and widely used models are the SIR (susceptible-infected-removed) model and the SIS (susceptible-infected-susceptible) model.

In 2000 and 2001, Hethcote, Pastor-Satorras and Vespignani conducted detailed analysis of SIR based on scale-free network, and obtained important threshold conclusions that the transmission rate of viruses in a scale-free network.

In this paper, the organizational structure of the banks in the inter-bank market can be regarded as a scale-free network structure. Giving to each bank in the market is equivalent to a node in the network structure. When two banks are related, it is considered that there are edge connections between two nodes. The risk infection between two banks is considered to be a virus between two nodes in a scale-free network. The degree of a node is defined as the number of edges connecting the node, that is, the number of interbank banks associated with the bank. The degree distribution represents the probability distribution function $P(k)$ of the node degree, which refers to the probability that the node is connected with k edges. Usually, the degree distribution function $P(k)$ of the scale-free network satisfies.

$$P(k) = Ck^{-\alpha} \tag{25.1}$$

where C is the normalized constant and α is the power-law exponent.

In the SIS (susceptible-infected-susceptible) model, Each node in the network is in one of the following states: susceptible to infection, The S-state, for short, Nodes in this state do not infect other nodes, But it may be infected by other nodes; Infection status, Short for state I, The node in this state is already infected with the virus and infectious; the propagation rule of the SIS model is at any time t, If there is an edge connection between the S-state node and the I-state node, Then the S state node will change to the I state node with probability δ, If using the $s_k(t)$, $i_k(t)$ respectively represent S at time t during virus transmission, Density of the k-degree nodes in state I, The propagation process of SIS model in the scale-free network can be represented by the following system of differential equations:

$$\frac{di_k(t)}{dt} = -i_k(t) + \delta k(1 - i_k(t))\theta(t) \tag{25.2}$$

$$i_k(t) + s_k(t) = 1 \tag{25.3}$$

$$i_k(0) \approx 0, \;\; s_k(0) \approx 1 \tag{25.4}$$

where $\theta(t)$ is the probability that any edge points to an infected node at time t.

Assuming that the infectious bank in the interbank market is limited and there is no super infectious person, in this paper, the maximum contagion capacity of any node (each bank in the interbank market) is defined as follows:

$$\beta = \sum_{i \neq j} kr_{ij} \tag{25.5}$$

r_{ij} is the correlation degree of two nodes i and j (i. e., the correlation degree of bank j and bank i in the interbank market, and the correlation degree between the creditor bank and the debt bank in the interbank market is defined as the ratio of the loan amount to the total assets), which k is the degree of the node. When the maximum infectious capacity is $\beta = \sum\limits_{i \neq j} kr_{ij}$, according to the calculation formula of $\theta(t)$ defined by Pei Weidong et al.:

$$\theta(t) = \frac{\sum \min\{k, \beta\} P(k) i_k(t)}{\langle k \rangle} \tag{25.6}$$

where the $\langle k \rangle = \sum kP(k)$ is the average degree of the network nodes.

Let m be the minimum degree in the network. When the power law index α is between 2 and 3, that is, $2 < \alpha < 3$, the threshold of virus transmission between the nodes in the scale-free network can be obtained as follows:

$$\eta = \frac{3-\alpha}{m\left[\left(\frac{\beta}{m}\right)^{3-\alpha} - (\alpha - 2)\right]} \tag{25.7}$$

When the $\alpha = 3$,

$$\eta = \frac{1}{m\left[1 + \ln\frac{\beta}{m}\right]} \tag{25.8}$$

Obviously, it is not difficult to see from the above analysis, in SIS model, when the power law index meet $2 < \alpha \leq 3$ scale-free network, risk infection threshold λ is present, and η only with the network minimum m and maximum infection ability β relationship, and has no relationship with the size of the network, when $\beta \to +\infty$, $\eta = 0$, virus is always able to spread in the scale-free network.

To sum up, when the power law index meets $2 < \alpha \leq 3$, the risk is, and the contagion threshold in the interbank market is related to the maximum contagion capacity between the banks. The stronger the maximum contagion capacity, the smaller the transmission threshold, the more likely the risk is to spread in the market.

25.4 Model Construction

Based on the content of this paper, we limit the path of risk contagion to the creditor and debt association formed by banks through inter-bank lending business, which is a direct contagion path. Debt banks fall into liquidity difficulties due to external shocks. If their own capital cannot fully absorb the losses caused by the shocks, the banks will be insolvent and fail.

25.4.1 Premise Assumptions

To facilitate the analysis of the infectious process, we set the preconditions:

The first external shock is limited to the collapse of a single bank in the interbank market, rather than the collapse of the whole system, that is, there is no non-infectious systemic risk.

The asset loss of the second bank shall be borne by its core capital. If the asset loss exceeds its core capital C, the bank will go bankrupt;

Third, in the process of contagion, the loss rate of bank assets is always expressed in λ.

Fourth, ignore the factors such as financial security relief and bankruptcy cost, and assume that the risk of capital shock occurs at the same time for every bank in the market, and the bank failure occurs at the same time in the same round.

Fifth, in the risk contagion studied in this chapter, there is no indirect contagion, only the risk contagion based on the related relationship between creditor's rights and debt, that is, there is no inter-bank risk contagion under the path of holding homogeneous assets.

25.4.2 Model Construction and Solution

Since the financial statements of Chinese banks only disclose the total assets and total liabilities in the interbank market, we cannot obtain the detailed data of the two parties in the interbank market. Therefore, we need to estimate the credit assets and credit liabilities of each bank in the interbank market according to specific models. We assume that there are N banks in the interbank market, and the value of N is greater than 2. Matrix NX is used to represent the debt relationship between banks due to inter-bank interbank connection. The interbank lending relationship can be represented in the following matrix:

$$
\begin{array}{cc}
X = \begin{bmatrix} x_{11} & \dots & x_{1j} & \dots & x_{1n} \\ \dots & \dots & \dots & \dots & \dots \\ x_{i1} & \dots & x_{ij} & \dots & x_{in} \\ \dots & \dots & \dots & \dots & \dots \\ x_{n1} & \dots & x_{nj} & \dots & x_{nn} \end{bmatrix} &
\begin{array}{l} \sum_{i=1}^{n} x_{i1} = x_{1g} \\ \sum_{i=1}^{n} x_{i1} = x_{2g} \\ \sum_{i=1}^{n} x_{i1} = x_{ng} \end{array} \\
\sum_{i=1}^{n} x_{i1} = x_{g1} \quad \sum_{i=1}^{n} x_{ij} = x_{gj} \quad \sum_{i=1}^{n} x_{i1} = x_{gn} &
\end{array}
$$

x_{ij} indicates the borrowing position of bank i to bank j, namely the nominal liability of bank i to bank j. x_{ij} 0, which is due to the nominal borrowing amount of banks in the market is non-negative. At the same time, because it is impossible for banks to borrow from themselves, the elements on the main diagonal of the matrix are all 0, that is, Xii = 0. $x_{ig}= \sum_{j=1}^{n} x_{ij}$ represents the bank i's lending position in the entire interbank market.

Below, we try to solve the matrix. As the detailed data of the interbank lending transaction are not disclosed, apparently the value of x_{ij} is not known, but the x_{ig} of the total lending position of each bank in the lending market is available.

Since it is not clear how many banks each bank borrows in the market, we cannot tell how many sides are connected between the nodes in the interbank network. At the same time, because the interbank network structure in the lending market is similar to the non-free network structure, this paper takes the mathematical expectation of the number of the banks offered by each bank as the number of the banks offered in the interbank market, namely $\sum_{k=1}^{n} kP(k)$.

It means that bank i borrowed from $\sum_{k=1}^{n} kP(k)$ banks in the interbank market, where k indicates the number of banks with a lending relationship with bank i, that is, the number of edges connected to the central node i in the scale-free network. $p(k)$ indicates the probability that the number of banks lending related to i banks is k.

We use $\sum_{\mathrm{k}=1}^{\mathrm{n}} \mathrm{k}P(\mathrm{k})$ to calculate and represent the number of banks that are related to bank i, because we do not know that I can borrow positions from each bank

$$\frac{\mathrm{x_{ig}}}{\sum\limits_{\mathrm{k}=1}^{\mathrm{n}} \mathrm{k}P(\mathrm{k})} \tag{25.9}$$

Represents bank i's lending position to each bank, and $x_{i\cdot}$ represents the total lending position of bank i in the entire interbank market.

25.5 Risk Contagion Effect Under the Impact of Credit Default Risk

In order to investigate the impact of credit default risk on the risk contagion effect in the interbank market, this paper explores the risk contagion effect from the established default loss rate, the data of different years and the different default loss rate, and the average data of different years.

25.5.1 Identification of Infection and Infection Process

We explore the process of risk contagion in the interbank market under the impact of credit default. In the market, a bank first went bankrupt and defaulted due to external shocks. Without considering the rollover risk, that is, assuming that the bank can extend its maturing debt, the risk contagion process is as follows:

The first round: the bank i defaults by external impact, and the creditor bank j with inter-bank lending connection with I is impacted.

If at this time

$$\frac{\lambda \mathrm{x_{i}}_{g}}{\sum\limits_{\mathrm{k}=1}^{\mathrm{n}} \mathrm{k}P(\mathrm{k})} \leq C_{\mathrm{j}} \tag{25.10}$$

It means that after the first round of shock, the own capital of bank j can absorb the losses caused by bank i interbank default, and bank j does not default, where λ means the default loss rate, and C_{j} is the core asset of bank j;

like

$$\frac{\lambda x_{ig}}{\sum_{k=1}^{n} kP(k)} > C_j \tag{25.11}$$

It means that after the bank j defaults by the first round of shock, then the risk continues to spread contagion in the interbank market, so the second round of contagion occurs.

Second round: If the bank impacted in the first round of contagion defaults, the bank with the lending relationship t will be impacted, if so after the first two rounds

$$\sum_{j} \frac{\lambda x_{jg}}{\sum_{k=1}^{n} kP(k)} \leq C_t \tag{25.12}$$

It means that after the first two rounds of impact, the asset loss of the bank t is less than the core assets, and the bank t t can resist the impact without default;

like

$$\sum_{j} \frac{\lambda x_{jg}}{\sum_{k=1}^{n} kP(k)} > C_t \tag{25.13}$$

It means that after the first two rounds of shocks, the bank t cannot fully absorb the asset losses and default. At this time, the risk continues to spread the contagion in the interbank market, so the third round of contagion occurs.

Similarly, in the m round of infection, the banks that defaulted after the previous m-1 round of shock continue to spread the risk to the bank w associated with inter-bank lending,

like

$$\sum_{f} \frac{\lambda x_{f\nu}}{\sum_{k=1}^{n} kP(k)} \leq C_h \tag{25.14}$$

It means that the bank w did not default after the previous m-1 round of impact;

like

$$\sum_{f} \frac{\lambda x_{f\nu}}{\sum_{k=1}^{n} kP(k)} > C_h \tag{25.15}$$

It means that the bank h defaulted after the previous m-1 round of shock, and the risk continues to spread contagion in the inter-bank market, so the m + 1 round of contagion occurs. Until many rounds of shocks in the interbank market, until the core assets of the bank can absorb all the default losses in the market, all the banks participating in the inter-bank lending business will no longer fail or default due to the impact, and the risk contagion will stop, otherwise the risk contagion will continue to expand or even affect the whole market.

25.5.2 Selection of Sample Banks and Data Processing

According to the above analysis of the characteristics and network structure of risk contagion in China's inter-bank market, it is believed that the network structure of China's inter-bank market is obviously non-scale, and almost all banks are associated with large banks with the characteristics of "central node", while small banks are not connected with each other. In small banks, the asset scale of rural credit cooperatives and urban commercial banks accounts for a very small market share, and there is no connection with each other, so it is of no practical significance to study their risk contagion effect alone. In addition, based on the consideration of data availability and research focus, this paper selects 16 listed banks, 3 policy banks and 19 banks from the fourth quarter of 2013 to 2020 as the sample data of the research. In terms of data selection, the assets in the bank's balance sheet are equal to the sum of interbank and split funds, and the liabilities are equal to the sum of interbank and split assets in the balance sheet. Here we edit the 19 banks into code for easy comprehension (Table 25.1).

25.5.3 Selection of Default Loss Rate

Based on the risk determination conditions analyzed above, this paper stipulates that a bank fails when its loss is greater than its core capital. Therefore, the default loss rate (LGD) here is a percentage of the total assets of the debtor once the debtor defaults, and the value is directly proportional to the degree of loss. On the other hand, from the perspective of the recovery situation of bank loans, because $\lambda = 1$-recovery rate, the default loss rate determines the degree of bank loan recovery. By combing through other research literature, this paper holds that the default loss rate of non-performing assets can be indirectly estimated through the recovery rate of Chinese asset management companies. Because the traditional fixed value method has strong subjective factors, it may deviate from the actual value, which has a certain impact on the estimation of the risk contagion effect in the interbank market. Therefore, this paper simulates it at different default loss rates to ensure the accuracy of the results.

Table 25.1 Sample banks and codes

The type of bank	Code of the bank name	Bank type code bank name
State-owned bank	B1 Industrial and Commercial Bank of China	Joint-stock commercial bank
	B2 Bank of China	B9 Shanghai Pudong
	B3 Agricultural Bank of China	Development bank
	B4 Construction Bank of China	B10 Ping An bank
	B5 Communications Bank of China	B11 Huaxia bank
	B6 China Everbright bank	B12 Societe Generale bank
Joint-stock commercial bank	B7 China Merchants bank	B13 China CITIC bank
		City Commercial bank
	B8 China Minsheng bank	B14 Bank of Beijing
		B15 Bank of Nanjing
		B16 Bank of Ningbo
		Policy bank
		B17 Export-Import Bank
		B18 Agricultural development bank
		B19National
		Development bank

25.5.4 Empirical Results

The simulation results show (Table 25.2 and Fig. 25.1) that the risk contagion effect of China's interbank market varies under different default loss rates. The higher the default loss rate, the more the number of banks with contagion effect, the number of bankrupt banks and the capital loss in the whole market. To be specific: when the default loss rate exceeds 80%, all state-owned banks have contagion effect, and the infectious round is generally more than 2 rounds, and the infected banks are 2–3, resulting in the asset loss of the whole system accounting for more than 38%. After the default loss rate is lower than 70%, the contagion effect of the risk is significantly weakened. When the default loss rate drops from 70 to 60%, the risk contagion only causes the collapse of one bank, and the contagion round is only one round. When the default loss rate is lower than 50% (including 50%), there is no bank with contagion effect in the market, which does not cause any bank to fail, that is, no risk contagion occurs. But there are still asset losses from the impact of defaults, which the bank's core capital can withstand.

Table 25.2 Simulation results of credit default risk shock under different default loss rates

Default loss rate of λ (%)	Banks with a contagion effect	The number of bank failures	Cause transmission rounds	Cause capital losses in the banking system of (%)
100	B_1, B2, B3, B4, B5, B7, B9, B12	3	3	47.89
90	B_1, B2, B3, B4, B5, B9	2	2	41.67
80	B_1, B2, B3, B4, B5, B9	2	1	38.36
70	B_1, B2, B3, B4, B5	1	1	35.71
60	B_1, B2, B4	1	1	29.46
50	None	0	0	21.23
40	None	0	0	17.67
30	None	0	0	13.12
20	None	0	0	9.01
10	None	0	0	4.89

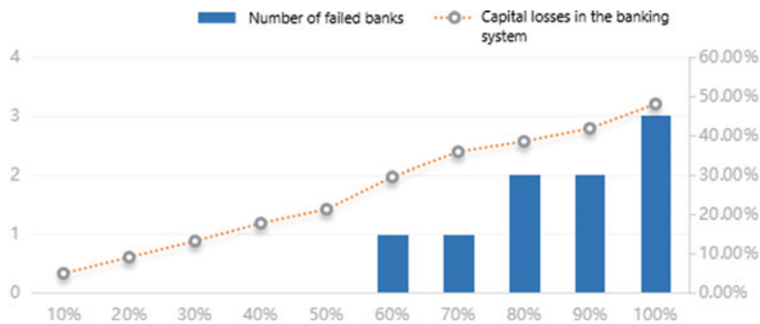


Fig. 25.1 Risk contagion effect of credit default impact under different default loss rates

25.6 Empirical Conclusions

Based on the simulation results of the risk contagion effect in Chinese interbank market, the following empirical conclusions are obtained:

(1) Based on the non-scale of the Bank of China network, which is divided into core layer and peripheral layer, there must be central nodes. State-owned banks are in a relatively core position in the whole system, especially the Bank of China, which is the most important central node in the inter-bank network. Its collapse will cause stronger contagion effect and asset loss of the system. The Industrial and Commercial Bank of China, China Construction Bank, Agricultural Bank of China, Bank of Communications, Bank of Communications, Industrial Bank of

China, Shanghai Pudong Development Bank are also more important, at the core of the bank network. Other banks, especially the joint-stock banks belonging to the city commercial banks, are in the outer network, with very little correlation with each other and weak contagion effect;

(2) In general, the risk contagion effect in China's interbank market is small. When the default loss rate is below 100%, the number of banks that fail is very small, and although there are still asset losses in the market, they will not cause large bank bankruptcies. However, the larger the scale of inter-bank lending business is, the stronger the effect of risk contagion is. Five state-owned Banks is the main source of infection, this is due to the larger business scale, their risk exposure in the interbank market position is larger, and the correlation between other Banks is higher, so that the risk infection effect more intense, among them, the bank of China collapse caused by the strongest infectious effect, followed by industrial and commercial bank, they have systematic importance, should cause the focus of the regulatory monitoring.

(3) The risk contagion effect is related to the core capital level. Banks with high core capital levels can rely on core capital to absorb losses from contagion, and insolvency will not occur. From this perspective, the main reason why policy banks are affected by risk contagion is their low core capital level.

(4) The risk contagion effect of China's interbank market is time-varying. By assigning a 70% value to the default loss rate, the contagion effect varied slightly between years from 2013 and 2020. The overall decline is rising, with more and more connections between banks in recent years, so the greater the contagion. In addition, in the time nodes of 2013, 2015 and 2020, the contagion effect is relatively obvious, indicating that the contagion effect is affected by the stock market assets held by banks, and external factors such as the epidemic will also affect the risk contagion.

References

1. M. Toivanen, Financial interlinkages and risk of contagion in the Finnish interbank market. Bank Finl. Res. Discuss. Pap., **6**, (2009)
2. P. Mistrulli, L. Casolaro, *Distance, lending relationships and interest rates* (Bank of Italy, mimeo, 2010)
3. M. Blavarg, P. Nimander, Interbank exposures and systemic risk. in *Risk measurement and systemic risk-proceedings of the third joint central bank research conference* (Bank for International Settlements, Basel, 2022), pp. 287–305
4. V. Castro, Macroeconomic determinants of the credit risk in the banking system: The case of the GIPSI. Econ. Model., **31**, 672–683 (2013)
5. T. Bollerslev, Generalized autoregressive conditional heteroskedasticity. Econ. Model. **31**(3), 307–327 (1986)
6. G. Bei, Z. Anqi, T. Xiaofen, The impact of interbank changes on the operation stability of commercial banks —— Empirical analysis of microscopic data of 16 listed banks in China. Econ. Res. Nankai Univ. **05**, 78–97 (2019)

7. Mass troops, *Research on systemic risk contagion from the perspective of the banking network* (Fudan University, 2013)
8. C. Borio, C. Furfine, P. Lowe, Procyclicality of financial systems and financial stability. BIS Papers No.1. Bank Int. Settl., (2001)
9. E. Nier, J. Yang, T. Yorulmazer, et al., Network models and financial stability. J. Econ. Dyn. Control., **31**(6), 2033–2060 (2007)
10. S. Ba, S. Changzheng, Discuss the reform of financial regulatory system from the perspective of financial structure. Contemp. Financ. **09**, 43–51 (2016)
11. C H. Furfine, Interbank exposures: Quantifying the risk of contagion. J. Money, Credit. Bank., 111–128 (2003)
12. J. Ma, X. Fan, Y. Cao, Risk estimation and systematic characteristics analysis of bilateral contagion in China's interbank market. Econ. Res. **142** (01), 68–78 (2007).
13. A. Hasman, M. Samartín, Information acquisition and financial contagion. J. Bank. Financ., **32**(10), 2136–2147 (2008)
14. X. Freixas, J.C. Rochet, *Microeconomics of banking* (MIT press, 2008)
15. M. Boss, M. Summer, S. Thurner, Contagion flow through banking networks. In *International conference on computational science* (Springer, Berlin, Heidelberg, 2004), pp. 1070–1077
16. P. Gai, S. Kapadia, S. Millard et al., Financial innovation, macroeconomic stability and systemic crises. Econ. J. **118**(527), 401–426 (2008)
17. F. Allen, A. Babus, E. Carletti, *Financial connections and systemic risk* (National Bureau of Economic Research, 2010)
18. Z. Li, Y. Li, Positive study on the risk of "contagion" in China interbank lending market. Financ. Trade Res., (06), 51-58 (2005)
19. H.S. Disemadi, A.I. Shaleh, Banking credit restructuring policy amid COVID-19 pandemic in Indonesia. J. Inov. Ekon., **5**(02), (2020)
20. Z. Yi, H. Xiaofeng, W. Baoxiu W, Study on the influence of macroeconomic information release on the contagion effect of the international financial crisis. Manag. Rev., **29** (04), 3–11 + 24 (2017)
21. W. Yi, H. Li, Model of bank run and risk contagion caused by information asymmetry. J. Beijing Norm. Univ. (Nat. Sci. Ed.) **48**(03), 313–317 (2012)
22. D. Chao, C. Xuejun, Research on the financial contagion risk model based on complex networks. Chin. Manag. Sci. **22**(11), 11–18 (2014)
23. N. Xiaojian, C. Xinyu, Research on multi-layer topology structure and stability of China A-share market — Based on complex network analysis method. NTU Bus. Sci. Rev. **03**, 36–58 (2021)
24. Fei Zi micro, *Research on interbank risk contagion and capital slow-release mechanism based on homogenization* (Hunan University, 2019)

Chapter 26
Stock Price Prediction Using Optimized Hybrid Model

Deepti Patnaik, N. V. Jagannadha Rao, Brajabandhu Padhiari, and Srikanta Patnaik

Abstract Forecast has a vital role to be played in all fields such as business and industry, medicine, social science, politics, finance, government, economics, environmental sciences and others. Recently it is observed that the stock price forecasting has gained a lot of interest in common people as well as in business. Keeping in view of this demand, here a hybrid prediction model is proposed and it is optimized by Jaya algorithm. The hybrid model used in this work is a Convolutional Neural Network–Long Short-Term Memory (CNN-LSTM) network model. Stock prices of various challenging stock exchanges of the globe such as: NIFTY 50, Standard and Poor 500, Dow Jones, Nikkei 225 is used here for prediction and validation. The proposed model is analyzed in terms of Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE).

Keywords Predication · Stock price · Hybrid model · Jaya algorithm · Optimization · Root mean square error

26.1 Introduction

Forecast, a scientifically calculated guess is a challenging task. Forecasting the future is always a mystery and it is observed from ages about the human nature that human beings tend to show more curiosity about the future. Owing to the rise of social media and few applications the forecasting attracted the investors. These financial sector advances are responsible for the economic growth and stability [1]. The various market complexities make the forecast a tuff task in the business domain. Despite of these difficulties faced it is essential for the business so that the future plan of action can be studied such as allocation of resources, foreseen costs in the forthcoming

D. Patnaik (✉) · N. V. J. Rao
GIET- University, Gunupur, Rayagada, Odisha 765 022, India
e-mail: deepti.patnaik@giet.edu

B. Padhiari · S. Patnaik
IIMT Bhubaneswar, Khurda, Odisha 751 003, India

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_26

time [2]. The investors in order to get higher rate of return on their investments thy monitor it in real time. Hence with the help of forecasting the investors can safeguard their securities by eliminating the risk [3].

It is known fact that a forecast is nothing but a calculated guess in a scientific manner. This calculated guess is very much essential for each and every profit-making business organization [4]. Basing on this, the strategies is developed for future. A good forecast must be easily understandable, reliable, accurate, time efficient and simple. The forecasting problems are categorized as short-term forecast, medium-term forecast and long-term forecast [5]. The prediction of future events up to a small time period fall under the category short-term forecast. Small time period in particular is a period ranging less than a year. While medium-term forecast is predicting future up to one to two years. Any forecast extending the medium-term forecast is long-term forecast. Many organizations follow short and medium term forecast for budgeting or project selection while long-term forecast is required when there is a strategic planning. However, the short- and medium-term forecast revolves around modeling, extrapolating or pattern recognition in the historical data [6].

A stock market forecasting refers to estimation of future possible direction of price basing on historical data. It is a time series problem. At the same time forecasting the stock market is a challenging task as it is affected by many factors and moreover it is non-linear in nature. There is no accepted approach for stock market forecast [7]. The present approaches have their own pros and cons. Stock market forecasting refers to the process of using various analytical techniques and methods to predict the future performance of stock prices in the financial markets. It involves analyzing historical market data, economic indicators, company financial reports, news, and other factors that can impact stock prices to make predictions about future market trends. Forecasting stock prices is an important activity for investors, traders, and financial analysts, as it helps them make informed decisions about buying or selling stocks, managing risks, and optimizing investment portfolios. However, it is important to note that stock market forecasting is a complex and challenging task, as it involves dealing with multiple variables and uncertainties that can affect market performance [8].

26.2 Convolutional Neural Network (CNN) Model

A Convolutional Neural Network (CNN) is a type of artificial neural network that is particularly suited for analyzing visual imagery. It minimizes human effort by detecting the features and high accuracy. It is designed to recognize patterns in two-dimensional arrays, such as images, and can be used for image classification, object detection, prediction and image segmentation. CNNs consist of multiple layers of interconnected nodes that perform a series of operations on input data. The first layer typically applies a set of convolutional filters to the input image, extracting low-level features such as edges and corners. Subsequent layers apply additional filters, building up more complex features by combining the outputs of the previous layer [8]. Pooling layers are often used to reduce the dimensionality of the feature maps, making the network more efficient and reducing the risk of over fitting. At the end of the network, one or more fully connected layers are used to perform the final classification or regression task, depending on the application. During training, the network adjusts the weights of its connections based on a set of labeled training data, so that it can learn to recognize features and patterns in new images. Overall, CNNs have shown remarkable performance in a wide range of image processing tasks, and have become a cornerstone of modern computer vision systems. The basic architecture of CNN has main parts such as feature extraction, pooling layers and fully connected layer. The process of separating and identifying various features for analysis through a convolution tool is feature extraction. The network of feature extraction consisting of many pairs of convolutional layers utilizes the output from the process to predict the class which is based on the features extracted from the previous stages. These new features are the summary of the existing features of the original data set [9].

26.3 Long Short-Term Memory(LSTM) Model

LSTM stands for Long Short-Term Memory, which is a type of recurrent neural network (RNN) architecture that is designed to handle the problem of vanishing gradients in traditional RNNs. LSTMs, are capable of learning long-term dependencies by selectively remembering and forgetting information over multiple time steps. This is achieved through the use of specialized memory cells and gating mechanisms that control the flow of information through the network. The memory cells are able to store information over long periods of time, while the gating mechanisms allow the network to selectively update, forget or output information. LSTMs have been widely used for a variety of tasks, such as natural language processing, speech recognition, and image captioning. They have been shown to be particularly effective in tasks that require modeling of long-term dependencies, such as predicting the next word in a sentence or generating captions for a sequence of images. Since the stock market is highly volatile and uncertain, the traditional approaches fail to predict accurately. However, it is found by the researchers that LSTM network can forecast the stock prices as it is good at processing nonlinear financial time series [10].

26.4 Jaya Optimization Algorithm

The Jaya algorithm is a metaheuristic optimization algorithm that was introduced in 2014 by R. V. Rao. It is a population-based algorithm that is inspired by the Jaya (victory) concept in ancient Indian mythology. The Jaya algorithm works by iteratively improving a set of candidate solutions to an optimization problem. At

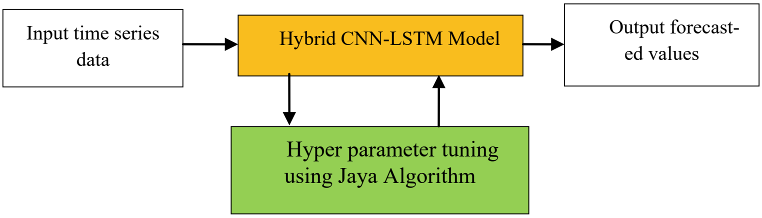


Fig. 26.1 Proposed model

each iteration, the algorithm evaluates the fitness of each solution in the population, and then updates each solution based on the best solution found so far. The updates are performed in a way that promotes cooperation and avoids competition among the solutions. The Jaya algorithm is simple, easy to implement, and has been shown to be effective for a wide range of optimization problems, including engineering design, feature selection, and machine learning. However, like all meta-heuristic algorithms, its performance can be sensitive to the choice of parameters and problem characteristics [11].

26.5 Proposed Model, Results and Discussion

The block diagram of the proposed hybrid model is shown in Fig. 26.1. It uses CNN-LSTM hybrid model and its hyper parameters are optimized by Jaya algorithm. Stock prices of various stock exchanges across the globe namely S and P 500, NIFTY 50, Nikkei 225, DJIA of last 12 years are given as input data. 90% data is used for training purpose and 10% is used for forecasting purpose. At first, the model has been simulated and RMSE value of the closing stock prices has been evaluated. Based on the RMSE value, using Jaya algorithm, the hyper parameters are tuned and fed to the model. This process has been continued, till minimum RMSE is obtained.

26.6 Results and Discussion

Stock prices are volatile, non-linear and noisy in nature. Thus for analyzing its characteristics properly bar charts of recent 10 weeks are plotted. Figure 26.2 shows the bar charts of open, high, low and close prices of the stock indices for recent last 10 weeks (last two weeks of January to March 2023). These bar plots are plotted for volatility analysis. Thus, the traders observe the trends, volatility and price movements more clearly. If the bar height difference between high and low stock prices are more than volatility is more and vice versa. Then the proposed model is experimented in PYTHON simulation environment. RMSE, MAPE, MAE values for various models are obtained for the 10% of the tested data. Tables 26.1, 26.2, 26.3 and 26.4 shows the statistical analysis (RMSE, MAPE, MAE values) of stock price indices of S and P 500, NIFTY 50, Nikkei 225, DJIA. It is observed that the proposed model performs better compared to the existing models in the literature in terms of RMSE, MAPE, MAE values [12–14].

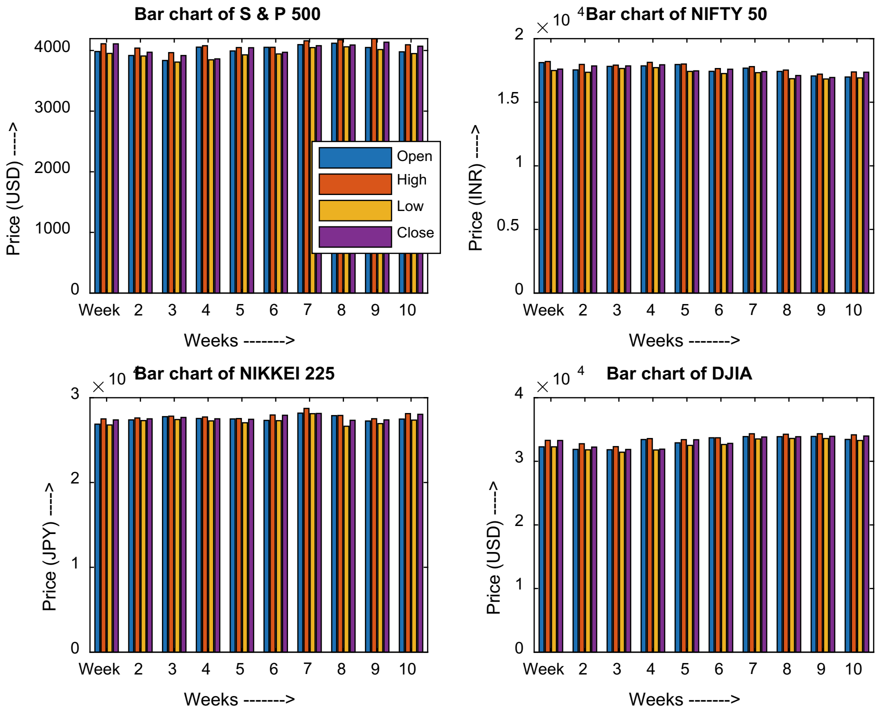


Fig. 26.2 Bar chart of various stock prices

Table 26.1 Statistical analysis of stock price indices of S and P 500

Model used	RMSE	MAPE (%)	MAE
EMD-CNN-LSTM model [12]	14.88	0.611	12.04
CNN—LSTM model optimized by enhanced GWO [14]	8.67	0.366	7.54
Proposed (CNN—LSTM model optimized by Jaya algorithm)	7.31	0.289	6.47

Table 26.2 Statistical analysis of stock price indices of NIFTY 50

Model used	RMSE	MAPE (%)	MAE
SVM prediction model [13]	128.883	0.902	110.33
CNN—LSTM model optimized by enhanced GWO [14]	97.48	0.576	81.27
Proposed (CNN—LSTM model optimized by Jaya algorithm)	96.32	0.459	79.88

Table3 Statistical analysis of stock price indices of Nikkei 225

Model used	RMSE	MAPE (%)	MAE
EMD-CNN-LSTM model [12]	194.17	0.9413	147.18
CNN—LSTM model optimized by enhanced GWO [14]	180.77	0.665	132.34
Proposed (CNN—LSTM model optimized by Jaya algorithm)	178.99	0.567	131.33

Table 26.4 Statistical analysis of stock price indices of DJIA

Model used	RMSE	MAPE (%)	MAE
EMD-CNN-LSTM model [12]	163.56	0.6729	120.97
CNN—LSTM model optimized by enhanced GWO [14]	144.23	0.443	98.45
Proposed (CNN—LSTM model optimized by Jaya algorithm)	141.22	0.337	96.87

26.7 Conclusion

An optimized CNN-LSTM based stock price prediction model is proposed. Jaya algorithm is used for optimization purposes. Using this model, stock prices of various stock markets can be predicted efficiently. The model is analyzed here for various challenging stock exchanges of the globe such as: S and P 500, NIFTY 50, Nikkei 225, Dow Jones. It is found that the proposed model performs better compared to other models as advanced artificial intelligence and optimization techniques have been used. The model will be very useful for traders and investors for future investment.

26.8 Future Scope

The model may further be analyzed for other stock price prediction of various stock exchanges of the globe, gold price prediction, crude oil prediction etc. Various other hybrid models and optimization techniques may also be used for achieving better performance of the prediction scheme.

References

1. U. Ahmed, J. C. W. Lin, G. Srivastava, U. Yun, Enhancing stock portfolios for enterprise management and investment in energy industry. IEEE Trans. Industr. Inf. 1–9 (2022). https://doi.org/10.1109/TII.2022.3214518
2. Y. Zhanga, B. Yana, M. Aasma, A novel deep learning framework: prediction and analysis of financial time series using CEEMD and LSTM. Expert Syst. Appl. (2020). https://doi.org/10.1016/j.eswa.2020.113609
3. J. Wang, J. Wang, Z. Zhang, S. Guo, Stock index forecasting based on a hybrid model. Omega **40**, 758–766 (2012)
4. L. Wei, A hybrid model based on ANFIS and adaptive expectation genetic algorithm to forecast TAIEX. Econ. Model. **33**, 893–899 (2013)
5. D.C. Montgomery, C.L. Jennings, M. Kulahci, *Introduction to TimeSeries Analysis and Forecasting* (Wiley, Hoboken, NJ, USA, 2015)
6. An Introduction to Indian Stock Market (2018) https://www.selfgrowth.com/articles/an-introduction-to-theindian-stock-market
7. A.M. Ashik, K.S. Kannan, Time series model for stock price forecasting in India, in *Logistics, Supply Chain and Financial Predictive Analytics* (Springer, Singapore 2019), pp. 221–231
8. D.M.Q. Nelson, A.C.M. Pereira, R.A.D. Oliveira, Stock market's price movement prediction with LSTM neural networks, in *Proceedings International Joint Conference on Neural Networks (IJCNN), Anchorage, AK, USA* (2017), pp. 1419–1426
9. J. Hong, Analysis of image similarity using CNN and ANNOY. Int. J. Softw. Innov. (IJSI) **10**(2), 1–11 (2022). https://doi.org/10.4018/IJSI.289593
10. W. Budiharto, Data science approach to stock prices forecasting in Indonesia during Covid-19 using Long Short-Term Memory (LSTM). J. Big Data **8**(47) (2021). https://doi.org/10.1186/s40537-021-00430-0
11. C. Huang, L. Wang, R.S. Yeung, Z. Zhang, H.S. Chung, A. Bensoussan, A prediction model-guided jaya algorithm for the PV system maximum power point tracking. IEEE Trans. Sustain. Energy **9**(1), 45–55 (2018). https://doi.org/10.1109/TSTE.2017.2714705
12. H. Rezaei, H. Faaljou, G. Mansourfar, *Stock Price Prediction Using Deep Learning and Frequency Decomposition, Expert Systems with Applications* (Elsevier, 2020)
13. R. Jindal, N. Bansal, N. Chawla, S. Singhal, Improving traditional stock market prediction algorithms using Covid-19 analysis. In: *2021 International Conference on Emerging Smart Computing and Informatics* (*ESCI*) (2021), pp. 374–379. https://doi.org/10.1109/ESCI50559.2021.9396887
14. D. Patnaik, N.V.J. Rao, B. Padhiari, S. Patnaik, Optimized hybrid CNN-LSTM model for stock price prediction. Int. J. Manag. Decis. Mak. Indersci. (2023). https://doi.org/10.1504/IJMDM.2024.10053713

Chapter 27
A Study on the Relationship Between Economic Growth and Carbon Emissions in the Pilot Provinces of China's Carbon Trading Rights

Xia Zixuan, Zitong Wang, and Xu Shaojun

Abstract China's rapid economic growth has achieved great success but at a great cost to the environment. At the same time, carbon emission reduction has become a major trend due to global warming caused by the release of greenhouse gases. In recent years, China has been actively promoting sustainable national economic and social development and responding to global climate change issues. This paper takes the six provinces and cities in the first batch of national carbon trading pilot sites of the National Development and Reform Commission of China as the research object, and accounts for the total carbon dioxide emissions due to energy consumption from 2014 to 2019 according to the criteria of the IPCC national inventory of total greenhouse gas emissions in large and medium-sized cities, and uses VAR models and impulse response functions to analyse the relationship between economic growth and carbon dioxide emissions, and applies The relationship between economic growth and CO2 emissions was analysed using VAR models, impulse response functions and a decoupling index. The empirical findings show that the economic growth of the six provinces was accompanied by a reduction in total carbon emissions, and the two showed a strong decoupling trend overall.

Keywords Economic growth · Total carbon emissions · VAR model · Impulse response function · Decoupling index

X. Zixuan (✉) · Z. Wang · X. Shaojun
Faculty of Economics, Wuhan University of Technology, Wuhan, China

Z. Wang
e-mail: 979975161@qq.com

X. Shaojun
e-mail: 1830012201@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_27

27.1 Introduction

In recent years, greenhouse gases have contributed to global warming and caused a range of problems such as climate extremes. China's rapid economic growth has also caused a great deal of environmental damage. In 2011, six provinces and municipalities, including Beijing, were established as pilot zones for carbon emissions trading rights, which were formally implemented in 2014. Carbon emissions trading is an important mechanism to promote environmental protection using the market, and is of great significance to China's sustainable economic development.

27.2 Review of the Literature

Using relevant studies, Wang and Wang analyzed the correlation between the increase in gross domestic product (GDP) and carbon emissions, and concluded that the main root cause of the rise in China's total greenhouse gases is the economic development model that relies excessively on investment and the industrial-based economic structure [1]. Yaohua and Zhongmin investigated the decoupling relationship between carbon emissions and economic growth rate using the Tapio decoupling index and found that there was a weak decoupling between economic growth rate and carbon emissions in most regions of the country at that time [2]. Chongmei based on the decoupling model and the LMDI model, Han Wenyan et al. explored the decoupling of carbon emissions from energy consumption and economic growth and the drivers of carbon emissions in eight typical large technology countries [3]. The decoupling trend of energy consumption and economic growth and the drivers of carbon emissions in eight typical S&T countries were explored by Wenyan and Yonglan conducted a non-linear analysis of the impact of China's economic growth on carbon emissions by building a panel smoothing regression model while selecting provincial panel data from 1997–2019 [4]. Zhang and Wang developed a factor analysis model of China's carbon emissions based on the EKC model and introduced the analysis of the average distribution margin to quantitatively analyse the contribution of the national economic scale, industry structure and its carbon emission intensity to carbon emissions [5]. Chuzhi et al. used the Kaya model, the Tapio decoupling model and the log-average divisor index (LMDI) model to analyze the spatial and temporal variation, decoupling of economic activities and drivers of carbon emissions using the middle Yangtze River urban agglomeration in China as the study area [6]. Hung Ngo Thai et al. used quantile-to-quantile regression to investigate the relationship between financial development, economic growth, globalization and carbon dioxide emissions in Vietnam from 1990 to 2020 [7]. growth, globalisation and the dynamics of CO At present, the issue of carbon emissions and economic development have become important social hotspots, and there are more studies on the analysis of the influence factors of the two and the empirical analysis using different models, but there are fewer studies on the relationship between carbon emissions and economic growth in pilot areas of carbon trading rights, and although the measurement methods are multiple, the analytical framework is relatively single [8]. Based on the limitations of the existing literature, this paper examines the relationship between carbon emissions and economic growth starting from the more representative carbon trading pilot areas, and uses a VAR model combined with a carbon decoupling index for in-depth analysis [9].

27.3 Data Sources and Measurements

27.3.1 Economic Growth Indicators

Gross Domestic Product (GDP) measures the sum of the value of final goods and services produced and provided by all resident units in a country or region over a certain period of time. Considering the availability of data, GDP was selected as the economic growth indicator for the six provinces from 2014 to 2019.

27.3.2 CO2 Emission Targets

Based on the actual situation of energy consumption and the availability of data, eight typical and representative energy sources, including coal, coke, electricity and fuel oil, were selected for costing from 2014 to 2019. The basic formula for carbon accounting provided by the IPCC was used:

$$\text{Total Carbon Emissions (TCO2)} = \text{Activity Data (AD)} \times \text{Emission Factor (EF)} \tag{27.1}$$

where AD represents the total consumption of various fossil fuels in all industrial production or social consumption social activities that produce greenhouse gas pollution; EF represents the total greenhouse waste gas pollutant emission factor per unit of production or consumption activity volume. At the same time, the calculation of carbon emissions requires the conversion of standard statistics, this paper is mainly based on the specific conversion provided by the China Energy Statistics Yearbook, using the international carbon accounting coefficients provided by the IPCC.

27.3.3 Decoupling Index

The decoupling status in decoupling theory is discriminated by the decoupling index, which is defined in this paper using the decoupling measure proposed by the OECD.

$$Di = (Yi - 1)/(Gi - 1) \tag{27.2}$$

$$Yi = Ei / E1 \tag{27.3}$$

$$Gi = GDPi / GDP1 \tag{27.4}$$

where Ei is the carbon emission value in the end year; E1 is the carbon emission value in the start year; GDPi is the GDP value in the end year; GDP1 is the GDP in the start year

27.3.4 Data Sources and Processing

In this paper, the sample period is from 2014 to 2019, where the GDP and energy consumption of each region are obtained from the database of the National Bureau of Statistics (NBS). 6 provinces' GDP data are obtained by using the GDP deflator (based on 2014) to remove the effect of inflation. Total carbon emissions were calculated using the above data and according to the relevant formulae. In the analysis, variables are taken as logarithms to ensure the linear form of the model and to avoid heteroskedasticity.

27.4 Empirical Analysis

27.4.1 Tests for Stationarity and Co-integration of Variables

The premise of using VAR models is to make the individual variable indicators smooth [6]. In this paper, using SPSS 16.0, the unit root of each data was tested by the more general ADF test, and the results are shown in Table 27.1. It can be seen that the first order difference values of LNTCO2 and LNGDP are stable time series at 5% level of significance, and therefore meet the requirements of the cointegration.

The maximum stagnation period of the VAR model was determined to be two, i.e. VAR(2), by using LR, AIC and SC before the co-integration test. This paper introduces the Trace test in Johansen's cointegration test. The results show that the cointegration test rejects the original hypothesis of cointegration coefficients at the 5% level of significance, thus concluding that there is no cointegration link between carbon emissions and economic growth rate, that is, there is no long-term equilibrium stability link between carbon emissions and economic growth rate.

Table 27.1 ADF stability check

ADF inspection form							
Variables	Differential orders	t	P	AIC	Threshold values		
		−1.854	0.354	11.286	1%	5%	10%
LNTCO2	0	−5.62	0.000***	14.695	−3.633	−2.949	−2.613
	1	−1.724	0.419	29.558	−3.639	−2.951	−2.614
LNGDP	0	−5.604	0.000***	33.657	−3.633	−2.949	−2.613
	1	t	P	AIC	−3.639	−2.951	−2.614

Note ***, **, * represent 1%, 5%, 10% level of significance respectively

Table 27.2 Granger causality test results

Matching samples		F	P
LNGDP	**LNTCO2**	0.112	0.995
LNTCO2	**LNGDP**	0.32	0.916

Note ***, **, * represent 1%, 5%, 10% level of significance respectively

27.4.2 Granger Causality Test

This paper uses the data after the first-order difference to carry out the Granger causality test, and the test results are shown in Table 27.2. There is no Granger causality between LNTCO2 and LNGDP, that is, carbon emissions have no effect on economic growth and economic growth has no effect on carbon emissions.

At the same time, a more in-depth ADF test on the stability of the VAR model is also necessary, and it is easy to see that the results of various unit root tests fall within the unit circle, and thus confirm the existence of smoothness in the VAR model.

27.4.3 Impulse Response Analysis

Impulse response functions are used to analyze the effect of a standard deviation shock to a random disturbance term on the current and future values of endogenous variables when an error term changes or the model suffers a shock [10] The impulse response function is used to analyse the effect of a standard deviation shock on the current and future values of the endogenous variables when a change in the error term or a shock to the model is experienced. As can be seen in Fig. 27.1, the reduction in carbon emissions has a short and weak negative impact on economic growth, almost simultaneously achieving a very small value in period 5 and then gradually stabilising, indicating that the reduction in carbon emissions has a small impact on economic growth. Figure 27.2 shows that economic growth has a weak positive impact on carbon emissions, which then stabilises and approaches 0. This suggests that economic growth affects carbon emissions in the short term, but has little effect in thelongterm.

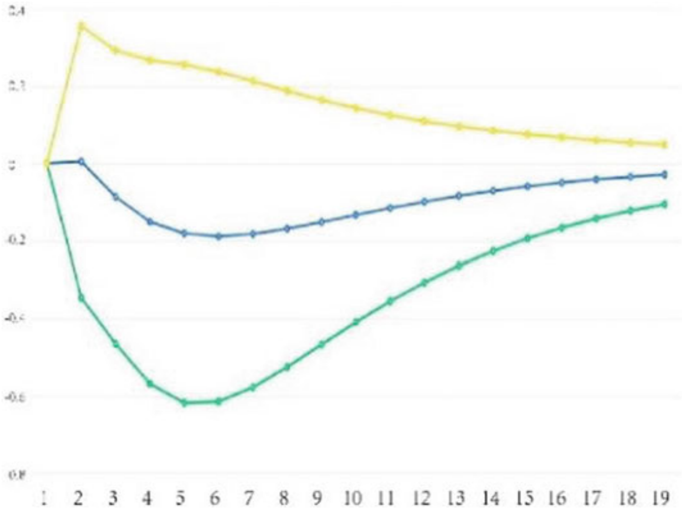


Fig. 27.1 GDP shock from carbon emissions

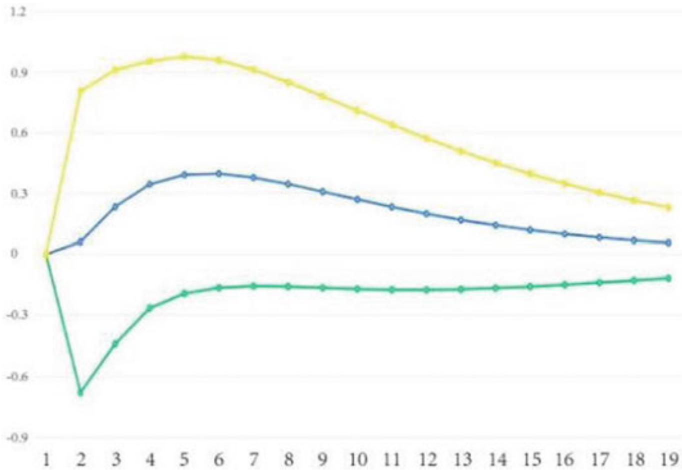


Fig. 27.2 Carbon emissions shock from GDP

Table 27.3 Predicted variance decomposition for LNGDP

Number of steps	Standard deviation	LNGDP%	LNTCO2%
1	0.386	100	0
2	0.509	99.95	0.05
3	0.563	99.362	0.638
4	0.59	98.24	1.76
5	0.605	96.876	3.124
6	0.614	95.525	4.475
7	0.62	94.332	5.668
8	0.625	93.351	6.649
9	0.628	92.583	7.417
10	0.63	92.002	7.998

27.4.4 Variance Decomposition

In order to further analyse the interaction between carbon emissions and economic growth, this paper will conduct an ANOVA on the VAR model. As shown in Table 27.3, China's GDP is only affected by its own fluctuations in the first period, and the negative impact of carbon emissions on overall economic growth does not manifest itself until the second period, when the intensity of the shock is small. The impact on carbon emissions also increases rapidly thereafter and obtains a mean value of 7.998% of the predicted variance decomposition in the tenth period. This shows that economic growth has a greater contribution to itself and carbon emissions have a smaller contribution to economic growth.

As Table 27.4 shows, carbon emissions are mainly influenced by fluctuations in macroeconomic growth in period 1, with a forecast variance decomposition value of 51.05%. Carbon emissions also contribute significantly to itself, with a forecast variance decomposition value of 48.95%. The contribution of carbon emissions to itself increases steadily from period 2 onwards, reaching a maximum in period 10 with a predicted variance decomposition of 62.676%. The contribution of economic growth remains at a high level. It can be seen that the impact of economic and social development on carbon emissions is gradually weakening.

27.4.5 Analysis of the Decoupling Index

Carbon decoupling is used to study the relationship between changes in CO2 emissions and economic growth, and the following results are obtained in this paper based on the analysis of the decoupling index formula. As can be seen from Table 27.5, the six pilot provinces of carbon trading rights in China showed a decreasing trend in total carbon emissions during the period 2014–2019. According to the decoupling index

Table 27.4 Predicted variance decomposition for LNTCO2

Number of steps	Standard deviation	LNGDP%	LNTCO2%
1	0.266	51.05	48.95
2	0.354	51.298	48.702
3	0.403	48.483	51.517
4	0.433	45.445	54.555
5	0.454	42.912	57.088
6	0.468	40.978	59.022
7	0.478	39.561	60.439
8	0.486	38.545	61.455
9	0.49	37.827	62.173
10	0.494	37.324	62.676

discriminations, all six provinces show a strong decoupling trend in general during the period 2014–2019. It can be seen that the further transformation of the manufacturing structure and energy consumption composition due to the development of high technology and the improvement of energy use efficiency has led to a gradual decoupling of the economy and energy consumption levels in the six provinces.

Table 27.5 Decoupling judgement for pilot provinces for carbon trading rights, 2014 – 2019

	2015	2016	2017	2018	2019
Beijing	−1.58	−0.75	−0.79	−0.32	−0.47
	Strong uncoupling	Strong uncoupling	Strong uncoupling	Strong uncoupling	Strong uncoupling
Tianjin	−0.2.37	−0.91	−0.74	−0.018	−0.11
	Strong uncoupling	Strong uncoupling	Strong uncoupling	Strong uncoupling	Strong uncoupling
Shanghai	−0.09	0.12	0.23	−0.62	−0.23
	Strong uncoupling	Weak decoupling	Weak decoupling	Strong uncoupling	Strong uncoupling
Hubei	−0.05	0.04	0.08	−0.21	0.83
	Strong uncoupling	Weak decoupling	Weak decoupling	Strong uncoupling	Weak decoupling
Guangdong	−0.09	0.17	0.38	0.05	0.01
	Strong uncoupling	Weak decoupling	Weak decoupling	Weak decoupling	Weak decoupling
Chongqing	0.12	−0.25	0.09	−0.82	−0.02
	Weak decoupling	Strong uncoupling	Weak decoupling	Strong decoupling	Strong uncoupling

27.5 Conclusion

This paper uses VAR models, impulse response function analysis and decoupling indices to explore the correlation between carbon emissions and national economic development in the six pilot provinces of carbon emission trading rights during the period 2014–2019. The empirical study shows that, under the current new normal of economic growth, there is no longer a strong correlation between economic growth and carbon emissions, and energy consumption cannot be directly used as a reference for the economy. The strong decoupling between the two also means that the contribution of energy to economic growth is gradually declining.

At present, although there is no strong decoupling between economic development and energy consumption, there is a very significant structural change in the contribution of factors to national economic growth, with the contribution of science and technology continuing to rise and the share of the low-energy tertiary sector in GDP continuing to increase. Therefore, a broader and deeper systemic reform of the existing economic and social system is needed to raise China's approach to green development to a whole new level, to promote sustainable development and to reach the "double carbon" target, contributing to the world's efforts to combat climate change.

References

1. C.Y. Wang, L.M. Wang, Analysis of the impact of economic growth on carbon emissions in China. J. Saf. Environ. **05**, 88–91 (2006)
2. S. Yaohua, L. Zhongmin, Study on the relationship between economic development and carbon emission decoupling in China's provinces and regions. China Popul.-Source Environ. **21**(05), 87-92 (2011)
3. W. Chongmei, Analysis of the decoupling of economic growth and energy consumption in China. China Popul.-Resour. Environ. **20**(03), 35–37 (2010)
4. H. Wenyan, X. Yonglan, Study on the decoupling relationship between carbon emissions from energy consumption and economic growth and the factors driving the relationship in large technology countries. Ecol. Econ. **38**(12), 13–22 (2022)
5. S. Zhang, J.Y. Wang, Analysis of the non-linear impact of China's economic growth on carbon emissions–an empirical study based on PSTR. Technol. Econ. Manag. Res. **11**, 27–32 (2022)
6. H. Chuzhi, H. Xianjin, Z. Taiyang, T. Dan, Analysis of carbon emission characteristics and its dynamic evolution in China. China Popul. Resour. Environ. 2008(3), 38-42
7. N.T. Hung, N.T. Trang, N.T. Thang, Quantile relationship between globalization, financial development, economic growth, and carbon emissions: evidence from Vietnam. Environ. Sci. Pollut. Res. **29**(40) (2022)
8. Scientific Platform Serving for Statistics Professional 2021. SPSSPRO. (Version 1.0.11) [Online Application Software]. Accessed https://www.spsspro.com
9. Q. Chen, *Advanced Econometrics and Stata Applications* (Higher Education Press, 2014)
10. H. Hu, T. Lv, X. Zhang, S. Fu, C. Geng, Z. Li, Spatiotemporal dynamics and decoupling mechanism of economic growth and carbon emissions in an urban agglomeration of China. Environ. Monit. Assess. **194**(9) (2022)

Chapter 28
Regional Economic Trend Prediction Based on Improved BP Neural Network Algorithm

Anmin Liu, Jiang Zhu, and Donghai Yue

Abstract The regional economic trend forecasting method has the problem of low accuracy. To solve the above problems, a regional economic trend forecasting method based on improved BP neural network algorithm is designed. From the factors and relationships that determine economic development as the entry point, extract the driving factors, introduce exogenous technical progress variables, describe the production function, divide the regional economic development stages, construct the trend assessment model, select the same classification price index, get the relative price difference value, and design the forecasting method. The test results show that the mean accuracy of the regional economic trend prediction method in the paper is: 67.63%, which indicates that the designed regional economic trend prediction method is more effective after fully incorporating the improved BP neural network algorithm.

Keywords Improved BP neural network · Regional economy · Trend forecasting · Exogenous economy · Endogenous model · Capital-output ratio

28.1 Introduction

Economic trend prediction can reduce the risks that enterprises may encounter in the decision-making process, so it is the basis for correct adjustment of strategies and economic activities to achieve the expected goals. It simulates the neurons of human brain with a large number of nonlinear parallel processors, and simulates the synaptic behaviour of human brain neurons with the intricate and flexible connection relationship between processors. The choice of forecasting method in turn determines the level of forecasting accuracy to a certain extent, and the application of improved BP neural network theory to design regional economic forecasting methods to achieve

A. Liu (✉) · J. Zhu · D. Yue
Mechanical and Electrical Engineering Department, Changzhou College of Information Technology, Jiangsu Province, Changzhou 213156, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_28

the analysis and study of regional economic forecasting. In recent years, BP neural network has been widely used in many disciplines such as electronic science and technology, information and communication engineering because of its good self-learning function, associative storage function and high-speed optimization ability. Applied to time series analysis, pattern recognition and control, and are constantly being expanded. It provides new methods and ideas for forecasting research. Due to the complex relationships of economic systems and the good performance of neural network technology, the study of improved BP neural networks applied to economic forecasting has become a valuable research topic, which is the main basis for the selection of the topic that forms this thesis.

28.2 Extraction of Driving Factors

Since the types and levels of regional economic development models are very diverse, it is also difficult to classify all regional economic development models by a single classification. It is built on a series of assumptions such as free flow of resource factors, complete substitutability of capital and labor, and complete mobility between information technologies. When all these conditions are satisfied, the regional distribution of factors no longer affects the final economic performance, making the economy tend to develop in a balanced way. Patterns have connotations of both spatial patterns and development approaches and characteristics. There are different classification methods according to different perspectives such as endogenous relationship, government-market relationship, and development goals. The law of diminishing marginal returns is the main basis of the neoclassical theory of balanced regional development. Due to the variability of regional economic development conditions, the regional economic development model is also in a constant dynamic evolution, and there is no or hardly any eternal development model. Labor is more plentiful in less developed regions and as it increases will lead to lower wage levels. In mature market economies, the cost of mobility of capital and labor is lower. Because of the different factor prices between developed and less developed regions, this difference will promote the emergence of cross-regional mobility of factor resources. The regional economic development model is influenced by many factors, and according to the factor combination characteristics, the regional economic development model can be divided into endogenous and exogenous economic models [1–3]. For example, labor from less developed regions will flow to capital-rich developed regions, and capital from developed regions will flow to labor-rich less developed regions. This inter-regional flow of factor resources makes the factor prices equalize among regions, and ultimately achieves the goal of regional economic development. The main types of regional economic development models are shown in Table 28.1.

And it can be seen from Table 28.1 that in the endogenous model, capital mainly comes from internal accumulation, the spontaneity of original capital accumulation is strong, and labor-intensive industries still dominate, but with domestic factors and markets. The study of regional economic development model needs to go back to its

Table 28.1 Main types of regional economic development models

Classification basis	Model type	Connotation and characteristics
Propulsion	Government-oriented model	Government as a leader, facilitator and practitioner of economic development
	Market-oriented model	Informal channels for organizing resources in the private sector
Development goals	Sustainable development	Based on the sound operation and optimization of the regional composite ecosystem and the cultivation of regional core competitiveness
	Economic development	The main goal is to attract foreign investment and economic development, etc
Endogenous and exogenous relationships	Endogenous model	Essentially a market solution model and self-organization model, characterized by socialized production based on cottage industry
	Exogenous model	Attracting investment, vigorously developing export-oriented economy, rapid growth of private enterprises focusing on attracting high-end foreign investment, attaching importance to cooperation between Chinese and foreign enterprises

roots and take the factors and relationships that determine economic development as an entry point, i.e., explore the factor determination theory of regional economic development. On the supply side, there is a vicious and repetitive cycle of low income—low saving capacity—insufficient capital formation—low productivity—low income. On the demand side, a vicious and repetitive cycle of low income—low purchasing power—insufficient demand—declining investment—reduced efficiency—low income. For any region, the issue of economic development always occupies a central position, and it is the basis for solving socio-economic development problems, thus regional economic development is also the core research content of regional economics and economic geography. The difference of regional economic infrastructure conditions is the basis of regional economic division of labor and collaboration. No region can have the same comparative advantage in every sector or industry, and the differentiated economic conditions prompt the region to develop the sector or industry with the most comparative advantage in order to maximize the overall regional competitiveness, promote the complementary development between heterogeneous regions, and form the economy of scale effect so as to obtain the maximum benefit.

28.3 Delineating the Stage of Regional Economic Development

The development of the economy generally has such basic characteristics as non-linearity, dynamism and uncertainty. The regional economic development model is influenced by many factors. They are closely interlinked, resulting in the economic system becoming a complex mega system. In the exogenous model, external capital will dominate production and operation, and actively participate in the global division of labor, developing labor-intensive industries and targeting international markets. In contrast, in the endogenous model, capital mainly comes from internal accumulation, the spontaneity of the original capital accumulation is stronger, and labor-intensive industries still dominate, but with domestic factors and markets. The importance of capital accumulation is emphasized and it is argued that the growth of savings rate is the only driver of economic growth. The Hanrod-Domar model is:

$$w = \frac{l \times e}{2} - \delta \tag{28.1}$$

In Eq. (28.1), l denotes the savings rate, e denotes the capital productivity, and δ denotes the capital depreciation rate. The characteristics of economic forecast can be summarized as follows: the occurrence and development of economic phenomena have inherent regularity. The assumption that the capital-output ratio is unchanged does not conform to the objective reality of economic development, because in the competitive market, the capital-labor ratio can be adjusted by price, and then the capital-output ratio will also be adjusted [4, 5]. The accuracy of economic forecasting is limited and relative. Secondly, with the development and deepening of commodity economy, labor has become a commodity, money has been transformed into capital, and capital factors have been innovated. Economic development begins to rely on land, labor and capital. Thirdly, with the further development of commodity economy and the movement of internal contradictions of capital, technology has become the factor that people compete to invest first, and thus independently manifests as the leading factor of economic development. The general form of Solow-Swan model is:

$$L = \frac{1}{\delta} \sum (S, D) \tag{28.2}$$

In formula (28.2), S represents capital and D represents labor. In the process of economic development, the continuously innovated efficient economic organizations and systems have gradually become independent elements of economic development that cannot be ignored. When the economy is in equilibrium, economic growth is only related to population growth, that is, as long as the growth of the working population is maintained, the economy can maintain continuous growth. When exogenous technological progress variable is introduced, the production function becomes:

$$U = E \times W\frac{r}{g} \quad (28.3)$$

In formula (28.3), E represents the growth rate of technological progress, W represents the growth rate of output, r represents the growth rate of labor force, and g represents the elasticity of capital output. Considering that the impact of contingency on economic development is random fluctuation, the economic forecast results deviate from the fact of actual economic development to a certain extent. But this does not necessarily mean that the prediction fails. Because the ultimate goal of economic forecasting is to formulate reasonable economic policies and local development plans. Therefore, if the human intervention is effective, the prediction result will deviate from the actual value to a certain extent, it proves the validity of economic prediction. This reveals the mutual benefit of regional trade and puts forward the idea of mutually beneficial development according to the differences of labor costs and labor productivity.

28.4 Building Trend Assessment Model

Under the guidance of certain economic theories, economic forecasting is to make scientific speculation on the future situation of economic development, taking the history and present situation of economic development as the starting point and realistic data as the basis, on the basis of sufficient qualitative analysis and strict quantitative analysis of economic process. Economic prediction is a scientific prediction based on grasping the inherent laws of economic phenomena. It is affected by many factors, which are intrinsically linked and will have an impact on the development and change of economic phenomena for a long time. The price index of the same category is selected to obtain the difference of relative prices:

$$\Delta T = \ln\left(\frac{q_\alpha}{p_{\alpha-1}}\right) - \ln\left(\frac{q_\beta}{p_{\beta-1}}\right) \quad (28.4)$$

In formula (28.4), p, q represents the commodity category, and α, β represents the regional market integration index and residual value respectively. Economic forecasting method is a method of processing, processing and analyzing the information needed for various forecasting and getting the forecasting conclusion. Economic forecasting is the process of combining forecasting methods with specific economic information [6–8]. The calculation formula of industrial integration index is:

$$G = \frac{\sum |\eta_\varepsilon - d_c|}{\sqrt{\sum_{c=1} |H - \varepsilon|^2}} \quad (28.5)$$

In formula (28.5), η represents the similarity coefficient of the industrial structure, d represents the region, H represents the reference region, ε represents the output value, and c represents the regional industrial consistency coefficient. The theory of economic forecasting is a methodology of measuring unknown events from known events according to the understanding of the regularity of the development and change of economic phenomena. Economic forecasting theory, is produced and developed in the process of economic forecasting practice, is a scientific generalization of economic forecasting practice experience, in turn to be applied to economic practice, to guide practice, to serve practice, accept the test of practice, so that economic forecasting theory is enriched and developed. The technical method of forecasting is based on the development of modern science. It studies various scientific achievements that can be used in the service of economic forecasting, and then establishes the methodology of forecasting on this basis. Because the development and change of economic phenomenon has both contingency and inevitability, the change of contingency influence is random fluctuation, and the inevitability behind contingency determines the development process of things. Therefore, continuous research and improvement of forecasting methods can maximize the accuracy and scientificity of economic forecasting. Thus, the mathematical expression of trend evaluation model can be concluded as follows:

$$R = \frac{|\lambda - \varphi|}{\sum G \times \left|\frac{L+U}{2}\right|} + \sum \sum (\lambda, \varphi) \tag{28.6}$$

In formula (28.6), λ represents the regional division of labor index and φ represents the regional economic concentration degree. Regional economic development pattern is at a specific time and environment conditions, certain areas depending on various factors of production and economic development path and the way of the production relations, and behaved in a sustained and rapid economic development, has strong demonstration in other areas such as features, can under certain conditions for reference by other regions, simply speaking, is the "path" of economic development can be used for reference. Because forecasting analysis is widely used in various fields of economic life and has diversity in application, there are many technical methods in forecasting science, which can be derived from many deformation when combined with each other. The economic development model is a regular summary of the internal mechanism and basic characteristics of economic development. It is a concept after fully absorbing the relevant categories of the modern economic theory, such as the development strategy model, economic development mechanism and economic development source, and it is the integrated innovation achievement of the economic theoretical circle and the decision-making level. Although there are many forecasts, according to their properties, we can basically summarize them into two categories, that is, qualitative forecasting methods and quantitative forecasting methods.

28.5 Design Prediction Method Based on Improved BP Neural Network Algorithm

Economic forecasting method should first determine the purpose of forecasting, starting from the needs of decision-making and management, closely connect with the actual needs and possibilities, and determine the problems to be solved by forecasting. The improved BP neural network is a system composed of many simple parallel processing units. Its function depends on the network structure, connection strength and processing mode of each unit [9, 10]. Based on the basic understanding of BP neural network, the economic trend prediction model is established. Collecting, reviewing and sorting out data, accurate survey statistical data and economic information is the basis of economic forecasting, economic forecasting needs to master a large number of data and conditions, collecting, reviewing and sorting out a variety of historical data related to the purpose and content of forecasting needs to start from many aspects. First, data collection should adhere to the direct relevance, reliability, the latest three criteria to screen. The improved BP neural network stores knowledge and information through the interaction between neurons. Combined with the action mechanism of the improved BP neural network algorithm, the economic model is established, which is as follows:

$$F_{GDP} = \sum \left(\frac{V_1 + V_2 + V_3 + V_4}{\varpi} \right) \tag{28.7}$$

In formula (28.7), V_1, V_2, V_3, V_4 represents the total social investment, retail price index, per capita disposable income and per capita consumption level of residents respectively, and ϖ represents the number of input nodes in the network input layer. The essence of improved BP neural network reflects a functional relationship between network input and output. Third, data collation is mainly to verify or delete the inaccurate data, adjust the incomparable data, estimate the shortage of data, and carry out the necessary classification and combination of the overall data. Choosing appropriate method and establishing forecasting model are the key to the accuracy of economic forecasting. We should choose qualitative or quantitative forecasting methods according to the information we have. When the information is not complete and accurate, qualitative prediction method can be used. Due to the strong nonlinear fitting ability and self-organizing ability of improved BP neural network, we use it to model and forecast economic system, so as to obtain the “black box” model of economic system. Aiming at the problem that the number of samples is too small in the process of economic system modeling, we first conduct chain data reorganization of training samples to expand the training sample set. Therefore, we introduce economic index growth rate input nodes into the network input unit to improve the generalization ability of neural network. For the aforementioned four input nodes in Formula (28.7), the expression formula of economic growth rate is calculated as follows:

$$k_{i,j} = \frac{y_{i,j} - y_{i,j-1}}{y_{i,j-1}} \tag{28.8}$$

In formula (28.8), y represents economic indicator data, and i, j represents independent variable and dependent variable respectively. In the prediction method, we adopt the multi-layer feedforward neural network model, and the backpropagation learning algorithm can realize the training of multi-layer feedforward neural network, namely BP network, which includes input layer, hidden layer and output layer. In order to consider the influence of non-quantitative factors, qualitative analysis should be carried out on the basis of quantitative prediction, and the decision can be made after adjustment. Make economic forecasts. After selecting the forecasting method, qualitative and quantitative forecasting can be carried out. In qualitative forecasting, the forecaster makes a judgment on the nature, direction and extent of the future development of economic phenomena. By selecting different model structures and activation functions, various improved BP neural networks can be formed, different input/output relations can be obtained, and different design purposes can be achieved, and different tasks can be completed. So before using neural network to solve practical application problems, we must first master the structure of neural network model and its characteristics as well as the calculation of its output vector. In quantitative prediction, the forecaster estimates the dependent variable from the independent variable by using the mathematical model. Estimate the corresponding value of the dependent variable by the value of the independent variable, which is called point estimation: under the given probability guarantee, the estimated actual value may fall within the range of the estimated value, which is called interval estimation. Therefore, it is necessary to calculate the prediction error and control it within a certain range. To ensure that the predicted value is as close as possible to the actual situation.

28.6 The Simulation Analysis

28.6.1 The Deployment Environment

The hardware environment of this experiment is as follows:

Operating system: Windows 10 64 bit;

MySQL—5.6.25;

Jdk:Jdk 1.8.071;

Server: Tomcat-8.0.23;

Java development language;

Browser: Google Chrome;

During the experiment, based on B/S mode, the classical SSM framework is adopted for design. Use VC ++ 6.0 programming software to write computer programs, convert the designed model into computer language, and then input the learning data and test data into the computer program for calculation. In the process of program execution, the computer continuously optimizes the parameters of the model according to the input learning data and test data, and finally obtains the optimal prediction model.

The logical structure of the whole experiment is divided into presentation layer, control layer, business logic layer and data persistence layer. At the same time, after the improved BP neural network is generated and initialized, the existing "input output" sample vector data can be used to train through training functions and network training parameters. Set trainParam correctly before training.

28.6.2 The Test Results

In order to verify the practical application effect of the proposed method, this paper compares LSTM method and time series model. A certain region is taken as the research object to test the accuracy of the three regional economic trend prediction methods under different year scale scenarios, as shown in Figs. 28.1, 28.2 and 28.3:

It can be seen from Figs. 28.1, 28.2, 28.3, 28.4 and 28.5 that the accuracy of the method in this paper is 67.63%, the accuracy of LSTM method is 59.46%, and the accuracy of time series model is 61.44%. Therefore, under the conditions of five different year scales, the prediction accuracy of this method is always higher than that of the two comparison methods.

Fig. 28.1. 5-year forecast results

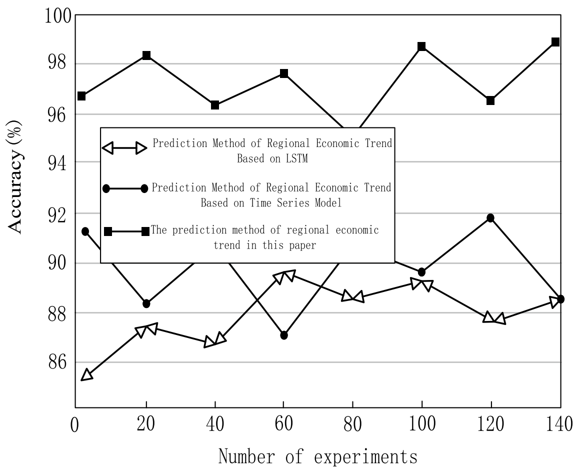


Fig. 28.2. 10-year forecast results(%)

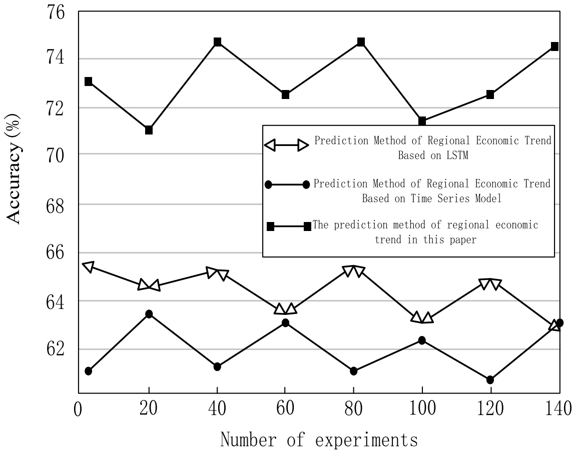


Fig. 28.3. 20-year forecast results(%)

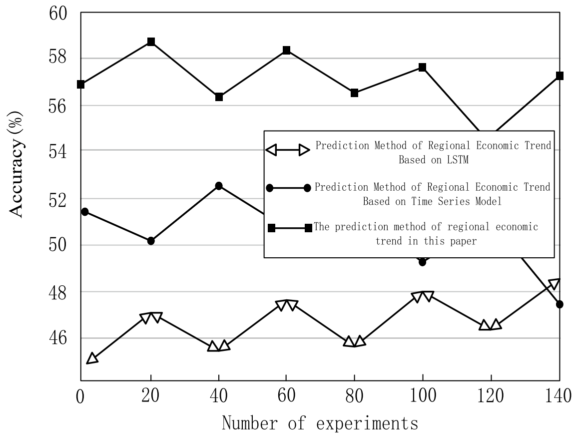
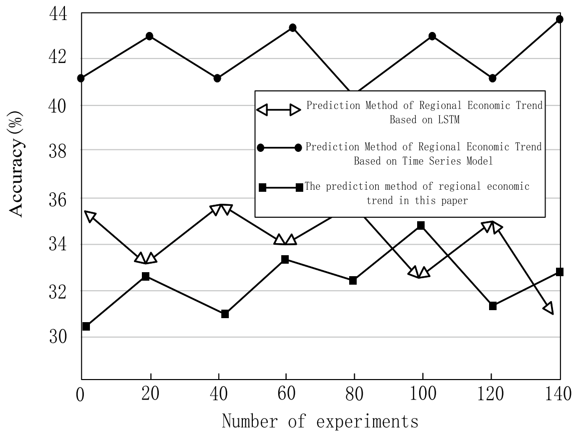


Fig. 28.4. 30-year forecast results(%)



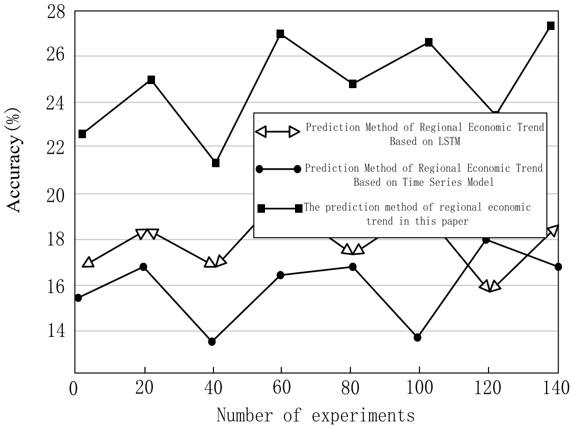


Fig. 28.5. 40-year forecast results(%)

28.7 Conclusion

In this paper, the research of economic forecasting based on improved BP neural network algorithm shows that combined with the development of economic theory, practice has proved that the application of neural network for economic forecasting can achieve good results. The conclusion that the forecast of economic system needs to be guided by economic theory is summarized, and the regional economic indicator system is studied, and the comprehensive integration method combining qualitative and quantitative analysis is adopted. However, the research on the technical basis of neural networks needs to be further strengthened, and the internal black box needs to be made transparent through in-depth research, so that internal information can be used to further reveal the nature of economic phenomena.

References

1. Y.N. Gao, B. Zhou, H. Yu et al., Research on the spatiotemporal difference of inbound tourism in Changjiang River Economic Belt and its trend forecast. Resour. Dev. Mark. **36**(10), 1153–1158 (2020)
2. F. Ma, Mathematical prediction model of regional Edible Fungi industry economic development trend. Edible Fungi China **39**(4), 87–90 (2020)
3. Z.F. Wang, Q.Q. Chen, Spatio-temporal pattern evolution and trend prediction of tourism ecological security in the Yangtze River Economic Belt since 1998. Acta Ecol. Sin. **41**(1), 320–332 (2021)
4. K. Song, Y.J. Zhu, Patent frontier technology topic identification and trend prediction: a case analysis of artificial intelligence. J. Intell. **40**(1), 33–38 (2021)
5. M. Afanasiev, A. Kudrov, Economic complexity and inclusion of regional economies. SHS Web Conf. **106**(4), 01003 (2021)
6. G. Lu, S. Nam, Effects of oil price shocks on heterogeneous regional economies: the case of China. J. Korea Res. Assoc. Int. Commer. **20**(6), 135–152 (2020)

7. X.K. Chen, C.H. Yang, K.F. Zhu et al., Forecast of China's economic growth rate in 2021 and policy suggestions. Bull. Chin. Acad. Sci. **36**(1), 37–46 (2021)
8. O.V. Kuznetsova, Vulnerability of regional economies' structure in crisis conditions. Federalism **12**(2), 20–38 (2020)
9. Y.H. Xing, F.F. Li, Maintenance time prediction of equipment failure with improved GA-BP neural network. Comput. Simul. **38**(8), 97–102, 166 (2021)
10. K. Liu, N. Liu, N. Zhang et al., Research on cucumber leaf disease recognition based on improved BP neural network and feature extraction. Anhui Agric. Sci. Bull. **28**(3), 119–122 (2022)

Chapter 29
Construction of Cross-Border E-Business Pricing Decision Model Based on Decision Tree Algorithm

Haolong Zhang, Xingzhi Li, and Yuexiao Jia

Abstract With the development of Internet technology, e-business is changing the traditional business model of various industries in social economy. Due to the rise of data mining, classification analysis has been more widely used and studied. Not only the original algorithms have been continuously improved and innovated, but also new algorithms with better performance have been continuously discovered. In this paper, the rough set theory and decision tree technology in data mining are organically combined, and the data mining model based on rough set theory is studied, and the pricing decision model of transborder e-business based on decision tree algorithm is constructed, aiming at encouraging overseas warehouses to improve the logistics service level and promoting the healthy and rapid development of transborder e-business. The results show that the comprehensive error of this algorithm is small, and the accuracy is excellent, which can reach 95.69%. Data mining methods such as classification analysis are used to find the rules and knowledge in the data, which provides substantial suggestions and guidance for enterprise decision-making. Compared with decentralized decision-making, centralized decision-making can coordinate the operation among members more effectively.

Keywords Cross-borde E-business · Supply chain · Pricing decision · Data mining

29.1 Introduction

Pricing is one of the most important accounting decisions of enterprises. In the highly competitive global business environment, how to price commodities has become the key to the success or failure of enterprises. With the rapid growth of Internet technology, more and more traditional trade has been transformed and upgraded [1]. Among them, a large number of transborder e-business companies have been

H. Zhang (✉) · X. Li · Y. Jia
Jining Polytechnic, Jining Shandong 27210, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_29

born, and the transaction scale of transborder e-business companies has also been increasing. Price is the most sensitive variable that an enterprise can control. It often changes very quickly and directly affects the interests of producers, distributors, consumers and many other aspects [2]. Transborder e-business crosses national boundaries, and the links from supply to consumers are complicated, and the subjects are scattered, and consumers' expectations for products and logistics services are constantly improving. It is difficult for a single enterprise to efficiently complete the whole transborder transaction, and enterprises are exploring new development models [3]. Many manufacturing countries with low labor costs began to ship more and more goods to all parts of the world through the Internet. More people in the world can browse and buy many kinds of goods through transborder e-business, avoiding the traditional distributors [4]. Although the traditional information system and the advanced website record have produced a lot of customer characteristic information and customer behavior information, however, this information are only limited to the superficial record, lacking in-depth analysis. Using data mining methods such as classification analysis to mine data and discover the rules and knowledge in the data can provide substantial suggestions and guidance for enterprise decision [5].

When customers shop in the mall, they leave only the relevant data about the goods purchased by the customers, such as the purchase amount, purchase quantity and purchase time. However, if the customers record the purchase information on the Internet, they also leave the time information and path information of the users browsing the web [6]. This information can be obtained through website logs and client objects, and the recorded data can be used to analyze the potential value of customers. The research on transborder e-business supply chain pricing coordination provides an optimized commodity pricing model for each node of the transborder e-business supply chain, which makes each node of the supply chain have a realistic and reliable basis for commodity pricing [7].

Zhang et al. studied that when there is asymmetric information among supply chain members, a profit maximization model was established to get the best strategy, and three situations of information asymmetry, information sharing and strategic alliance formation were compared respectively [8]. Liu et al. studied the existing price and quality competition among enterprises in the Internet market. Consumers buy products based on price and quality level. Therefore, enterprises maximize profits through price and quality competition [9]. Li et al. studied how manufacturers and retailers of node enterprises in a two-stage closed-loop supply chain determine their own wholesale and retail prices to obtain their own optimal profits, and on this basis, put forward a simple coordination mechanism to coordinate the closed-loop supply chain with decentralized decision-making in order to improve system efficiency [10]. The decision tree algorithm based on rough set theory can be used to mine useful knowledge that users are interested in from large amounts of data, and solve the problem of more data but less useful information in modern e-business enterprises [11]. Based on this, this article studies the construction of a transborder e-business supply chain composed of product manufacturers, transborder e-business platforms and overseas warehouses and its coordination mechanism, and builds a decision-making model of transborder e-business pricing based on decision tree algorithm, which aims to encourage overseas warehouses to improve logistics service level and promote the healthy and rapid growth of transborder e-business.

29.2 Pricing Decision Model of Transborder E-Business Based on Decision Tree Algorithm

29.2.1 Transborder E-Business Supply Chain Coordination Decision-Making Mechanism

There is an obvious antinomy between logistics service cost and logistics service level. As an overseas warehouse, the logistics service level is often maintained at a low level to reduce the logistics cost, and the lower logistics service level will affect the consumer's experience. Similarly, to maximize their own interests, manufacturers maintain the level of production capacity to the lowest level that can guarantee the quality of goods, which is not conducive to expanding the market scale. The transborder e-business platform has an obvious interest game relationship with manufacturers and overseas warehouses, which affects the sustainable growth of transborder e-business. In the bilateral transaction mode, transborder e-business enterprises negotiate the transaction price with foreign agents. Although the higher the agreement pricing result is, the higher the profit of transborder e-business enterprises from unit products will be, but foreign agents may reduce their product purchases, which will lead to the reduction of total revenue [12]. During the negotiation process, both parties to the agreement do not know each other's real trading bottom line, thus greatly improving the difficulty of realizing interest coordination. In this case, one party of the agreement can only update its judgment on the bottom line of the transaction according to the quotation of the other party, and on this basis, make its own possible minimum concession, thus gradually approaching the equilibrium price.

The ultimate goal of system coordination is to transform the disordered state into an orderly state by a means, so that the system can form an orderly state and all parts of the system can achieve overall coordination. Compared with the manufacturers and retailers who have not opened e-business channels, there are essential differences between manufacturers and retailers in the e-business environment in terms of business model and cost composition. The competition between e-business channels and traditional channels poses new challenges to manufacturers and retailers in the e-business environment. The architecture of transborder e-business supply chain coordination decision system based on data visualization is shown in Fig. 29.1.

Overseas warehouses sign logistics service price contracts and revenue sharing contracts with transborder e-business platforms, and the produced goods are transported to third-party overseas warehouses in advance, which will keep them in storage. When consumers in overseas warehouses place orders, overseas warehouses deliver goods to consumers in a timely, accurate and intact manner with the best logistics service level according to the order information, and provide discounts on

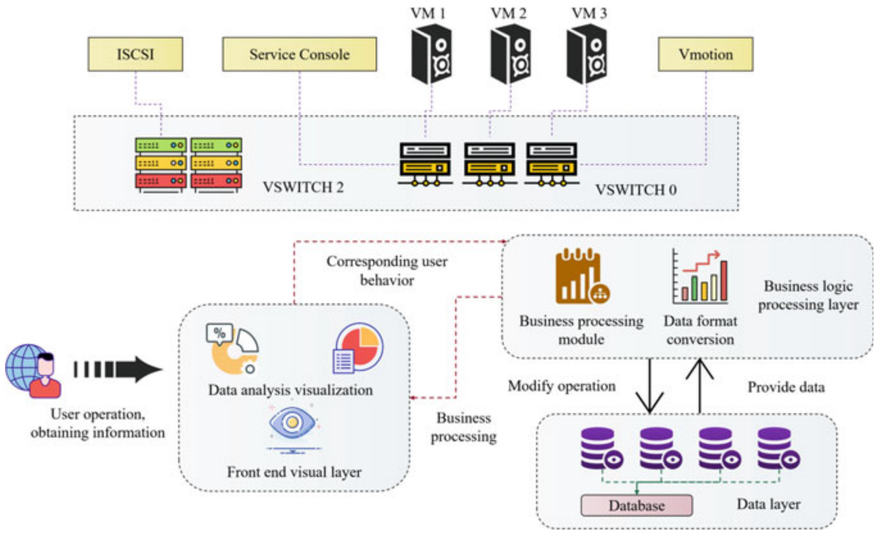


Fig. 29.1 Framework of transborder e-business supply chain coordination decision system

logistics service volume for transborder e-business platforms according to the logistics service volume, so as to determine the best logistics service price, thus ensuring the maximization of supply chain benefits [13]. Supply chain pricing coordination is to realize the pricing cooperation among the nodes and platforms of the supply chain by some method, so that the benefits of decentralized decision-making are less than those of collective decision-making, and to maximize the overall profit of the supply chain by contract. Therefore, the ultimate goal of supply chain coordination is to make the contradictory enterprises in the supply chain change from contradiction to cooperation through various methods, so as to keep the whole supply chain running smoothly, and give full play to the advantages of the overall cooperation of the supply chain to obtain the greatest benefits.

29.2.2 Transborder E-Business Pricing Decision Model

The transborder e-business platform, manufacturers and overseas warehouses have established a long-term and stable cooperative relationship. The three companies aim at maximizing the overall interests of the transborder e-business supply chain, sharing profits and risks. By taking the transborder e-business platform as the center, they sign wholesale prices, logistics service prices and set sales prices to maximize the overall profits of the three parties. Sign wholesale price contracts and revenue sharing contracts with manufacturers' transborder e-business platforms. Transborder e-business platforms order a certain number of products from manufacturers through market forecasts [14]. According to the manufacturer's ordering information, on the premise of ensuring the quality of goods and maximizing the benefits of supply chain, the manufacturer produces at the optimal level of production capacity, and determines the optimal wholesale price of goods according to the quantity of goods ordered by the transborder e-business platform. Asymmetric quality information generally exists between manufacturers and consumers in e-business channels, and the quality information and the degree of asymmetry directly affect the pricing strategy and profit of manufacturers in e-business channels.

In order to process intelligent data, knowledge needs to be represented symbolically. Knowledge expression system is the research of describing the knowledge of an object by specifying its basic features and characteristic values, so as to find useful knowledge or decision rules from a large amount of data by certain methods. Let y_t be a $k \times 1$-dimensional observable variable containing k e-business price variables. These variables are related to $m \times 1$ dimension vector a_t. The measurement equation is defined as:

$$y_t = z_t \times a_t + d_t + \mu_t \quad t = 1, 2, \ldots, T \tag{1}$$

where T represents sample length, z_t represents $k \times m$ matrix, and d_t represents $k \times 1$ vector. μ_t stands for $k \times 1$ vector, which is a continuous uncorrelated disturbance term with mean value of 0 and covariance matrix of H_t:

$$E(\mu_t) = 0, \quad \text{var}(u_t) = H \tag{2}$$

The general elements of a_t are unobservable, and the equation of state is defined as:

$$a_t = T_t a_{t-1} + c_t + R_t \xi_t \quad t = 1, 2, \ldots, T \tag{3}$$

where, T_t represents the $m \times m$ matrix, c_t represents the vector of $m \times 1$, and R_t represents the $m \times g$ matrix. ξ_t represents the mean value 0 of $g \times 1$ vector, and the random uncorrelated disturbance term whose covariance is Q_t:

$$E(\xi_t) = 0, \quad \text{var}(\xi_t) = Q_t \tag{4}$$

In the market of rational economic man, the market is in a vigorous period. Manufacturers want to raise wholesale prices to get higher profits, and transborder e-business wants to lower prices to get bigger profits. This situation causes the price conflict between the two sides when the exchange rate rises, which reduces the overall efficiency of the transborder e-business supply chain. Some transborder e-business companies compete by reducing costs and adopting lower pricing, while others compete by improving quality. For transborder e-business companies, it is indispensable to control their production and operation costs through exchange rate factors, otherwise they can only make up for their extra costs by raising prices.

29.3 Result Analysis and Discussion

Because of the uncertainty of platform, operation, connection and behavior among nodes, the uncertainty of organization is the instability caused by the lack of an effective member's control mechanism in the supply chain. For manufacturers, transborder e-business and customers are located in the downstream of the supply chain. The growth of customer groups requires high cost for each transborder platform. No matter what pricing method and pricing strategy, it is always necessary to maintain a loyal customer group, so that pricing can be accepted by this group [15]. Any two parties will bargain when buying and selling goods, and there will also be price complaints from supply chain members. However, reasonable treatment of price complaints will increase the satisfaction and loyalty of supply chain members, thus increasing the overall profit of supply chain. Due to the complexity of transborder e-business's actual transactions, quantitative data with large differences in data distribution intervals can be discretized, as shown in Fig. 29.2.

Market demand determines commodity price, and how much profit an enterprise wants to make in commodity trading mainly depends on the market's ability to bear the price, and this ability can be mainly reflected by demand. Because the transborder e-business supply chain system is relatively loose, a relatively close transborder e-business supply chain relationship cannot be formed. As a result, when the market is most favorable, it still can't make a big profit. In reality, the transborder e-business platform is only a supply-marketing relationship rather than a close partnership with manufacturers, which leads to the fact that the pricing of transborder e-business cannot form obvious advantages in the market. When the transborder e-business platform wants to gain too much profit in the transaction, it will inevitably lead to the price increase, and then it will lead to the market demand decrease. In the marketing theory, it is pointed out that for products with elastic demand, lower profit acquisition and pricing can stimulate a substantial increase in demand. The comparison of F1 value between transborder e-business pricing decision model based on decision tree algorithm and traditional back propagation neural network (BPNN) model is shown in Fig. 29.3.

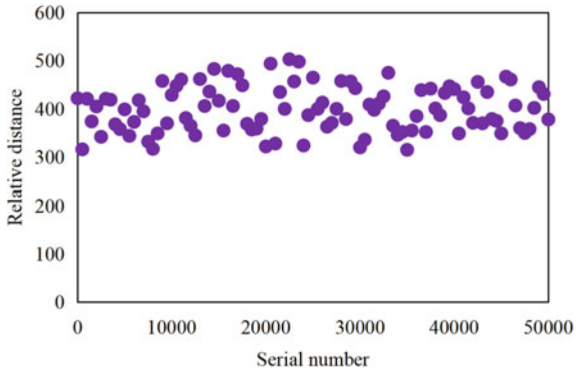


Fig. 29.2 Data outlier removal processing

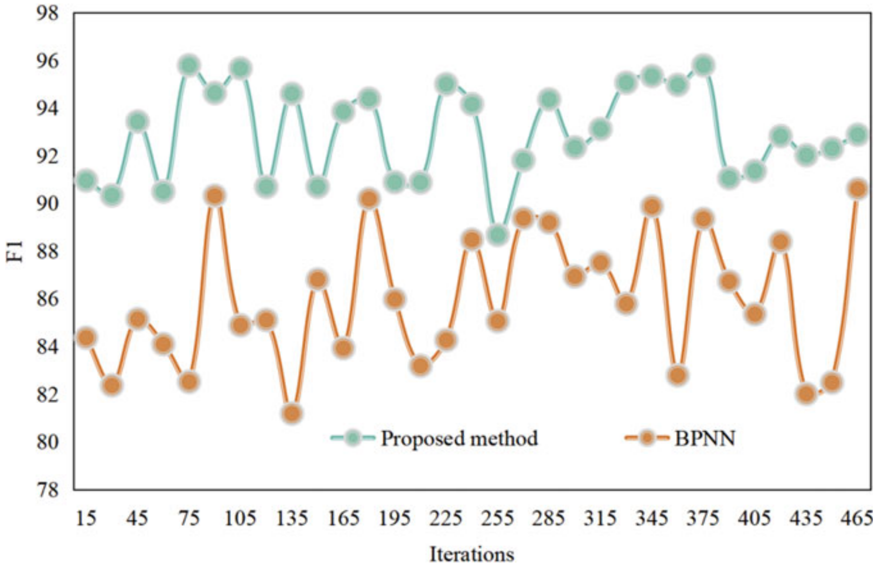


Fig. 29.3 F1 of different algorithms

After the coordination of the revenue sharing contract, the profits of each node in the transborder e-business supply chain are greater than those before the coordination. When the exchange rate rises, it is a good time for the market of the country where the transborder e-business is located. Currently, the manufacturer and transborder e-business form a strategic alliance, and the manufacturer provides a lower wholesale price for transborder e-business. In order to obtain the wholesale price lower than the cost, the transborder e-business will give the manufacturer a certain compensation of sales revenue through agreement. The performance comparison experiment of the algorithm is carried out under different transaction sets, and the error of the algorithm is shown in Fig. 29.4. The accuracy of the algorithm is shown in Fig. 29.5.

Experimental results show that the comprehensive error of this algorithm is small, and the accuracy rate is high, reaching 95.69%. A healthy enterprise's cash flow mainly comes from its daily business activities. The faster the recovery rate of sales funds, the smaller the risk of bad debt losses. Enterprises need cash to repay loans, pay dividends, expand production scale and invest abroad, and the cash flow from business activities is the most fundamental source to meet these needs. The cash collection period of goods sold by manufacturers in e-business channel is short and has strong certainty, so it can be assumed that the sales money of manufacturers in e-business channel can be recovered in the current period, and there is no receivable. With the advent of economic globalization and the new economic era, and the increasing market competition, it is objectively required that the business concept of enterprises must turn to customer-centered, strengthen the interactive relationship between enterprises and customers, and establish a long-term and mutually beneficial

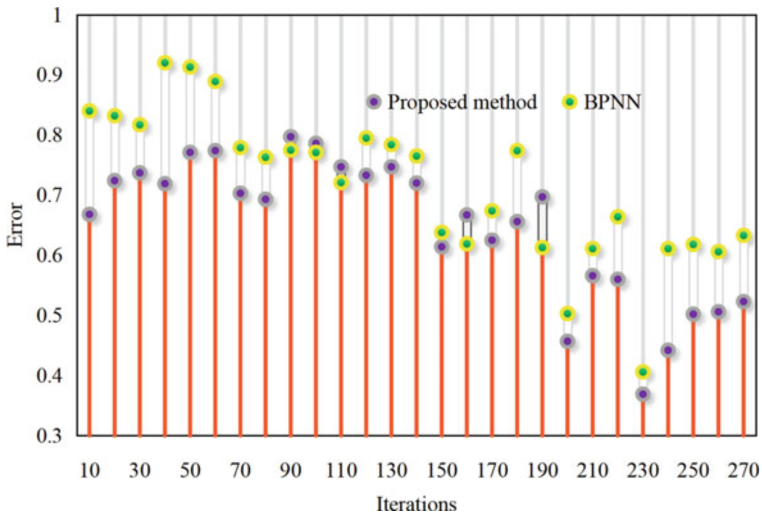


Fig. 29.4 Errors of different algorithms

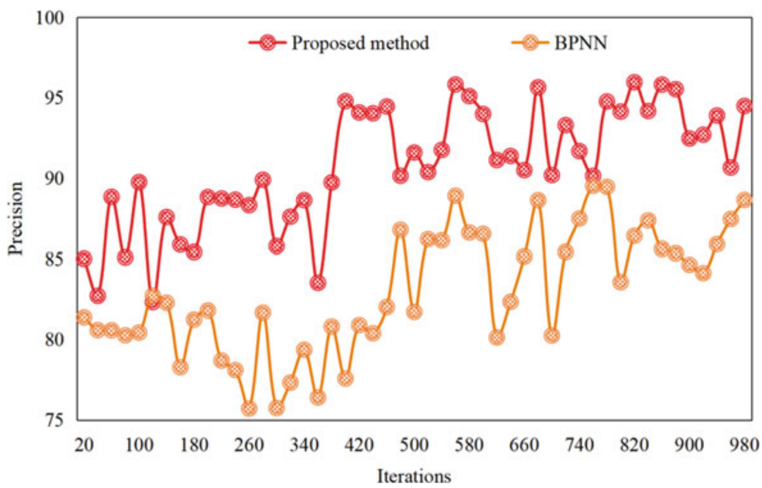


Fig. 29.5 Accuracy of different algorithms

good relationship with customers, that is, realize customer satisfaction and finally achieve long-term profit.

29.4 Conclusions

Successfully determining the pricing strategy of an enterprise can significantly enhance its competitiveness and achieve its business objectives. Using data mining methods such as classification analysis to find the rules and knowledge in the data can provide substantial suggestions and guidance for enterprise decision-making. This paper studies the construction of transborder e-business supply chain composed of product manufacturers, transborder e-business platforms and overseas warehouses and its coordination mechanism, and constructs a transborder e-business pricing decision-making model based on decision tree algorithm. The results show that the comprehensive error of this algorithm is small, and the accuracy is excellent, which can reach 95.69%. By studying the data mining model based on rough set, we can mine valuable decision rules from the massive data of data warehouse and store them in the knowledge base to guide the future decision-making process. Using this model to formulate a reasonable pricing strategy to encourage overseas warehouses to improve the level of logistics services and promote the healthy and rapid development of transborder e-business.

References

1. H. Zhao, A cross-border e-commerce approach based on blockchain technology. Mob. Inf. Syst. **2021**, 1–10 (2021)
2. Z. Liu, Z. Li, A blockchain-based framework of cross-border e-commerce supply chain. Int. J. Inf. Manag. **52** (2020)
3. L. Feng, J. Ma, Y. Wang, J. Yang, Supply chain downstream strategic cost evaluation using L-COPRAS method in cross-border E-commerce (2017)
4. B. Song, W. Yan, T. Zhang, Cross-border e-commerce commodity risk assessment using text mining and fuzzy rule-based reasoning. Adv. Eng. Inform. **40**, 69–80 (2019)
5. X. Zhang, S. Liu, Action mechanism and model of cross-border e-commerce green supply chain based on customer behavior. Math. Probl. Eng. **2021**, 1–11 (2021)
6. T. Ahmed, S. Mekhilef, R. Shah, N. Mithulananthan, Investigation into transmission options for cross-border power trading in ASEAN power grid. Energy Policy **108**, 91–101 (2017)
7. M. Humphery-Jenner, Z. Sautner, J.A. Suchard, Cross-border mergers and acquisitions: the role of private equity firms. Strateg. Manag. J. **38**, 1688–1700 (2017)
8. Y. Zhang, J. Zhu, N. Xu, S.X. Duan, X. Huang, Optimal selection of expatriates for cross-border assignment to enhance manufacturing efficiency. Int. J. Prod. Econ. **232**, 107926 (2021)
9. D. Liu, D. Li, X. Zheng, Research on product pricing considering channel service level in transborder e-business environment. Comput. Integr. Manuf. Syst. **26**(8), 10 (2020)
10. H. Li, Cross-cultural perspective of China's transborder e-business marketing strategy research. Bus. Econ. Res. **2020**(12), 3 (2020)
11. N. Chen, J. Yang, Mechanism of government policies in cross-border e-commerce on firm performance and implications on m-commerce. Int. J. Mobile Commun. **15**, 69–84 (2017)
12. Y. Zhang, Application of improved BP neural network based on e-commerce supply chain network data in the forecast of aquatic product export volume. Cogn. Syst. Res. **57**, 228–235 (2019)
13. B. Li, J. Li, X. Ou, Hybrid recommendation algorithm of cross-border e-commerce items based on artificial intelligence and multiview collaborative fusion (2021)

14. D. Geneiatakis, Y. Soupionis, G. Steri, I. Kounelis, R. Neisse, I. Nai-Fovino, Blockchain performance analysis for supporting cross-border E-government services. IEEE Trans. Eng. Manage. **67**, 1310–1322 (2020)
15. Y. He, R. Wu, Y.-J. Choi, International logistics and cross-border E-commerce trade: who matters whom? Sustainability **13**, 1745 (2021)

Chapter 30
Construction of China Digital Economy Scale Prediction Model Based on Random Forest Algorithm

Yineng Xiao

Abstract At present, the popularity of digital infrastructure such as computers and the Internet in China is very high, with more than one billion potential innovators and demanders, and with the strong support of the government, they can be connected in series to form a powerful driving force. Thus, the new economy based on digital technology is expected to inject new impetus into the future development of China. The main attempt of this paper is to put forward a prediction model of China digital economy scale based on RF(Random forest) algorithm. By analyzing the influencing factors and other factors of digital economic growth, the observed data are obtained, and the observed data are normalized and KF(Kalman filtering), and the regression prediction model of digital economic growth parameters is established by using RF algorithm. The results show that the scale of core industries in China's digital economy is growing well. Judging from the R2 index, the model in this paper is above 0.97, which shows that the predicted result of this model is almost identical with the actual value trend. Based on the results of the above three indicators, it can be concluded that the model in this paper is obviously superior to the comparative model.

Keywords Random forest algorithm · Digital economy · Prediction · Economy scale · China

30.1 Introduction

In the era of digital economy, the role of data in economic activities is becoming more and more important, which can not only help people to better organize and plan production and operation, but also make judgments and forecasts more effectively.

Y. Xiao (✉)
The Global Intellectual Property Institute, Nanjing University, Suzhou 215163, China
e-mail: xiaoyineng@pku.edu.cn

Advanced Institute of Information Technology, Peking University, Hangzhou 311200, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_30

With the popularization and development of digital infrastructure, ICT technology and Internet have gradually become the basic facilities of enterprises and society, and the scope of digital economy is gradually expanding [1]. At present, the popularity of digital infrastructure such as computers and the Internet in China is very high, with more than one billion potential innovators and demanders, and with the strong support of the government, it can be connected in series into a powerful driving force [2, 3]. Thus, the new economy based on digital technology is expected to inject new impetus into the future development of China.

With the development of new generation digital technologies such as Internet of Things and artificial intelligence and their deep integration and application in agriculture, manufacturing and service industries, the boundaries of digital economy have also changed greatly. Literature [4] based on Machlup's calculation method, using the input–output table data, this paper calculates the scale of China's digital economy from two parts: digital industry sector and digital auxiliary activities. Literature [5] classifies sub-industries into the category of digital economy accounting, ignoring the increase of consumer surplus and efficiency optimization brought by new formats and new models in digital economy, which will lead to underestimation of the efficiency of digital economy. Literature [6] points out that the digital economy is developing very rapidly at present, and it is deeply integrated with various industries and industries in society. Literature [7] attempts to construct an internationally comparable satellite account of digital economy in China, and preliminarily calculates the added value of the main sectors of digital economy in China.

Driven by the new technological revolution, mankind has entered a new era of "digital economy". Digital technology is developing at a jaw-dropping speed, penetrating into all fields of economy and society at an unprecedented speed, triggering a profound change, reshaping the governance mode of the whole society, and becoming a "wind vane" leading reform, development and innovation [8, 9]. The main attempt of this paper is to put forward a prediction model of China digital economy scale based on RF(Random forest) algorithm. By analyzing the influencing factors and other factors of digital economic growth, the observed data are obtained, and the observed data are normalized and KF(Kalman filtering), and the regression prediction model of digital economic growth parameters is established by using RF algorithm.

30.2 Research Method

30.2.1 Construction of Measurement Index System and Data Explanation

Now, we have entered the era of digital economy, and the role of data in economic activities is becoming more and more important. It can not only help people to organize and plan production and operation better, but also make judgments and forecasts more effectively. Measure the development level of digital economy. That is, by constructing a multi-dimensional index system and using various evaluation methods to measure the development level of digital economy. In order to make more data effectively produced, and at the same time make the produced data more effectively configured and utilized, it is extremely important to scientifically design relevant rules and regulate people's data production and trading behaviour. To do this, we must first understand the characteristics of data, a factor of production. We should actively encourage the trading of data so as to give full play to the economies of scale and scope of data. Corresponding mechanisms should be designed to reduce the cost of data transactions, so that data can be effectively circulated and those who need data most can obtain data in time.

In the digital economy, individuals, enterprises, governments and other economic activities, transactions, management, management and other activities, goods, services, currency and other activities, all of which can be expressed by digital information. Many real economies begin to develop in the direction of online virtualization, and the extraordinary compression of time and space enables demand and supply to be connected at low cost, weakening the role of traditional location factors. Considering the high permeability of digital technology, it is obviously impossible to give an accurate measurement only by dividing the industry scope and using the traditional method to calculate the economic scale. We must consider the contribution of its integration part while clarifying its industry foundation, measure it separately and then sum up the two, thus giving the final accounting result.

The basic composition of input–output technology is a chessboard statistical balance table, and based on it, it has been continuously developed and finally formed a tool for quantitative analysis of economic and social problems [10]. The input–output model used is a mathematical model. In order to ensure its application in economy, it is necessary to investigate the logical conditions that the model should meet in the process of solving and make some reasonable assumptions in connection with economic reality. According to different units of measurement, it can be divided into physical input–output table, value input–output table and mixed input–output table (such as physical value type) [11].

Digital economy is a new economic form with the characteristics of technological economy paradigm, and its main characteristics are shown in three aspects: connection, data, and integration. Based on the relevant indicators of the existing research, this paper constructs a digital economic measurement index system consisting of five first-level indicators: digital technology, digital infrastructure, digital value, digital industrialization and industrial digitalization. See Fig. 30.1 for details.

From a technical perspective, the interoperability of digital technology is an important means to improve the efficiency of digital economy. This paper selects three basic indexes reflecting the development degree of digital technology: the number of artificial intelligence patents, the number of industrial robots patents and the digital technology index. From the digital point of view, the digital infrastructure based on network is the premise of the development of digital economy. The expenditure on technological transformation of industrial enterprises above designated size and the development index of integration of informatization and industrialization reflect the digital development level of the secondary industry.

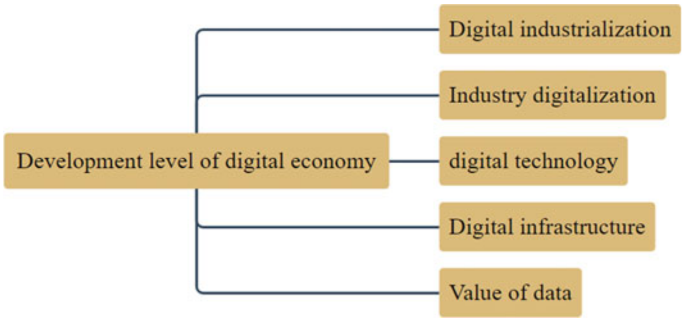


Fig. 30.1 China digital economy development level measurement index system

There are few statistical data about digital economy in China. This paper collects and sorts out the data from 2015 to 2021, which are from China Statistical Yearbook, China Internet Development Report and China New Economy White Paper. The missing data in this paper are supplemented by the average growth rate.

30.2.2 Prediction Model Construction

From the current research, there is no consistent standard for digital economic accounting. Of course, this difference comes not only from the differences in calculation methods, but also from the deviation in understanding the concept and accounting scope of digital economy. Overestimation or underestimation of the total amount of digital economy will affect the accuracy of GDP data. Each country needs to make corresponding adjustments when making the supply and use table of digital economy. Therefore, many problems need to be solved before the application of the digital economy satellite account method, and the actual situation of the country and the applicability of accounting accounts need to be further explored in the formal application.

RF algorithm is an integrated learning algorithm. Compared with decision tree algorithm, two important randomization strategies are introduced in its construction process: randomization of training samples and randomization of feature selection. RF algorithm can be processed in parallel, and the anti-over-fitting ability is enhanced. RF algorithm has high prediction accuracy. RF algorithm can use out-of-pocket data to evaluate the importance of features. The results of RF algorithm are more stable and have good anti-noise ability. The performance is not inferior to that of complex algorithms such as neural network and support vector machine. Based on the decision tree algorithm, RF algorithm randomly selects variables and data to generate multiple decision trees, and then summarizes the results of each decision tree according to the majority voting results.

In this paper, RFalgorithm is mainly used to establish regression prediction model [12]. By bringing the historical data of digital economic growth into the basic RF framework for training, an RF prediction model suitable for digital economic growth can be obtained. The forecast value of digital economic growth can be obtained by bringing the observation data of last year into the trained RF prediction model. The flow chart of China digital economy scale prediction model based on RF algorithm is shown in Fig. 30.2.

Because these data are arranged in chronological order, the sample size of the data is small. The overall economic index is usually based on month, quarter, or year. After the reform and opening up, our country rarely has a comprehensive and clear economic statistics. The values of the sampled data vary greatly. The development of China has the characteristics of stages. By standardizing the data, the data obtained meet the standard normal distribution, that is, the average is 0 and the variance is 1. The effect after transformation is:

$$\overline{x} = \frac{x - mean}{std} \tag{30.1}$$

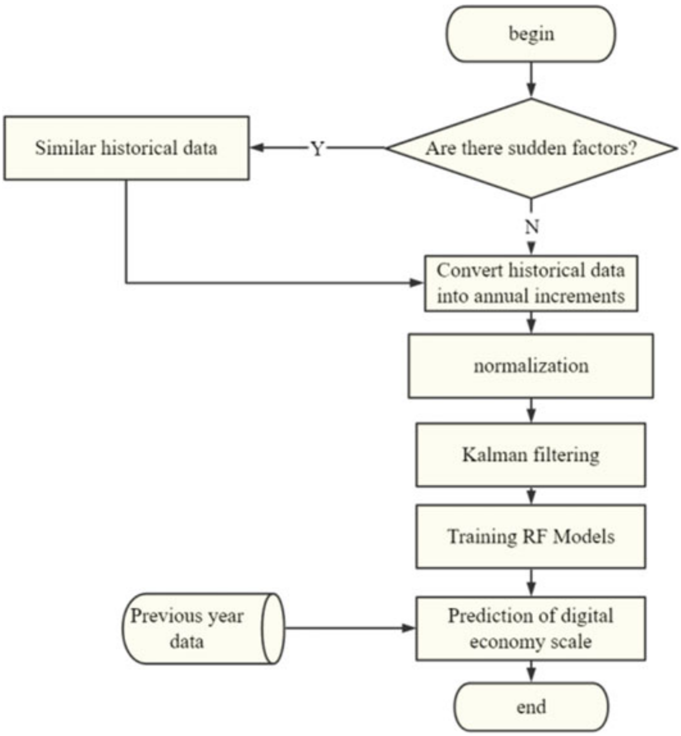


Fig. 30.2 Flow chart of the model

mean represents the average value of the original data sample, and *std* represents the standard deviation of the original data sample.

R^2 indicates the goodness of fit of the model, and the higher the value of R^2 indicates that the predicted value is closer to the observed value, and its definition is expressed by the following formula (30.2):

$$R^2 = 1 - \frac{\sum_{t=1}^{n} (y_t - x_t)^2}{\sum_{t=1}^{n} (y_t - \overline{y})^2} \tag{30.2}$$

x_t represents the predicted value, y_t represents the observed value, $\overline{y}$ represents the average value of y_t, and n represents the total number of samples. The higher R^2 indicates that the method used is more suitable and accurate.

In practice, the observation data will be disturbed by noise, and directly using the observation data containing noise to establish the prediction model will lead to the fitting of the prediction model to the observation noise, that is, the phenomenon of over-fitting, which will lead to the prediction deviation. Since there is no obvious separation between the observation data and the observation noise in time domain and frequency domain, it is impossible to use low-pass, high-pass or band-pass filters to filter out the noise, and KF is needed to process the observation data, as shown in Formula (30.3).

$$\begin{aligned}
\hat{x}(k) &= \hat{x}(k-1) + b(k)\big[x(k) - \hat{x}(k-1)\big] \\
b(k) &= p_1(k)\big[p_1(k) + \sigma_v^2\big] \\
p_1(k) &= p(k-1) + \sigma_w^2 \\
p(k) &= p_1(k) - b(k)p_1(k)
\end{aligned} \tag{30.3}$$

where x is the actual observed value, $\hat{x}$ is the predicted value, σ_w is the modeling noise and σ_v is the observation noise.

30.3 Result Analysis

In this paper, according to the above-mentioned framework, data sources and processing methods of digital economy core industry scale, China digital economy scale is systematically predicted. The scale of the core industries of digital economy predicted by the model is shown in Fig. 30.3.

By 2030, the pillar industries of digital economy in China will reach 235,828 billion yuan, and in 2021 it will be 90,993 billion yuan. The application of digital technology and the driving industry of digital elements have developed rapidly, and the digital production and service industry has also developed well. The average

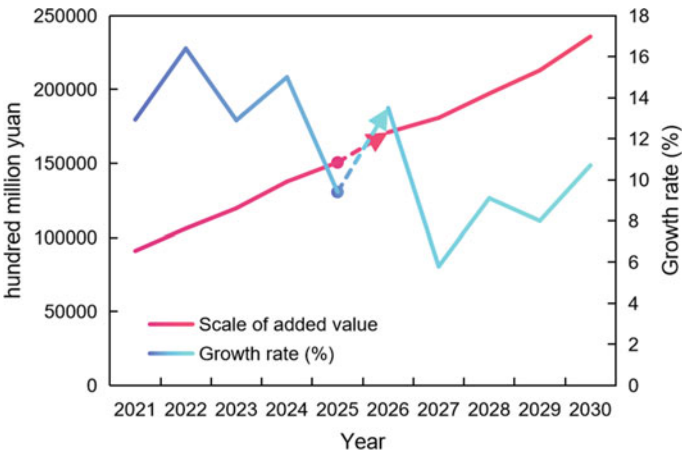


Fig. 30.3 The added value of the core industries of China digital economy predicted by the model from 2021 to 2030

annual growth rate of digital technology application industry and digital factor driving industry is as high as 11.17% and 9.82% respectively, and their proportion in core industries will increase year by year.

In order to further test the prediction effect of the model, this paper compares the proposed prediction model with two linear prediction models and four machine learning prediction models. The two linear prediction models are ARMA (Auto-Regressive Moving Average) model and MLR (Multiple Linear Regression) model. The four machine learning prediction models are BPNN (BP neural network), RBFNN (Radial basis function neural network), SVM (Support Vector Machine), and LSTM (Long Short Term Memory). Figure 30.4 shows the calculation results of each model on three indicators.

Judging from the R2 index, this model ranks first, and its value reaches above 0.97, which shows that the predicted result of this model is almost identical with the actual value trend. Based on the results of the above three indicators, it can be concluded that the model in this paper is obviously superior to the comparative model.

In recent years, all kinds of final demand have increased the production induction of digital economy industry. From the perspective of different types of final demand, consumption induces the output of digital economy industry to the greatest extent, followed by export and finally investment. Therefore, expanding consumption is an important way to promote the development of digital economy industry in China. The development of digital economy is inseparable from the financial support for related enterprises, and capital is the premise of sufficient innovation potential of enterprises. All major platforms should also strengthen the innovative combination with the Internet, create new consumption forms, and build a comprehensive, functional, intelligent and convenient digital service system to continuously stimulate people's consumption potential. Therefore, technology, mode, format and institutional innovation should work together to make good use of data elements, promote

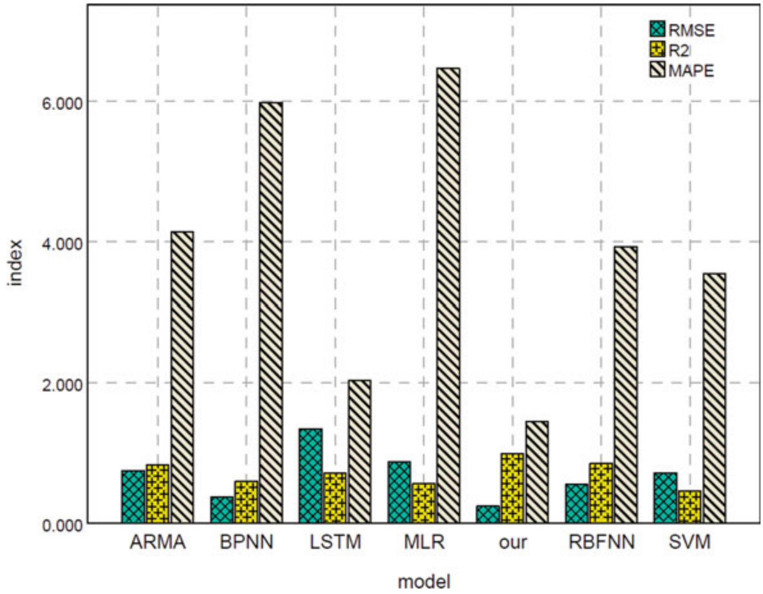


Fig. 30.4 Statistical results of prediction indexes of each model

the digital development of the economy and society, and promote the comprehensive and coordinated development of the digital economy.

The essence of economic change brought by digital economy is the Internet of Everything as the fundamental feature, data as the core production factor, and integration as the driving force for innovation, thus promoting economic efficiency improvement and economic structure optimization and empowering high-quality economic development. On the one hand, we will continue to increase the investment in digital technology research and development, focus on joint research in hardware technologies such as sensors, high-end chips and integrated circuits, and software technologies such as operating systems and core algorithms, strengthen the supply capacity of digital technology research and development, make up for the shortcomings of digital technology development, and provide technical support for the realization of the Internet of Everything; On the other hand, strengthen the breadth and depth of new digital infrastructure construction. We will build a national integrated data center system, establish a virtual agglomeration mechanism for various industries, and promote the integration and sharing of innovative elements across networks and time and space.

30.4 Conclusion

Digital technology is developing at a jaw-dropping speed, penetrating into all fields of economy and society at an unprecedented speed, triggering a profound change, reshaping the governance mode of the whole society, and becoming a "wind vane" leading reform, development and innovation. In this paper, a prediction model of China digital economy scale based on RF algorithm is proposed. Through analysis, the influencing factors and other factors of digital economy growth are obtained. It is predicted that by 2030, the pillar industries of digital economy in China will reach 235,828 billion yuan, compared with 90,993 billion yuan in 2021 and 235,828 billion yuan in 2030. The application of digital technology and the driving industry of digital elements have developed rapidly, and the digital production and service industry has also developed well. Judging from the R2 index, the model in this paper is above 0.97, which shows that the predicted result of this model is almost identical with the actual value trend. Based on the results of the above three indicators, it can be concluded that the model in this paper is obviously superior to the comparative model.

References

1. Z.D. Xian, T.Q. Wang, China digital economy core industry scale calculation and prediction. Stat. Res. **39**, 4–14 (2022)
2. Y.X. Zhong, S.Y. Wu, Meta-universe empowers digital economy to develop with high quality: foundation, mechanism, path and application scenarios. J. Chongqing Univ.: Soc. Sci. Ed. **28**, 1–12 (2022)
3. X.C. Xu, M.H. Zhang, China digital economy scale measurement research-based on the perspective of international comparison. China Ind. Econ. 23–41 (2020)
4. Y.Z. Cai, Calculation of added value and contribution of digital economy: historical evolution, theoretical basis and method framework. Seek. Truth **45**, 65–71 (2018)
5. H.X. Zhang, The scale and structure of digital economy in China from the perspective of production network-an empirical study based on time series input-output table. J. China Renmin Univ. **36**, 76 (2022)
6. Z.H. Fu, X.M. Yang, Y. Song, Classification scale, temporal and spatial differentiation and driving characteristics of regional digital economy in China. Stat. Decis. **38**, 5–9 (2022)
7. F. Zhao, J. Wallis, M. Singh, E-government development and the digital economy: a reciprocal relationship. Internet Res. (2015)
8. L. Nyhagen, *Book Review: Profit and Gift in the Digital Economy* (SAGE Publications Sage UK, London, England, 2017)
9. H. Park, C.M.J. Armstrong, Collaborative apparel consumption in the digital sharing economy: an agenda for academic inquiry. Int. J. Consum. Stud. **41**, 465–474 (2017)
10. W. Sutherland, M.H. Jarrahi, The sharing economy and digital platforms: a review and research agenda. Int. J. Inf. Manage. **43**, 328–341 (2018)
11. A. Grigorescu, E. Pelinescu, A.E. Ion, M.F. Dutcas, Human capital in digital economy: an empirical analysis of Central and Eastern European Countries from the European Union. Sustainability **13**, 2020 (2021)
12. S. Lacey, Reality check: the lack of consensus on new trade rules to govern the digital economy. J. World Trade 54 (2020)

Part II
Human Resource Analytics

Chapter 31
Exploration on the Construction of Quality Management Decision-Making System of Teachers' Ethics in Universities

BaoLong Zhang

Abstract College students are the hope and main driving force of social and economic development, colleges and universities are the places for students to train, and college teachers are the backbone to guide and educate the healthy growth of students. The construction of teachers' ethics and ethics in colleges and universities is great significance for students' education. However, in recent years, the phenomenon of teachers' ethics anomies occasionally occurs in colleges and universities. Establishing a scientific and complete management and decision-making system of teachers' ethics and ethics is the key to guarantee the quality of higher education.

Keywords College teachers · Ethics · Ethics anomie · Management decision-making · Education quality

31.1 Introduction

Chinese institutions of higher learning include undergraduate institutions and junior colleges, and college teachers include teachers, counselors and administrative personnel of various courses. The target of college education is usually young students, and the age distribution is generally over 16 years old. As the guide of young students' growth, college teachers shoulder the important task of preaching and receiving, helping students to set up correct values, outlook on life and world outlook. With the development of society and the popularization of higher education, the social trend of thought is becoming more and more complicated, and the construction of teachers' ethics and style in colleges and universities has more and more influence on students.

On predecessors' research results, the most representative research for Burton R. Clark, editor-in-chief of the higher education system multinational study of academic

B. Zhang (✉)
Hao Jing College of Shaanxi University of Science and Technology, Xian Shaanxi, China
e-mail: 780854828@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_31

organization and John? Van Der Graaff wrote a Comparison of the Higher Education Management Systems of Academic Power in 117 Countries, which clearly defined academic power and had a great influence on China. New Theories of Higher Education—Multi-Studies Research, Places of Inquiry—Research and Graduate Education in Modern Universities, and Scientific Research Foundation of Graduate Education, edited by Burton R. Clark, have provided valuable reference materials for the study of academic power and university governance.

The teacher's improper ethics not only hurt the students, but also the students' families and the expectations of the society. However, at present, the governance of college teachers' deviant behavior is not mature, so it is urgent to establish the quality management decision-making system of college teachers' moral and professional style. In 2015, the total number of full-time teachers in Chinese universities alone reached 1.57 million [1].

31.2 The Concrete Manifestation of Teachers 'Deviant Behavior in Current Colleges and Universities

31.2.1 Basic Investigation

From the Internet public information, the major websites have reported on the incident of teachers' ethics anomie. It can be seen from these reports that in recent years, the incident of teacher ethics is rising year by year. In line with the user-oriented thinking, 247 college students from 6 colleges and universities were investigated on the satisfaction of teachers' ethics. Through the questionnaire survey, the students all expressed their true ideas. The specific data are shown in Table 1.

It is obvious from the data in Table 1 that there are still a certain proportion of students who are not satisfied with the performance of teachers' ethics. It is found in the interviews of students that the network and the real teachers' ethics anomy have an impact on students.

31.2.2 Concrete Embodiment

In recent years, incidents of teachers' misconduct in some colleges and universities have frequently appeared on the news. Through searching the incidents of teachers' misconduct in Internet websites and sorting out relevant notification documents of higher education administrative departments, representative incidents are shown in Table 31.2.

The cases in Table 31.2 are only some representative cases in recent years. According to the nature, specific process, influence and motivation of the above cases, the problems of teachers' ethics in colleges and universities can be divided into

Table 31.1 .College students' satisfaction with teachers' ethics

Degree	Quantity	Percentage (%)
Very satisfied	29	11.74
Be satisfied	103	41.70
Basic satisfaction	81	32.79
Not satisfied	34	13.77

Table 31.2 The case of teachers 'ethics anomie in colleges and universities

Notified department	Brief description of events	Disposal decision	Type of discipline violation
Ministry of Education	Liu, a teacher at X College, took fees from students without permission	Such punishments as expulsion from the Party or removal from office shall be further dealt with according to law and regulations according to the conclusion of the judicial organs on the suspected crimes	Economic problem
Ministry of Education	S University teacher Kang s academic misconduct	Serious warning within the Party, administrative demerit demerit punishment, disqualified from appointing higher professional and technical posts within two years	Academic problem
Ministry of Education	Y University teacher Hwa sexually harassed students	He shall be suspended in the Party for one year, his post grade shall be lowered, he shall be transferred from his post as a teacher, his honorary title shall be revoked, the relevant bonus shall be recovered, and his teacher qualification shall be revoked according to law	Sexual harassment problem
Discipline Inspection Team of H Provincial Discipline Inspection Commission in Education Department	J University teacher Wang loose work discipline, charging student fees and lifestyle problems	Administrative warning	Life style problem
Z College of Political Science and Law	Z School of Political Science and Law teachers publicly made inappropriate remarks	Teachers shall be transferred from their posts, have written examinations, and be disqualified from the qualification of evaluation and promotion	Bad speech problem

five aspects: economic problem, academic misconduct problem, sexual harassment problem, life style problem and bad speech problem [2].

31.2.3 Economic Problems

As a profession respected by the whole society, college teachers should behave in the process of performing their duties, and have corresponding salaries in their own work. However, there are still some teachers who deviate from professional ethics in the process of teaching, and use the power of evaluation and award, achievement conferment and so on to grab money and property. Some teachers are taking advantage of their jobs to set up businesses illegally, and using students as cheap labor for the purpose of benefiting themselves [3].

31.2.4 Academic Problems

Colleges and universities not only undertake the responsibility of teaching, but also undertake certain scientific research tasks, so there are corresponding indicators in the professional title promotion and other aspects. However, some teachers do not devote themselves to in-depth research in their own academic fields, and seek fame and wealth by resorting to fraud and plagiarizing others' achievements.

31.2.5 The Problem of Sexual Harassment

In the process of teaching, some college teachers not only deviate from professional ethics, maintain improper relations with students, or harassing students of the opposite sex with words and behaviors during their duties, which has a negative impact on the industry. Such behavior seriously discredit teachers, cause long-term physical and mental harm to students, and seriously challenge the educational equity and the sanctity of educational cause [4].

31.2.6 Style of Life

There are some teachers in the process of work and life can not follow the example, the existence of extramarital affairs, cheating and other phenomena, seriously damaged the image of teachers. As a teacher, these behaviors can not play a positive role model among students, and damage the image of the school [5].

31.2.7 The Problem of Bad Speech

In the notification, some teachers made public opinions in class or on public opinion platforms that went against the facts, public good customs, improper values, etc., which had a bad impact on both students and the public. In the specific teaching process, he violated the original intention of teaching and educating as a teacher and failed to live up to the expectations of society and parents [6].

31.3 Analysis on Inducement of Misconduct of College Teachers

As for the above abnormal behavior of teachers' ethics in colleges and universities, it is classified according to the types and explored deeply from the three aspects of values, professional ability and professional identity at the source of the problem, and analyzed from the perspectives of behavioral motivation, subjective and objective factors, so as to provide the basis for the construction of the management decision-making system of teachers' ethics in colleges and universities [7].

31.3.1 There is a Bridging Gap Between Career Development and Work Practice

From the perspective of internal reasons, in the specific work process, some teachers' material desires do not match their actual work benefits. Under the influence of consumerism mentality, in addition to the pursuit of necessary material needs, some teachers will choose to go against professional ethics to seek personal gains for greater economic returns. In the process of academic research, the workload is relatively difficult, but it is not proportional to the academic return. Under this background, some teachers try to reach the standard through "shortcut" [8].

31.3.2 Lack of Professional Identity and Awet

In the process of teaching, some teachers lack the sense of professional identification and awe, lose the minimum professional ethics in daily work and life, drag down the bottom line, do not pay attention to private morality, and make behaviors against professional ethics and human bottom line. The civilized and harmonious relationship between men and women is the expression of social progress. Sexual harassment and personal style problems not only damage professional ethics, but also are against the development of social civilization [9].

31.3.3 The Original Aspiration and Ideal Faith Have Been Loosened

Teachers' original intention and mission is to teach and educate people, ten years of trees, a hundred years of trees. Conveying positive energy and correct values to students in the classroom and in the public arena is not only a basic requirement of the profession, but also a requirement of taking responsibility for students. Some teachers are affected by some undesirable social trends, which leads to the negative deviation of their own values, the deterioration of their original ideals and beliefs, and then they will publicly make inappropriate remarks in the workplace [10].

31.4 Thoughts on Constructing the Decision-Making System of Teacher Ethics Management in Colleges and Universities

Universities and educational administrative departments should play an important role in establishing the decision-making system of teachers' ethics and ethics. By constructing an effective three-dimensional supervision mechanism and a timely, fair, reasonable, legal and compliant decision-making system, the quality of teachers' ethics and style in colleges and universities can be fully guaranteed, laying a foundation for training college students who meet social needs. The simple management of colleges and universities is prone to legal disputes.

The construction system of teachers' ethics and ethics in colleges and universities should be based on the relevant regulations of the superior, and approved by the superior regulatory agencies and relevant administrative departments for the record. In the process of the construction of teachers' ethics and ethics, all relevant departments and stakeholders work together to achieve true compliance with laws and regulations.

31.4.1 Strengthen the Education and Leadership of Teachers' Ethics and Style in Colleges and Universities

Establish a long-term mechanism for the education of teachers' ethics and style in colleges and universities, improve teachers' self-quality through continuous education, and enhance teachers' ethics as a whole. Ensure that college teachers not only educate students academically, but also set an example for students. The education of teachers' ethics and style should be included in the daily work, and the attendance rate of teachers should be strictly controlled to ensure the quality of education. Timely take the relevant departments to release the violation cases of college teachers as the material for warning education, organize teachers to reflect on the ethics of teachers cultivation.

31.4.2 Shaping the Environment of College Teachers' Career Planning and Development

Establish a scientific performance evaluation system for teachers, and guarantee the basic life of teachers. Labor unions in colleges and universities play a subjective and active role in formulating practical and feasible assistance policies for teachers with difficulties, helping teachers to solve economic and other difficulties, and solving their worries. At the same time, it provides a platform for teachers to carry out scientific research, establishes a reasonable incentive system for scientific research, creates an atmosphere of writing papers and doing projects for the spirit of scientific research, and brings multiple elements such as scientific research and teaching performance into the content of professional title evaluation and award evaluation, avoiding the semi-compulsory scientific research work of making up numbers for professional title and award evaluation.

31.4.3 Strengthen the Discipline of College Teachers

There is zero tolerance for violations of rules and regulations, especially in respect of ethics. The severity of punishment, the requirements of rules and regulations to be implemented, the relevant provisions on the treatment of teachers' ethics and ethics violations to be detailed, in the overall requirements of the relevant documents of the Ministry of Education to be implemented one by one, one by one, each has the corresponding reward and punishment plan. For relatively minor illegal acts, timely detection, timely criticism and education. Dynamic management by virtue, prevention, can effectively prevent small mistakes from evolving into big mistakes, learn from past mistakes to avoid future ones, cure diseases and save people. Humanized and standardized management is the only way to ensure the comprehensive quality of college teachers and the vital interests of students.4.4 Improving the evaluation system for teachers' ethics and ethics in colleges and universities.

Pay attention to supervision and feedback on the evaluation of teachers' ethics and style. The three-dimensional supervision method of student supervision, peer supervision and department evaluation should be constructed to supervise the daily words and deeds of teachers, collect and feedback evaluation data in time, and develop application terminals so that every teacher can receive supervision feedback from others and conduct self-examination and self-correction in time. The evaluation data of teachers' ethics shall be summarized according to a certain period, reward standards shall be formulated for those with excellent evaluation results, early warning shall be given to those with poor evaluation data, further investigation shall be carried out on the established violation facts that have caused consequences, and corresponding punishment shall be given to the parties concerned according to regulations.

31.5 Conclusion

The construction of teachers' ethics and style is of great significance to the growth of college students. Therefore, it is urgent to take corresponding measures to solve the problem of teachers' moral anomie in colleges and universities. Through careful investigation and research, these problems can be roughly divided into economic problems, academic problems, sexual harassment problems, lifestyle problems and bad speech problems. To construct the management and decision-making system of teachers' ethics in colleges and universities, from strengthening the education and leadership of teachers' ethics in colleges and universities, shaping the career planning and development environment of teachers in colleges and universities, serious discipline constraints of teachers in colleges and universities, improving the evaluation system of teachers' ethics in colleges and universities, it is responsible for teachers, colleges and universities, students, as well as parents and society. Comprehensive role, multi-dimensional development, can avoid the problems in the construction of ethics.

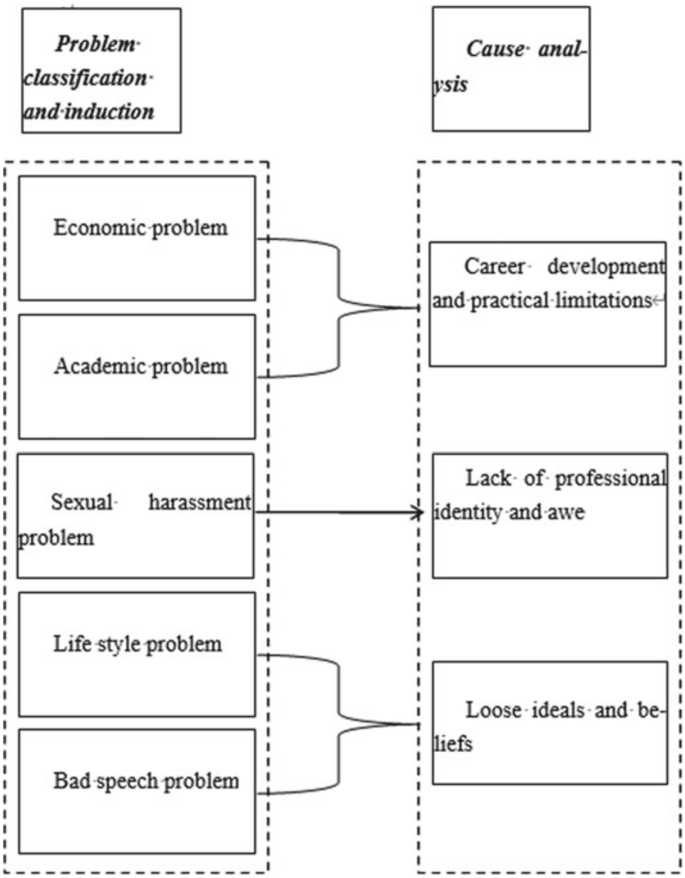


Fig. 31.1 Causal analysis network

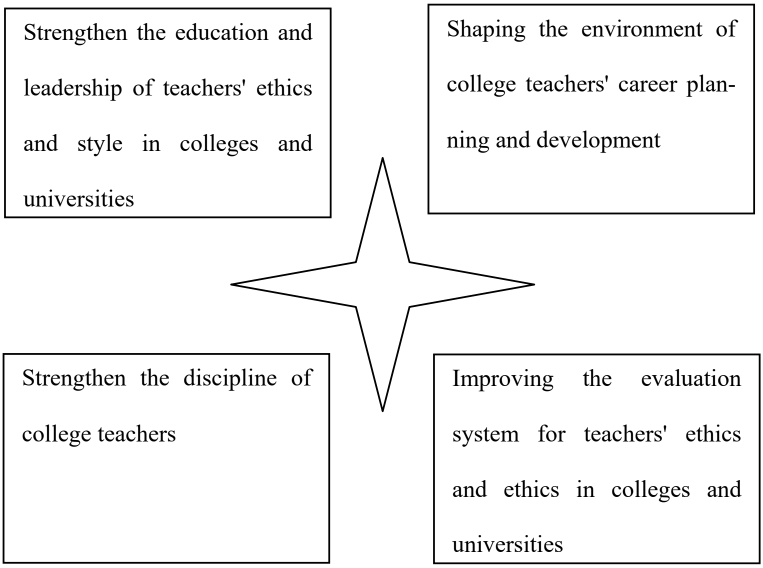


Fig. 31.2 Constructing the decision-making system of teacher ethics Management in colleges and universities

Acknowledgements 2022 Shaanxi University Student Work Research Project Results (Research on the Strategy of Improving the Moral Quality of College Counselors under the "Three Complete Education" System) Project No. (2022XKT84).

References

1. W. Zhou, Change of gender structure and resolution of gender gap of full-time teachers in colleges and universities. China Women's News, 2017–12–30(A01)
2. In Yunnan province, Kunming polytechnic learned discipline in colleges and universities education base to carry out the warning education. https://www.kmust.edu.cn/info/1011/18984.htm, 2020–12–30
3. Y. Lianjun, J. Jiancheng, Firmly establish the Faith Foundation of teacher ethics construction in the new era. Jiangsu High. Educ. **03**, 105–108 (2021)
4. G.A.O. Fangkai, On the performance, causes and countermeasures of teachers' anomie in colleges and universities. Mod. Commun. **6**(03), 45–47 (2021)
5. Y. Li, Problems, Tension and improvement of the system for dealing with teachers' deviant behavior in public universities. Contemp. Educ. BBS **4**(08), 1–14(2023)
6. Q. Fan, Lack of university teachers "legislation" coordination and standard construction. J. China Higher Educ. Res. **12**(03):70–76 (2023)
7. N. Xia, L. Zhang, College ethics anomie public opinion guide mechanism based on the theory of entropy to explore . J. Jiujiang Vocat. Tech. Coll. (01), 87–92 (2023)
8. N. Ren, Increase school evaluation weight teacher ethics anomie. One vote rejected. Xi 'an Daily **20**(006) (2023–02–01)

9. W. Hong, Y. Zhigang, Y. Huadong, A Case study of Teachers' deviant behavior in Colleges and universities: Basic characteristics and governance path. J. Chengdu Normal Univ. **38**(11), 54–61 (2022)
10. X.C. Su, On the construction of teachers' ethics in colleges and universities. J. Jilin Univ. Chem. Technol. **36**(10), 10–13 (2019)

Chapter 32
Research on Supply and Demand and Management Decision-Making of Home-Based Elderly Care Services

Li Yanyan

Abstract At present, the mismatch between supply and demand of home-based elderly care services is more serious, such as day care services as the main supply items, but the oversupply is more prominent and the utilization rate is low. However, the entertainment and health care projects with the highest demand and willingness of the elderly have a serious shortage of supply; The development of urban and rural elderly care services is extremely unbalanced, and the elderly have a large difference in their willingness to demand for elderly care services. In this regard, it is proposed to expand financing channels and establish a diversified input mechanism; Strengthen the construction of home-based elderly care service teams, improve the quality of elderly care service supply and other decision-making suggestions for elderly care service management.

Keywords Care services · willingness to demand · Supply and demand structure · Pension · Financial support for children

32.1 Introduction

China is the country with the largest elderly population in the world, and home care has become an inevitable choice for China to solve aging problems. Home care service refers to a way of providing life care, medical care and spiritual comfort to the elderly by social departments. Such as the government, market, society, community and family, so as to meet the needs of the elderly for home care. With the acceleration of social transformation and the increasing miniaturization of traditional family structures, more and more elderly people living alone have become "elderly people living alone", empty nest elderly families are showing a rapid increase trend, the rapid increase of the elderly population, especially empty nest elderly people, and

L. Yanyan (✉)
Haojing College, Shaanxi University of Science and Technology, Xixian, China
e-mail: 897003805@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_32

the aging of the elderly population, all require the establishment of a sound social pension service system[1, 2]. The contradiction between the development of old-age services and the elderly before getting rich is more prominent, and there are many unfavorable factors that hinder the construction and development of the home-based old-age service system. Actively responding to the aging of the population and accelerating the construction of the home-based elderly care service system will not only help safeguard the legitimate rights and interests of the elderly, meet the growing demand for elderly care services, and enhance the sense of gain and happiness of the elderly, but also help stimulate domestic demand, expand employment, improve people's livelihood, and promote social harmony.

32.2 Current Situation of Supply and Demand of Home Care Services

32.2.1 The Supply and Demand for Home-Based Elderly Care Services is Unbalanced

Under the influence of the concept of hierarchical order of needs, the satisfaction of the spiritual needs of the elderly is often placed in an "important but not urgent" position. There is less research and exploration of relevant elderly care service measures on the value attribution of the elderly group, political participation, and the re-creation of elderly life. The content of elderly care services focuses on physiological needs and does not pay enough attention to psychological needs. In fact, the needs of the elderly for belonging, self-esteem and self-realization at the spiritual level are not "luxuries" that can only be talked about after satisfying physical needs. On the contrary, the mental state of the elderly plays an important role in physical health and mental health [3, 4]. At the same time, in many projects of the home care service center, day care service is to provide care care, lunch break meals, rehabilitation entertainment and other day care services for the elderly who need to be taken care of, the service needs to sign an agreement with the family of the elderly and pay a certain fee, but because many elderly people are actually not old, the physical condition is also good, if it is day care, although there is a special person to accompany, but can not move freely, can only stay in the service center, so the project oversupply.

32.2.2 There Are Differences in the Supply and Demand of Urban and Rural Home-Based Elderly Care Services

With the development of home-based elderly care services, the demand for healthcare services in urban areas will become the first in the future, followed by daily life care, leisure and entertainment, and social participation. It can be predicted that with the enhancement of the economic capacity of the elderly, the demand for higher-level services such as health care and leisure will become dominant. The first demand for home-based elderly care services in rural areas is health care services, followed by spiritual comfort services, and the demand for daily care services is the lowest.

The development of urban and rural home-based elderly care services is uneven, most rural home-based elderly care services have not basically started, and most of the rural elderly have not used various community elderly care services. Therefore, we must vigorously promote the equal development of urban and rural elderly care services. Rural medical conditions in rural areas are relatively backward, and there has always been a problem of difficulty and high cost of medical treatment, especially the elderly are more inconvenient to see a doctor, so there is a huge demand for medical care in rural areas. The second demand is spiritual comfort services, which are due on the one hand to the serious phenomenon of empty nests in rural areas and the lack of spiritual sustenance for the elderly, and on the other hand to the lack of cultural and recreational activities in the vast rural areas. The lower demand for life-care services is mainly influenced by the collective living tradition of mutual assistance among neighbors in rural areas.

Table 2 Demand, supply and utilization of urban home-based elderly care service projects (%)

Service Items Service	Service requirements	Service supply	Service Utilization	Demand difference	Utilization difference
Door-to-door housework	18.8	68.2	7.0	−49.4	61.2
Home care	13.8	55.1	1.9	-41.3	53.2
Home visits	20.5	59.8	5.4	-39.3	54.4

(continued)

Table 1 Demand, supply and utilization of rural home-based elderly care service projects (%)

Service items service	Service requirements	Service supply	Service Utilization	Demand difference	Utilization difference
Door-to-door housework	32.2	6.8	0.4	25.4	6.4
Home care	35.9	8.2	1.3	27.7	6.9
Home visits	67.8	53.9	32.4	13.9	21.5
Chat to relieve boredom	46.8	14.3	6.9	32.5	7.4

(continued)

Service Items Service	Service requirements	Service supply	Service Utilization	Demand difference	Utilization difference
Chat to relieve boredom	16.8	24.6	1.5	-7.8	23.1
Recreation	17.1	23.7	0.9	-6.6	22.8
Dinner tables for the elderly or food delivery	11.5	19.5	0.4	-8.0	19.1
Accompany to the doctor	13.0	20.7	0.7	-7.7	20.0
Help with everyday shopping	10.9	21.8	0.5	-10.9	21.3
Rehabilitation	21.0	43.8	1.9	-22.8	41.9
legal aid	22.2	55.9	0.8	-33.7	55.1

32.3 Analysis of Problems and Root Causes in the Development of Home-Based Elderly Care Services

32.3.1 The Operation of the Service Center is Difficult and the Financial Support is not in Place

Most community home-based elderly care service centers are idle and semi-idle to varying degrees. The community home-based elderly care service center is not built around the needs of the elderly in the covered community, mahjong tables are in short supply, while the rehabilitation nursing room and canteen are idle, and the service center operates at a loss. At the same time, in order to build a community home-based elderly care service center with a scale of no less than 200 square meters and complete equipment, the average construction fund needs 85–1 million, and the average rural area needs 100,000, resulting in great pressure on this financial fund [5, 6].

32.3.2 There is not Enough Nursing Staff and Low Motivation to Work

According to the Ministry of Civil Affairs' "Requirements for the Management of Social Welfare Institutions", the ratio of caregivers for the elderly who need more than first-level nursing (dependent on others or mild mental dysfunction) in nursing homes should reach 4:1, and the nursing ratio for healthy elderly people should be 7:1. At present, taking Jiangxi Province as an example, the total number of elderly care service employees: 10,830. Among them: 4098 management personnel, accounting for 37.84%; There were 2,895 elderly care workers, accounting for 26.27%; There were 1055 professional and technical personnel, accounting for 9.74%; There were 2,782 service personnel, accounting for 26.15%.The rate of holding professional qualification certificates is very low, and the rate of certified nursing staff is less than 30%. Therefore, most nursing personnel in nursing institutions are in short supply, and the quality needs to be improved. At the same time, the average salary of nursing staff is low and their motivation to work is not high.

32.3.3 The Effective Demand for Elderly Care Services is Insufficient

The difference in pension level in different regions and the amount of pension has an impact on the economic support of the elderly to obtain children, affect the asset level of the elderly, and then affect the demand of the elderly for old-age services [7, 8]. Based on the research of relevant literature, an empirical analysis model (32.1) was constructed to analyze the data of the 2020 CHARLS follow-up survey. Among them, the dependent variable is the net economic transfer of elderly children, and the main independent variable is the annual pension amount received by the elderly; In addition, a set of control variables is introduced into the model, such as region, health status, elderly personal assets, and other factors.

$$y = c + \alpha I + \beta X + u. \tag{32.1}$$

where y represents the net transfer of the economy of the children of the elderly; I represents the annual pension amount received by the elderly, and X represents a set of exogenous control variables.The description of the variables and the description of the samples are shown in Table 1.

The results of the study show that for every 1% increase in the annual pension received by the elderly, the net economic transfer of children decreases by 0.224%, and the pension has a significant "crowding out effect" on the economic support of children. The crowding out effect is mainly aimed at the elderly, the elderly who are in better health, and the western region. The different pension ratios have widened the gap between the quality of life of the elderly in the West and the central and eastern regions, which is not conducive to the equalization of public goods between regions. Compared with the elderly in the central region, the economic support for the elderly in the east and west is lower, but the west is very significant, while there is no significant difference in the central and eastern regions. It can be seen that the elderly in the central part receive the highest child support, and the west has the lowest. The possible reason is that the economic conditions of children in the west are relatively poor, and their ability to support them is weaker; However, the economic conditions of children in the central and eastern regions are relatively high, the ability to support them is strong, and the financial support for their parents is relatively large.The empirical results are shown at Table 2.

In addition, the concept of community home care services has not been widely recognized by the elderly. As a result, community home-based elderly care service resources have not been effectively utilized, which greatly reduces the participation ratio of the home-based elderly and causes insufficient effective demand. Some existing community home-based elderly care service projects, due to lack of prior planning, the layout is too fragmented, the radiation range is small, and the service objects are few, the consequence is that on the one hand, the service price is high, the elderly cannot afford it, and cannot expand the market scope; On the other hand, income is not enough to cover costs, loss-making operations, cannot form a market, and is not attractive.

32.4 Management Decisions for the Development of Home-Based Elderly Care Services

32.4.1 Improve the Mechanism for Government Procurement of Services

Formulate policies and measures for the government to purchase old-age services from social forces, and gradually increase the types and quantities of services purchased by the government. At the same time, stimulate the enthusiasm of enterprises and social forces to participate, rather than simply provided by the government, and provide good policy development space through tax incentives, policy support, financial investment, etc. Cultivate and develop social organizations of old-age services to participate in the old-age undertakings, and form a service mechanism of “the government builds a platform, policies support guarantees, and society operates”. In terms of operation, it adopts the “public welfare venture capital” model of “government investment and construction, social organizations participating in service management, and benefiting the residents”, which can expand the comprehensive service field of community services and social organization services that complement each other.

32.4.2 Strengthen the Construction of Home-Based Elderly Care Service Teams

In view of the current problems such as low specialization, few elderly service facilities and single functions in Jiangxi Province, it is necessary to actively strive to establish a professional home care service team. Elderly care service managers, service personnel and volunteer teams are the three major forces in the home care service system [9, 10]. At present, the number of these three types of personnel is seriously insufficient and the overall level is low, so it is necessary to establish a complete human resources development and management system for home care services. Gradually promote the appraisal of vocational skills for old-age services, and implement a system of holding certificates. According to the gap in community elderly care service personnel, provincial colleges and universities or non-local colleges and universities can be entrusted to train professional students related to elderly service, and guide and encourage graduates of related majors to engage in elderly service work to ensure a steady stream of professional talents for the community.

32.4.3 Improve the Quality of the Supply of Home-Based Elderly Care Services

Starting from the most urgent needs of the elderly, and then expanding to characteristic and personalized service projects, providing the elderly with different levels and aspects of all-round professional services. Different groups of elderly people (different economic status, different physical conditions, different living styles, etc.) require different service content, level and service methods. Classify the elderly group, provide personalized service items, and provide a full range of medical care services and home care services for the elderly who cannot take care of themselves; Provide some life care services for the semi-self-care middle-aged and elderly elderly, such as meal delivery, laundry and cleaning; In order to be able to take care of healthy young people who are fully able to take care of themselves, provide them with medical, entertainment and communication places as needed, and organize various cultural and sports entertainment activities.

32.4.4 The Two Sides Will Increase Financial Subsidies and Raise the Standard of Basic Pensions

At present, the gap between the per capita financial subsidies of urban and rural and regional endowment insurance is relatively large, and social endowment insurance is a public good, and all citizens have the right to enjoy it equally. Increasing financial

Table 32.3 Descriptive statistics of variable descriptions and samples

The variable name	Variable description	count	percentage
Age	60–69	761	62.4%
	Over 70 years old	458	32.3%
Place of residence	East = 1	280	23%
	Central = 2 (reference group)	485	39.8%
Health status	West = 3	454	37.2%
	Good = 0	214	17.6%
Annual amount	Generally below = 1	1005	82.4%
Personal assets of the elderly	$828.957		
Household consumption expenditures	$3884.901		
Financial support for children	$7170.105		
The variable name	3862.01yuan		

Table 32.4 Estimated results of the impact of pensions on the financial support of children

The variable name	coefficient	standard deviation
Constant terms	6.660***	0.946
The amount of the pension	−0.224**	0.112
age	0.009	0.006
westward	–0.221***	0.081
eastern	−0.052	0.093
Health status	0.038	0.095
Personal assets of the elderly	0.107***	0.022
Model significance cases	The F value is 6.493 (P = 0.00)	

Note *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively

subsidies for rural insurance not only conforms to the principle of social fairness and justice, but also has a large room for actual increase. Of course, how to adjust the basic pension of urban and rural residents in the future depends to a large extent on the political ethics or social values of relevant decision-makers, that is, whether they can face up to the equal pension rights and interests of residents. In this way, the elderly can improve the purchasing ability of elderly care services, expand the audience, and improve the effective demand for elderly care services.

References

1. G. Shengzu, W.U. Huajun, C.A.O. Dongmei. Strategic thinking and suggestions on building a scientific and reasonable elderly care service system.Population Research 01:3–14 (2017)

2. W. HU, Policy Network Governance of Urban Community Home-based Elderly Care Service System:A Case Study of Government Purchasing Public Service Model[J].Administrative Management Reform,2023,01:52–60
3. Zheng Weina,WU Linye,Ruan Jiayin. Analysis of motivation of home-based elderly living alone in the community[J].Journal of Nursing,2022,12:83–85.
4. Tang Meiling et al. Research on the construction of smart community home-based elderly care service model[J].Northwest Population,2017,06:1007–0672.
5. Zhou Jianfang. The effective demand for home care services for the elderly in urban areas and its influencing factors[J].Beijing Social Sciences,.2022,11:117–124.
6. Sun Dan. Kane. The development and enlightenment of the construction of Japan's elderly care service talent team[J].Western Journal,2023,02:68–71.
7. Zhang Fushun.Comparison and reference of international experience in the development of elderly care services[J].Lanzhou Academic Journal,2023,04:12.
8. Du Ruixia. Rural Revitalization and Rural Elderly Care Services: Phased Characteristics and Governance Paths: Based on the Perspective of Scenario Interaction[J].Theory:Journal of China Agricultural University (Social Science Edition),2023:213–222.
9. Wang Qiong. The demand for home-based elderly care services in urban communities and its influencing factors:Based on the data of national urban elderly population survey[J].Population Research,2016,01:1000–6087.
10. Yu Yuqian. Research on countermeasures for the innovation of elderly service talent training mode under the background of the Internet[J].Employment and security,2022,11:151–153.

Chapter 33
The Role of Green Behavior Between Workplace Well-Being and Personal Green Value

Stuti Das, BiswaPrakash Jena, Sroojani Mohanty, Pritinanda Sahoo, and Prabhu Prasad Mohapatra

Abstract Workplace well-being (WWB) has emerged as a major topic in organizational behaviour literature as it affects a number of organizational outcomes. Numerous studies have looked at employee well-being in the presence of different work situations. The impact of green behaviour (GB) on workplace wellbeing in organisations, however, is not well understood. The purpose of this paper is to examine how each employee's individual green values (IGV) affect their workplace wellbeing. Additionally, it aims to investigate how green behavior can improve employee wellbeing by mediating the relationship between individual green value and workplace wellbeing. By reviewing the literature on individual green values, workplace wellbeing, and green behavior, this paper develops a conceptual framework. The model was empirically tested among Indian executives continuing their executive program at a top management institute in southern India while working in a variety of sectors. According to the study, utilizing individual green values can result in workplace well-being, which will be important for employees' well-being. Furthermore, we discovered that the link between individual green value and workplace wellbeing is mediated by green behavior. This paper discusses the ways in which workplace wellbeing can be improved by emphasizing individual green values and implementing green behaviors within the framework of the value-belief-norm (VBN) theory. This paper gives insight into how individual green value can

S. Das
SAMET School of Management, Bhubaneswar, India

B. Jena (✉)
Indian Institute of Management Bangalore, IIMB, Bangalore, India
e-mail: biswap.jena@iimb.ac.in

S. Mohanty
Interscience Institute of Management & Technology, Bhubaneswar, India

P. Sahoo · P. P. Mohapatra
IBCS, SOA University, Bhubaneswar, India

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_33

positively affect employees' workplace wellbeing through green behavior. Therefore, businesses should support initiatives that promote environmentally conscious behaviour because doing so will improve employee wellbeing.

Keywords Individual green value · Green behavior · Workplace wellbeing

33.1 Introduction

Given the severity of today's environmental issues, organizations are working more towards environment friendly practices with increased sense of responsibility and diligences [1]. The ever-growing use of natural resources for various organizational activities is leading to a situation which makes it imperative for all the organizations' stakeholders to divert their attention to responsible use of natural resources [2]. To achieve this balance between requirement and the usage of resources, individuals as well as the organizations are expected to be more accountable which can be possible by becoming 'Greener' [3]. Many past research works have suggested that there are various considerably important factors that work together when it comes to implement such green initiatives [4]. These form the essence of the corporate environmental strategy wherein the individual employee's green values have received attention. To be more precise, there are several studies which have proposed that the organizations which are aspiring to implement green practices effectively, need to encourage green behaviour among all the employees [5, 28]. It requires the minimal usage of natural resources and optimum effort to facilitate green behaviour including every individual in the organization starting from the lower most level of employees to the top management [6, 29].

One of the key areas of study across different fields is the problem related to environmental preservation and sustainable development. A significant micro-activity to address the issue of environmental protection and the organization's responsibility in protecting it is considered to be employee green behavior. For that reason, the focus of scholars in the area of organizational behavior and sustainable development is on identifying and analyzing various determinants of employee green behavior.Conserving resources, reusing as much possible, sustainable mobility, and sustainable work are just a few examples of employee green behaviour (EGB) [7, 8, 30] a positive organizational behaviour, which employees implement at work to protect the environment and advance the organization's sustainable development efforts [9].

An imminent perception of total job satisfaction and agreeable feelings about one's job is referred to as "wellbeing at work." Both organizations and individuals share a common interest in well-being. Researchers have found that people who feel better about themselves are more motivated to work and are more productive [10, 11]. EGB shows mutuality in approach from the viewpoint of the enforcer as it is a behavior that benefits both the organization and the environment.

33.2 Theoretical Background

33.2.1 Stern's Value Belief Norm (VBN) Theory

The Value-Belief-Norm (VBN) Theory [12] links three theories of environmentalism: norm activation theory [13], the theory of personal values [14], and the New Environmental Paradigm (NEP) [15]. This theory suggests that choosing environmentally friendly behaviors can be grounded on the individuals' awareness of moral obligations towards their environment. This theory offers an investigative background for normative factors that proliferate sustainable behaviors among individuals. It suggests a series of factors, starting with values and over-all environmental concern and moving on to explicit beliefs about the adverse effects of particular activities and the ability and obligation of the individual to avoid these adverse effects, which successively stimulates sustainable personal norms for behavior. Value, as defined by Schwartz [16] is "a desirable trans-situational goal varying in importance, which serves as a guiding principle in the life of a person or other social entity". Values are supposed to encourage behavior indirectly by guiding attention to and influencing the perception towards information corresponding to values. The behaviors which are not strongly influenced by circumstantial factors, can be driven by personal norms, which are the incorporated sense of obligation to act in a certain way. The personal norms get activated when violation of those norms generate negative consequences and the person believes that he/she will bear responsibility for those consequences. De Groot and Steg [17] devised a tool that assesses value types presumed to be predominantly important predecessors of environmental beliefs and behaviors based on Schwartz's value survey. The instrument measures value orientations such as biospheric, egoistic, and altruistic. It was later extended to take in hedonistic values as well [18]. The NEP emphasizes on limits associated with growth, the importance of how economic growth corresponds with protection of environment, and the necessity to preserve natural balance [19]. The paradigm includes extensive belief system on environment, having knowledge of environmental problems, and recognition of the necessity for sustainable development.

Several studies conducted over the years have provided evidence for the NEP scale's applicability [15]. According to the norm-activation theory [20], pro-social behavior, such as choosing environmentally friendly practices, should befall as a result of personal norms held for such behavior. The idea contends that environmental attitudes affect people's perception of the importance of particular activities and confidence in their capacity to prevent the negative effects. Numerous researches have revealed the significance of norm-activation for a range of sustainable behaviours [21–23]. When an individual is aware of the consequences and assigns responsibility, the predictive potential of the Value-Belief-Norm theory increases [24]. These specific ideas influence personal norms, which in turn influence a range of sustainable behaviors [23, 25]. It also affects whether a person feels morally obligated to act in an environmentally responsible manner [24].

33.3 Hypothesis Development

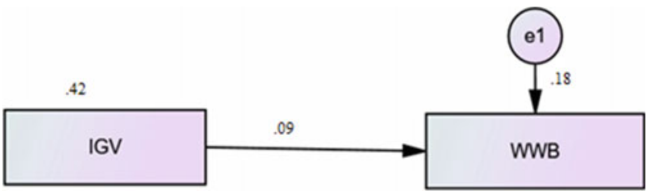
Based on the above proposed conceptual model, we predict the following:

Hypothesis 1: Individual Green Value will lead to Workplace wellbeing.

Hypothesis 2: Green Behavior will mediate the relationship between Individual Green Value and Workplace wellbeing.

Employees in various public and private sector organizations in India are the study's target audience. The goal and purpose of the study were explained to each participant, and respondents were informed regarding the confidentiality, anonymity, and data security. The scales utilized in this study were adapted from standardized scales that had been used in earlier publications. The demographic details are shown in Table 33.1. We used mediation analysis with AMOS to examine the relationship between individual green value (independent variable), green behavior (mediation variable), and workplace wellbeing (dependent variable) in order to test our hypothesis.

The aforementioned tables make it abundantly evident that the model and data are highly compatible. According to the advice of HU and Bentler [26], CMIN is 2.72; RMSEA is 0.04; Normed Fit Index is 0.95; Comparative Fit Index is 0.96; and Tucker Lewis Index is 0.94. As seen in the above graphic, all of the path loadings from latent constructs were significant.



As the P value is large, we can deduce that there is a significant association between individual green value (IGV) and workplace wellbeing (WWB). Given that P values are not always significant, we can infer from this that GB fully mediates the link between IGV and WWB.

Table 33.1 Analysis output from SPSS and AMOS

Demographic details of respondent		Number	Percentage (%)
Gender	Male female	228 147	60.8 39.2
Age	20–29 30–39 40–49 Above 50	113 142 86 34	30.1 37.8 22.9 9.06
Education	Graduate Post graduate Ph.D	189 182 4	50.4 48.5 1.06
Experience in years	Less than 1 1–5 years 6–10 years 11–15 years 16–20 years Above 20 years	23 174 82 48 32 16	6.13 46.4 21.8 12.8 8.53 4.26
Organization tenure	Less than 1 1–5 years 6–10 years 11–15 years 16–20 years Above 20 years	23 174 82 48 30 18	6.13 46.4 21.8 12.8 8 4.8

Category	Index	Level of acceptance	Index value	Comments
Absolute fit	Chi-Square RMSEA GFI	1–3 <0.08 >0.90	1.861 0.045 0.919	Accepted range Accepted range Accepted range
Incremental fit	AGFI CFI	>0.90 >0.90	0.901 0.970	Accepted range Accepted range
Parsimonious fit	TLI NFI	>0.90 >0.90	0.967 0.939	Accepted range Accepted range

Construct	Mean	SD	Item	Loadings	AVE	CR	Cronbach Alpha	Square root of AVE
GB (Kim et al. 2016; 5 items scale)	3.46	0.54	GB1 GB2 GB3 GB4 GB5	0.717 0.721 0.702 0.812 0.768	0.72	0.92	0.91	0.719

(continued)

Table 33.1 (continued)

Demographic details of respondent					Number	Percentage (%)			
WWB (Bartel et al. 2019; 8 items Scale)	3.62	0.58	WWB1 WWB2 WWB3 WWB4 WWB5 WWB6 WWB7 WWB8	0.721 0.814 0.823 0.772 0.742 0.713 0.758 0.732	0.78	0.92		0.89	0.779
IGV (Steg et al. 2005; 6 items Scale)	3.54	0.52	IGV1 IGV2 IGV3 IGV4 IGV5 IGV6	0.684 0.878 0.682 0.668 0.922 0.879	0.75	0.88		0.87	0.749

Table 33.2 Mediation analysis output from AMOS

			Estimate	S.E	C.R	P
CC	<–-	JCP	0.095	0.032	2.996	0.003
			Through	Mediation	Testing	
DID	<–-	JCP	0.080	0.025	3.203	0.001
CC	<–-	JCP	0.011	0.018	0.606	0.545
CC	<–-	DID	1.050	0.035	30.262	***

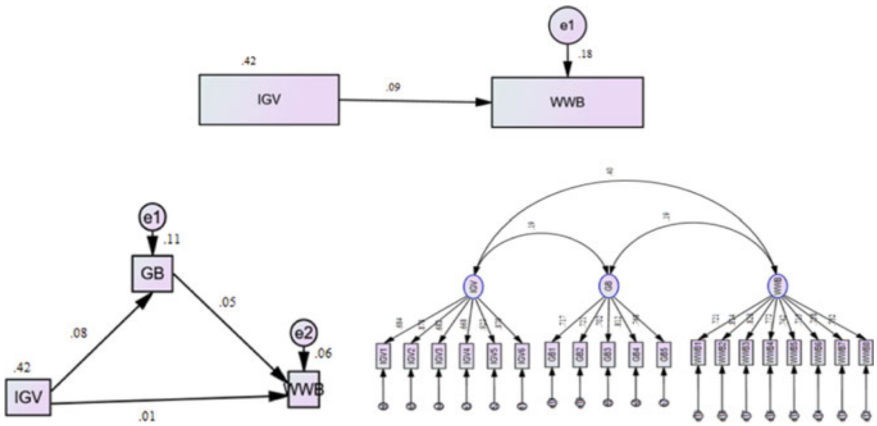


Fig. 33.1 Mediation model and measurement model from AMOS

33.4 Discussions and Implications

In the current study, we looked at the relationship between Individual Green Value, Individual Green Behavior, and Workplace Wellbeing. We hypothesized and empirically found that Green Behavior mediated between individual green value and workplace wellbeing, based on the prior literature that used value belief norm theory as a supporting mechanism of Individual green value. These findings have a number of theoretical and applied ramifications. The value belief norm theory is mostly applicable to an organization's working environment. Previous research by academics suggested that the Value Belief Norm Theory is the mediating factor or the spark between an individual's green values and their green conduct. But in our study, we contend that because of the Value Belief Norm Theory, people who have individual green values benefit from an improvement in workplace wellbeing. Since individual green values lead to workplace wellbeing, it follows that people who are committed to living sustainably are also committed to their values, with green behavior acting as a bridge between the two. As not everyone is fit for individual green values and green behaviour, value belief norm plays a significant influence. Thus, the main areas of our study are individual values for the environment, workplace wellbeing, and green behaviour as a mediating factor. The results of prior studies support the notion that those who exhibit individual green value through green behaviour are concerned about their environmental obligations and will use all of their talents to improve workplace wellbeing in order to better their environment [9, 27].

33.5 Conclusion

The relationship between individual green values, green behaviour, and workplace wellbeing was established and empirically verified in this research. The model's result is given below. Individual green values for each employee can improve workplace health, fostering growth and success for both the organisation and the individual employee. Finally, the authors have suggested that engaging in green behaviour can be a way to improve wellbeing from an organisational and personal perspective. In light of this, management staff can benefit from training on how to empower their coworkers and subordinates green behaviour, because doing so will have a good impact on actions that boost both organisational productivity and worker wellbeing. In this way, by elucidating the effects that employee green behaviour have on workplace well-being among employees in organisations, this study has been able to contribute new knowledge to the green value, green behaviour and wellbeing literature. Although this research contributes to the body of knowledge and its conclusions have significant managerial consequences, it has certain limitations. Convenience sampling with a small sample size was the sampling approach selected in this study. Caution should be used when extrapolating the study's findings. More samples from all industries can be used in future studies. Future researchers can employ both qualitative inquiry and a quantitative confirmatory strategy since this study only used a quantitative approach.

References

1. D.W. Renwick, T. Redman, S. Maguire, Green human resource management: a review and research agenda. Int. J. Manag. Rev. **15**(1), 1–14 (2013)
2. T. L. Friedman, The power of green. The New York Times, 15(2007)
3. D. Hyndman, D. Hyndman, Natural hazards and disasters. Cengage Learning (2016)
4. S.E. Jackson, J. Seo, The greening of strategic HRM scholarship. Organization Management Journal **7**(4), 278–290 (2010)
5. P. Kumari, Green HRM-Issues and challenges. Global Research Analysis **1**(5), 80–83 (2012)
6. H.H.P. Opatha, A.A. Arulrajah, Green human resource management: simplified general reflections. International Business Research, 7(8), 101(2014)
7. M. Busse, S. Menzel, The role of perceived socio-spatial distance in adolescents' willingness to engage in pro-environmental behavior. J. Environ. Psychol. **40**, 412–420 (2014)
8. D.S. Ones, S. Dilchert, Environmental Sustainability at Work: A Call to Action. Ind. Organ. Psychol. **5**, 444–466 (2012)
9. A. Kim, Y. Kim, K. Han, S.E. Jackson, R.E. Ployhart, Multilevel Influences on Voluntary Workplace Green Behavior: Individual Differences, Leader Behavior, and Coworker Advocacy. J. Manag. **43**, 1335–1358 (2017)
10. X. Fan, N. Deng, X. Dong, Y. Lin, J. Wang, Do others' self-presentation on social media influence individual's subjective well-being? A moderated mediation model. Telematics Inform. **41**, 86–102 (2019)
11. D. Kamerāde, M.R. Bennett, Rewarding work: Cross-national differences in benefits, volunteering during unemployment, well-being and mental health. Work Employ Soc. **32**(1), 38–56 (2018)
12. P.C. Stern, T.A. Dietz, D. Troy, G. Guagnano, L. Kalof, A Value-Belief-Norm Theory of Support for Social Movements: the Case of Environmentalism" College of the Environment on the Peninsulas Publications (1999)
13. S.H. Schwartz, Normative influences on altruism. In Advances in experimental social psychology Academic Press **10**, 221–279 (1977)
14. S.H. Schwartz, Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. In Advances in experimental social psychology, Academic Press. **25**, 1–65 (1992)
15. R.E. Dunlap, K.D. Van Liere, A.G. Mertig, R.E. Jones, New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. J. Soc. Issues **56**(3), 425–442 (2000)
16. S.H. Schwartz, Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. In Advances in experimental social psychology Academic Press. **25**, 1–65 (1992)
17. J.I. De Groot, L. Steg, Value orientations to explain beliefs related to environmental significant behavior: How to measure egoistic, altruistic, and biospheric value orientations. Environ. Behav. **40**(3), 330–354 (2008)
18. L. Steg, G. Perlaviciute, E. Van der Werff, J. Lurvink, The significance of hedonic values for environmentally relevant attitudes, preferences, and actions. Environ. Behav. **46**(2), 163–192 (2014)
19. R.E. Dunlap, The new environmental paradigm scale: From marginality to worldwide use. J. Environ. Educ. **40**(1), 3–18 (2008)
20. S.H. Schwartz, Normative influences on altruism. In: Advances in experimental social psychology Academic Press. Vol. 10, pp. 221–279 (1977)

21. P.C. Stern, T. Dietz, L. Kalof, Value orientations, gender, and environmental concern. Environ. Behav. **25**(5), 322–348 (1993)
22. G.A. Guagnano, P.C. Stern, T. Dietz, Influences on attitude-behavior relationships: A natural experiment with curbside recycling. Environ. Behav. **27**(5), 699–718 (1995)
23. P.C. Stern, T. Dietz, T. Abel, G.A. Guagnano, L. Kalof, A value-belief-norm theory of support for social movements: the case of environmentalism. Human Ecol Rev 81–97 (1999)
24. L. Steg, L. Dreijerink, W. Abrahamse, Factors influencing the acceptability of energy policies: A test of VBN theory. J. Environ. Psychol. **25**(4), 415–425 (2005)
25. P.C. Stern, Towards a coherent theory of environmentally significant behavior. J. Soc. Issues **56**, 407–424 (2000)
26. L.T. Hu, P.M. Bentler, Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct. Equ. Modeling **6**(1), 1–55 (1999)
27. W. Fan, P. Moen, E.L. Kelly, L.B. Hammer, L.F. Berkman, Job strain, time strain, and well-being: A longitudinal, person-centered approach in two industries. J. Vocat. Behav. **110**, 102–116 (2019)
28. H.S. Edosomwan, T.M. Oguegbe, C.O. Joe-Akunne, Workplace Well-Being in Manufacturing Organizations in Nigeria: Do Employee Green Behavior, Core Self-Evaluations and Empowering Leadership Matter? Int. J. Occup. Safety Health **13**(1), 97–107 (2023)
29. O.M. Karatepe, K. Dahleez, T. Jaffal, M. Aboramadan, Test of a sequential mediation model of green management innovation. Service Industri J. 1–24 (2023)
30. B. Yuan, J. Li, Understanding the Impact of Environmentally Specific Servant Leadership on Employees' Pro-Environmental Behaviors in the Workplace: Based on the Proactive Motivation Model. Int. J. Environ. Res. Public Health **20**(1), 567 (2023)

Chapter 34
A Study on HR Analytics Competency Model and Its Impact on Organisations Decision Making Process and Business Outcomes

Vidhu Gaur

Abstract The application of data in the organizations has changed its mode and concentrated on fulfilling the legal wants of the employment. This change in the use of data gradually changed dynamics of Human Resource Management (HRM) role and the organizations expect good analysis quality from Human Resource (HR) professions. Various studies suggested that the use of Human Resource Analytics (HRA) would assist HR professionals to develop diverse viewpoints on their contribution to the financial targets of the organizations through the creation of suitable measurements. Still, not many researchers explored the role of HRA in increasing the business out come in the context of Indian organizations. The present study analyses the role of HRA competencies in determining the organisational decision making and business outcomes. The analysis revealed that motivation and opportunities encouraged employees to utilize their skills in their jobs. It was found that motivation and opportunities provided to capable employees act as crucial aspects in encouraging them to develop analytical skills. The possession of such analytical skills has a significant impact on organisational decision making and business outcomes.

Keywords Human resource management · Human resource analytics · Decision-making · COM · HR analytics · Business outcome · Competency model · HR analytics · HRA · HRM

34.1 Introduction

HR analytics are now a growing trend in the HRM industry. The assumption that the HRA will eventually be the answer to many present HR difficulties grows as a result of this. Also, the goal will center on using these analytics to convert vast amounts of

V. Gaur (✉)
MDI Gurgaon, Gurgaon, India
e-mail: vidhugaur@gmail.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_34

complex data into knowledge. The HRM decision-making process is anticipated to help executives make more precise, data-driven decisions in the future, as opposed to only summarizing the past [25]. However, the addition of fundamental reporting, benchmarking, and scorecards has made HR analytics more complex. Predictive analytics may now be used as a result of the application of this technology. The emphasis has steadily shifted away from describing the past and toward improving future projections. It is apparent that in the near future, measuring the HRM decision-making process will shift from being reactive to being more proactive.

Even though HR analytics are said to have a lot of potential, there hasn't been much research done on it, which makes it hard to know what it's really good for. In a recent [9] report, it was found that just 8% of the organizations in the research area voted in favor of HR analytics' strong analytical capabilities, with one-third of the companies still actively developing the technology [9]. Other than them, there hasn't been much development compared to earlier years in this area. Because of this, it may be said that expectations for the future potential of HR analytics have not yet been realized.

34.2 Concept of HR Analytics

In recent years, there has been an increasing trend to provide employees with benefits and perks like food, snacks, pet insurance, baby cash, and annual travel bonuses.

Offering outstanding rewards and advantages of this caliber is done solely to broaden corporate cooperation beyond the confines of the "happy employee" campaign. This talent management strategy is used by many prosperous businesses, including Google, Facebook, and Apple, to track and assess the outcomes of data-driven decision-making. This human resource analytics strategy seeks to demonstrate the reliability of its findings by demonstrating the benefits of data-driven decision-making procedures on corporate performance. While having a diverse definition, the human resource (HR) analytics strategy incorporates data-driven methods to assist HR systems with decision-making, formulating policies, and implementing pertinent procedures. As a result, in the business environment where top management gives numbers priority when making decisions, HR analytics emerge as a powerful supporting tool for senior managers. As a result, this expanding trend and its strategic approaches help managers assess the efficacy of HR systems, programs, and actions. So, by embracing this new trend of big data and assessing its effects on the HR areas, senior company leaders can boost their organizations' productivity and profitability by up to 6% higher than their counterparts. According to HR procedures, it has been shown that measuring staff management practices is crucial for increasing shareholder value. This is because of their beneficial contributions to the growth of an organization's productivity, which also included requirements for profit, income, and improvements in regard to its human resources.

Mondore et al. [18] claimed that HR analytics should assess the effect of its human resource data on the advancement of the firm based on empirical evidence. Talent, workforce, strategic, and HR metrics are examples of synonyms that can be used to describe HR analytics. To provide uniformity in understanding, the term “HR analytics” has been utilized throughout this study based on these evidence-based methods.

The majority of HR analytics’ functions are based on data-driven analyses, which gather results. As a result, it is a method for measuring the results of HR initiatives, including their impact on executives and cross-departmental contacts [8]. The majority of current examples involve complicated processes that take into account the sophisticated methods of descriptive, predictive, and prescriptive analytics in an escalating order due to the inclusion of a number of methodologies in HR analytics and more especially in data analytics.

HR analytics is a broad field that uses a data-driven approach to assist sound decision-making and represents its advancement in accordance with the explosive expansion of data science. As a result, it can be said that HR analytics are broadly ingrained in the mentality of all business organizations. This century-old field has also had an impact on economics, statistics, and the branch of mathematics. Industrial and organizational psychologists have been using the data to justify staff selection and training with several other organizational practices for many years. Yet, the advent of HR analytics has been characterized as the birth of a completely new role in some organizations and a rebranding of a function in others. The trend of HR analytics, which entails the strategic approaches supported by feedback and subsequently their integration with HR operations, has received a lot of attention. Last but not least, HR-specific analytics cover a wide range of data-analytic concepts and methodologies that simultaneously consider the business, legal, and ethical ramifications.

Pfeffer and Sutton [21] emphasized how important evidence-based management is for a company’s success and how it differs from traditional management methods and habits. According to these scholars, if a decision is made based on the data, it will be appropriate and beneficial.

There has been a ton of analysis done on the important business disciplines of finance, marketing, supply chain management, and research and development, but there hasn’t been much done on data analysis of the workforce in any corporation. Businesses and ventures must adapt to the evolving workplace. The relationship between the employer and the employees will be considerably more productive when the HR department efficiently embraces the data analytics section, and this increase in productivity can be quantified.

Comparatively speaking, human resource analytics (HR Analytics) is the branch of analytics that works with employee analysis and applies analytical methods to the organization’s human capital in order to get notable results on employee retention and performance improvement. Data analytics therefore has a big impact on how HR functions are managed. Using HR analytics to improve and enhance employee performance will help businesses reach new heights of success. An organization must understand these human drivers if it is to achieve institutional success.

Research in academic fields and in the area of human resources, including its importance and value, has seen significant development. Some organizations have a unified approach to human capital management, but not all organizations can equate the value of HR with the productivity of the business. Many studies have been undertaken in this area [23]. 65. Human resources are crucial to the development of organizations. In the modern commercial climate, it has held an essential place [28]. Because of innovation in the field of developing technology, the job of HR has undergone a revolution. This advancement in technology has made the job of HR more clever and deft. It is important for any institution or business to be successful.

The best tool to measure a company's success is thought to be organizational development. Developing organizational abilities, knowledge, and skills is essential for improving the workforce. Building knowledgeable and adaptable workers is the top priority of all HR departments so that they may best serve their organizations and fully contribute to raising overall productivity. It would not only benefit the organizations, but it would also enable them to meet their objectives and realize their lofty aspirations. With the current cutting-edge technology progress, analytics has given HRM a new face. Many automated technologies have reduced the workload and stressed the HRM department. The administration of human resources has improved thanks to technological innovation. These cutting-edge strategies are used by large businesses and multinational corporations (MNCs) to facilitate effective management. The HR department's services have expanded and been enhanced thanks to technology, which has also reduced costs for businesses. Comparatively speaking, the business that successfully uses HR technology outperforms those that do not. In conclusion, it can be claimed that a business that uses creative strategies performs better.

Several parts of HR analytics, such as HR metrics, utility analysis, workforce economics, evidence-based management, HR scorecards, and HR return on investment, had been used and debated by businesses for a long time without making a big difference in how HR affected their bottom line [25].

Just because a business uses new technology and automation, that doesn't mean it will have a longer-lasting competitive advantage. Also, it must be decided that HR processes work best when they are combined with modern technology.HR's main job is to gather information about operations and put together reports on them.It looks at the data, makes rules, and does what needs to be done to make employees and businesses more productive. Prognosticative and explanatory analytics are crucial. Modern organizations must improve the services they offer to institutions and human resources, as well as their access to data for persuading decision-making and raising their bar for competitiveness.

HR analytics are referred to by a variety of terms. The process of using HR analytics to systematically report on many tasks like selection, recruiting, remuneration (internal and external), training and development, employee commitment, and sequential planning. The number of employees hired in the previous year, the number of people who participated in internal and external training programs, the number of people who were promoted, the number of people who improved their educational credentials, the number of people who used the leave facility, and many other things can all be measured in HR. By using these metrics or criteria, businesses may better understand the health of their workforce and take proactive steps to boost both the quantity and quality of their output. Only when the depreciation of prior years is compared to the current year or to the depreciation of other companies does the depreciation rate become a criterion.

In the age of analytics, there is a wealth of information at our disposal. One of the main responsibilities of the human resources department is to use the data in an accurate manner, which can only be accomplished through good data analysis and interpretation. Both qualitative and quantitative analysis of data is possible. There is a debate over whether HR analytics is being overtaken by more advanced and sophisticated operations like IT, finance, and marketing. This dominance will eventually rule organizations, giving HR analytics a stronger advantage [25]. In terms of data analytics, the fields of marketing, research, and development, or finance are still lagging behind the field of human resources. If the analytics are not used properly, it could have a detrimental effect on the value of the organization.

The improvement and expansion of the business, as well as that of its employees, is the only goal of HR analytics. The senior managers of an organization have a major responsibility to adapt and promote HR analytics when the Chief Executive Officer (CEO) disregards the organization. The next critical issue is determining who is in charge of HR analytics. Not the IT or finance departments, but the HR department would be the answer. By implementing HR analytics, HR can provide them with leverage. Many studies are being done in the area of HR analytics, but HR employees are still concerned about it because of how poorly understood it is and the negative effects it has on a regular basis. Yet, HR professionals must properly adopt these new skills in order to grasp HR analytics [25].

The phrase "HR analytics" is comparably more recent and is used frequently in HR management. The idea was initially introduced in a study titled HR Metrics and Analytics: Usage and Effect, 2003–2004. This report on human resource planning was the first. Levenson et al. [15] distinguished HRA as a distinct item from HR measurements. These indicators serve as the foundation for significant HRM outcomes that were further separated into proficiency, potency, and effect. On the other hand, Lawler et al. [13] asserted that HR analytics is a demonstration of statistical methods and empirical programs that might be used to demonstrate the impact of HR initiatives, tools, methods, and empirical approaches.

Despite a clear distinction between HR measurements and analytics, some uncertainty and ambiguity can be found in the available literature. Bassi (2011) disagrees, however, that HRA may be perceived as regularly giving data on a variety of HR measures or more sophisticated solutions, motivated by predicting models and speculative scenarios. Furthermore, there was a focus on "evidence-driven programs" to make judgments on the employee perspective of the profession. Additionally, HR analytics help build a program that is evidence-driven and effective in making decisions that benefit employees. It is made up of a variety of technologies and know-how, ranging from prognostic modeling to simple reporting of HR indicators.

Last but not least, stressing the connection to strategic HRM, Mondore et al. [18] emphasized that HRA demonstrated the direct influence of employees on significant business results. Any organization may therefore maximize the advantages of workforce analytics by adopting the agile development approach in conjunction with the evidence-based management philosophy.

Rasmussen and Ulrich [25] and Angrave et al. [2], on the other hand, believed that the HRA was a fad. According to Abrahamson and Eisenman [1], fads in general are viewed as unimportant and irrational since they have little to no influence on HRM strategies or organizational business processes. This kind of activity develops from the likelihood of forces converging and initiating diffusion, mostly based on bandwagon effects. Because of the unrealistic expectations from the inventions, they eventually vanish in the absence of the intended results. The HR definitions and their labeling have a great deal of significance in this field as a result of all these aspects in common. One should first recognize the distinction between HR analytics and HR metrics. This is because an extremely thorough examination of HR data is included. Second, the HRA rarely assesses the functional data related to HR, instead, it incorporates the data integration aspect based on the many intrinsic functions and the external data. Lastly, the HRA covers the use of information technology to compile and organize the reporting of data. The fourth feature is the substantial support provided by HRA for choices involving individuals. HR analytics also link business organizations to HR strategic decision-making methods in terms of outcomes and performance measures. Because of its importance in creating and connecting the HR functions to the strategic ones, this final facet of HRA is the most important part of the literature on strategic HRM.

HR analytics appear to offer more than HR metrics in terms of their ability to link HR processes and choices with organizational performance. being integrated into various corporate functions and seen as a strategically influential individual. HR analytics generally support HR-based practices and are encouraged by information technology to incorporate descriptive, predictive, and statistical analyses for evaluating the performance metrics of HR capital and organizational capital on the basis of all these analyses. Additionally, it promotes the use of data-driven analytical methods to assess external economic standards. In the context of a process for HRM innovation, this talk examines HRA characteristics.

A perspective of an HRM program, policy, or practice that is not only seen as novel but also significant for its use in implementing strategies to have an impact on workforce methods and behavior is what Kossek [12] defines as an HRM innovation. The user, who is also considered a new user, is the one who may evaluate the speed of the business owners' adoption of HRM practices when providing HR analytics for the first time to a company. A HR innovation's role in creating plans for changing employee attitudes and behaviors is a crucial second prerequisite. As a result, the HRA is seen as a component of HRM practices to develop methods for giving managers enough information, connecting that information to HRM procedures related to employee attitudes and behaviors, and eventually affecting organizational outcomes.

34.3 Analytics and Organisational Decision-Making

According to Acito and Khatri [3], the use of data analytics increases a company's efficiency and effectiveness. It is accomplished by making a difference in operational areas like accounting, organizational or managerial networks like supply chains, and commercial divisions such as health management and wellness programs. HRM is a new department on the data analytics bandwagon, but management acknowledges its value while expressing uncertainty about their own institutional readiness for adoption.

People analytics, for example, is only one of the many words used to refer to it in popular culture. There are several similarities between the aforementioned metrics. They are interested in the analysis of information pertaining to human resources departments, the synthesis of information from various internal departments, and even information from inside sources. Information technology departments assist in gathering, manipulating, interpreting, and disseminating a range of data, both organized and unorganized. All of the analytics are used to support choices that are pertinent to people in any company, and they are then linked to HR decisions for better business outcomes and improved employee performance in any firm.

In the 1940s, a number of large companies used analytics to improve and advance how they chose and managed their staff [14]. But with the advent of information technology, gathering data, analyzing it, and finally interpreting it have all become much easier. It has essentially made workforce analytics accessible to and used in every firm.

Also, the data gathered from a variety of new sources, including wearable technology, email, and calendars, provides better conditions for comprehending employee behavior and improving performance, which is difficult in the other situation. The development of analytical and fact-based decision-making presents the organization with a wealth of chances to increase its effectiveness and efficiency. Despite the abundance of hype and advertising, the organization still has difficulties completing and implementing workforce analytics successfully. Several organizations create workforce analytics teams and enforcements to attempt strategic intuitiveness and awareness from their personnel data, which often falls short of forecast and delays other activities [25]. For instance, Deloitte [24] found that although over 70% of those in the organization believe that workforce analytics is a key factor to improve employee performance and boost the business, only 8% of the firms reported having any type of useful data, while 9% believed that they knew the types of talents in their workforce that resulted in good performance, and 15% decided that three are talent indices or talent rosters for their managers.

34.4 Competency of HRA and COM Factors

The most effective model for illustrating how analytics affect business outcomes is COM'. Yet, at different levels of capability, with different possibilities, and with different supervisory support, it might be seen that there is a complex relationship between organizational functioning and the application of HR analytics [16].

The HR functions and their impact on organizational performance were the subject of a study undertaken by Becker, Huselid, and Ulrich in 2001. The authors examined the influence of several analytical elements on the behavior of HR professionals as part of their study. The study discovered that the competency aspects of communication of HR strategic performance outcomes (to senior managers), estimation of causal links, principles of effective evaluation, and critical causal thought processes had an impact on the competencies of HR professionals.

Kryscynski et al. [11] investigated the relationship between the analytical skills of HR and their performance. The necessary information was acquired from 1117 h specialists who worked at 449 different firms. The results showed that HR professionals with stronger analytical skills outperformed those with lesser analytical capabilities in terms of performance. The study also noted that job roles and opportunity factors were significant contributors to this linkage, as the strength of the link between analytic competence and HR performance varied according to job positions.

In order to increase employee engagement, Madhusudhan [19] investigated the role of HR analytics. According to the report, analytics are helpful in developing a talent value model, which in turn aids HR specialists in determining the retention rate. Also, an analytical model that increases retention rates can be created using analytics to identify the interests of employees. According to the report, using such an analytical model enables managers to develop customized performance incentives or choose the right moment to announce raises and promotions. Inputs from work engagement or job passion were found to be helpful to organizations when creating their policies.

Minbaeva [20] made an effort to develop reliable HR analytics in order to give her firm a competitive edge. The author tried to portray organizational analytics as human capital analytics after borrowing ideas from several other works. The three dimensions of analytics that the author created are strategic aptitude, analytical prowess, and data quality. We looked at the person, process, and structural levels of these three analytic skills. It was determined that analytics elements were capable at the individual, process, and structural levels on all three. The individual level displays the skills, knowledge, and competencies of HR specialists. The process level identifies organizational management capabilities, such as creating job roles and organizational infrastructure. The structural level solidifies the capacity for making decisions based on the best available data and fostering a culture of inquiry.

In order to investigate the impact of work force analytics on how HR professionals operate, employee happiness, and employee turnover, Schiesmann et al. (2018) undertook a case study. According to the results, talent analytics served as a motivating factor, which in turn affected employee happiness.

Over the last several years, analytics have become more popular. While descriptive and predictive analytics have flourished, prescriptive analytics is just now beginning to show signs of growth. Furthermore, studies demonstrate that HR has evolved from an operational partner to a strategic decision-making business partner. Collectively, the exploratory and empirical case studies demonstrate that HRA is being extensively embraced by businesses in order to boost employee performance and maximise ROI ([10]; Jain 2020).

Peter Drucker once said, “If you want to get something done, you’ve got to manage it.” In addition, accurate measurement is necessary for effective management. Data pertaining to every HR function may now be easily measured and managed thanks to the development of HR metrics and numerous technologies. Metrics, then, are quantitative statistics that represent some illustrative aspects of the results or procedures in question. It not only makes calculations and reporting easier but also generates enthusiasm for quantitative methods. As of 2015 (Jalagat), it also assesses and reports on HR metrics that contribute to enhanced business results. This allows for the data to be interpreted into meaningful reports that aid in managerial decision-making. As a result, the efficiency of the business increased. Reporting HR indicators using a return on investment framework also helps shift managers’ decision-making habits [15].

34.5 Methodology

In the wake of findings from an in-depth literature review, the present study prepares a framework based on Capability Motivation and Opportunity (CMO) to test the hypotheses, which were formulated to analyse the relationship among the study variables. A quantitative methodology was adopted to gather the data as it integrates the components of HRA competency and measures their impact on business outcomes. A structured questionnaire was designed and distributed to a sample population, which consisted of 130 h professionals, including HRA users as well as HR managers who work in different organizations in the city of Delhi/NCR. The data were analysed using various statistical tools to find out the role of HRA in organisational decision making and business outcomes.

34.6 Analysis

H1: The HRA competency significantly impacts the organisational decision making and business outcomes (Table 34.1).

The Wilk’s Lambda value for understanding of data, analytical and interpretation skills on business outcomes is 0.914, 0.988 and 0.751, respectively. This means that 91.4% of the variation in data understanding, 98.8% of variation in analytical skills

Table 34.1 Tests for HRA competency on organisational decision making and business outcomes

Effects	Wilks' lambda	F	df	Sig.	Partial eta squared
Understanding of data	0.914	10.115	2,224	0.000	0.086
Analytical skills	0.988	1.407	2,224	0.247	0.012
Interpretation skills	0.751	37.214	2,224	0.000	0.249
Understanding of data* Analytical skills * Interpretation skill	0.932	8.230	2,224	0.000	0.068

and 75.1% of the variation in the interpretation skills was not accounted for by the intergroup variations. The understanding of data exerted a significant impact on both Return of Investment (ROI) ($F = 13.984$, $p < 0.05$) and decision-making process ($F = 20.941$, $p < 0.05$). Similarly, interpretation skills exerted a significant impact both on ROI ($F = 33.461$, $p < 0.05$) and decision-making process ($F = 67.852$, $p < 0.05$). This indicates that HRA competencies have a significant impact on overall utilization of data and interpretation skills. Based on the results obtained above, the hypothesis (H1) is accepted which means that The HRA competency significantly impacts the organisational decision making and business outcomes.

H2: The HR competency significantly influences the utilisation of competency outcome by the organization (Tables 34.2 and 34.3).

The Wilk's Lambda value for understanding of data, analytical skills and interpretation skills is 0.766, 0.827 and 0.653, respectively. This implies that about 76.6% of the variations in understanding of data, 82.7% of analytical skills and 65.3% of the variation in the utilisation of competency outcomes by the organization for different processes is not accounted by the intergroup variations. Table above presents test between subject effects for impact of HRA competency on utilisation of data-based HRA competencies by the organization for different processes. Within HRA competencies, a significant impact was observed in the case of interaction between

Table 34.2 Tests for impact of HRA competency on the utilisation of data-based HRA competencies by the organization for different processes

HRA competency	Wilks' lambda	F	Df	Sig.	Partial eta squared
Understanding of data	0.766	34.304	2,224	0.000	0.234
Analytical skills	0.827	23.497	2,224	0.000	0.173
Interpretation skills	0.653	59.502	2,224	0.000	0.347
Understanding of data* Analytical skills * Interpretation skill	0.791	29.532	2,224	0.000	0.209

Table 34.3 Test of between subject effects for impact of HRA competency on utilisation of data-based HRA competencies by the organization for different processes

HRA competency	Utilisation of competencies outcome for different processes	Type III sum of squares	Df	Mean square	F	Sig.	Square d
Understanding of data	Process performance	22.051	1	22.051	56.494	0.000	0.201
	Strategies	11.516	1	11.516	20.415	0.000	0.083
Analytical skills	Process performance	12.171	1	12.171	31.181	0.000	0.122
	Strategies	26.515	1	26.515	47.004	0.000	0.173
Interpretation skill	Process performance	37.644	1	37.644	96.442	0.000	0.300
	Strategies	18.958	1	18.958	33.609	0.000	0.130
Understanding of data* Analytical skills* Interpretation skill	Process performance	21.504	1	21.504	55.092	0.000	0.197
	Strategies	15.332	1	15.332	27.230	0.000	0.108
R Squared = 0.528 (Adjusted R Squared = 0.520)							
R Squared = 0.390 (Adjusted R Squared = 0.379)							

analytical skills and process performance (F = 31.181, $\eta_p{}^2 = 0.122$), implying a low effect; analytical skills and strategies (F = 47.004, $\eta_p{}^2 = 0.173$) implying a medium effect and interpretation skills and process performance (F = 37.644, $\eta_p{}^2 = 0.30$), implying a large effect. In addition another significant impact was observed between understanding of data and process performance (F = 56.494, $\eta_p{}^2 = 0.201$) implying a medium effect and understanding of data and strategies (F = 20.415, $\eta_p{}^2 = 0.083$) implying low effects.

H3: Capability, Opportunities and Motivation provided to HRA significantly influences the competency they possess (Table 34.4).

The R^2 values shows that 41% variance in the Utilisation of HR analytics can be explained by HRA competencies ($R^2 = 0.413$). HR professionals who possess

Table 34.4 R-Squared

Construct	Coefficient of determination (R^2)	Adjusted of R^2
Util	0.413	0.409
Exist	0.572	0.562
BO	0.289	0.281

analytical qualifications and skills will also have the ability to utilise them effectively. Lack of such skills may hinder the utilisation of analytical competencies for generating value for both the organization and its stakeholders. The results also show that 57% variance in the HR analytical competencies can be explained by CMO (Capability, Motivation and Opportunity). Further, employees who have HRA capability when provided with adequate opportunities and motivation to utilise their skills, can perform their job well when compared to their employees. Therefore, the hypothesis has been accepted which means that Capability, Opportunities and Motivation provided to HRA significantly influences the competency they possess.

Moreover, it was observed that 28.9% variance in business outcomes could be explained by employees' HRA competencies and the utilisation of the same in their tasks. HR professionals who can understand, analyse and interpret the data at hand can utilise the same to make organisational decision making and implement strategies. The HR analytic competencies can be used by the employees to enhance the performance of various processes like recruitment, downsizing work force, organizational development, employee attitudes and competency analysis. The performance enhancement thus achieved can help the organizations to achieve returns on investments quickly.

34.7 Conclusion

The findings demonstrated that business outcomes can be improved by providing motivation and opportunities to employees, who possess HR analytical skills. It is found that utilization of analytical skills for implementing various HR strategies and for improving the performance of various HR processes like competency analysis and recruitment analysis plays an important role in enhancing business outcomes. It was found that motivation and opportunities provided to capable employees act as crucial aspects in encouraging them to develop analytical skills. The possession of such analytical skills has a significant impact on business outcomes. The study showed how the business outcomes can be improved by providing motivation and opportunities to employees who possess HR analytical skills. The motivation and opportunities provided to the employees encourage them to utilise their skills in their job. The study found that utilisation of analytical skills for implementing various HR strategies and for improving the performance of various HR processes like competency analysis, recruitment analysis, etc. mightplay a role in organisational decision making.

References

1. E. Abrahamson, M. Eisenman, Employee-management techniques: transient fads or trending fashions? Adm. Sci. Q. **53**, 719–744 (2008)
2. D. Angrave, A. Charlwood, I. Kirkpatrick, M. Lawrence, M. Stuart, HR and analytics: why HR is set to fail the big data challenge. Hum. Resour. Manag. J. **26**(1), 1–11 (2016)
3. F. Acito, V. Khatri, Business analytics: Why now and what next? Bus. Horiz. **57**(5), 565–570 (2014)
4. D. Barton, D. Court, Making advanced analytics work for you. Harv. Bus. Rev. **90**(10), 78–83 (2012)
5. P. Bekkering, People analytics breekt door. HR Strategie., (2014)
6. J.W. Boudreau, P.M. Ramstad, Talentship and human resource measurement and analysis: from roi to strategic organizational change. Hum. Resour. Plan. J., **29**, (2006)
7. B. E. Becker, M. A. Huselid, D. Ulrich, *The HR scorecard: Linking people, strategy, and performance* (Harvard Business Press, 2001)
8. C. Chadwick, J. Super, K. Kwon, Resource orchestration in practice: CEO emphasis on SHRM, commitment-based HR systems, and firm performance. Strateg. Manag. J. **36**, 360–376 (2015)
9. Deloitte, *Global human capital trends* (Deloitte University Press, Rewriting the rules for the digital age, 2021)
10. S.V. Falletta, W. Combs, The HR analytics cycle: a seven-step process for building evidence-based and ethical HR analytics capabilities. J. Work-Appl. Manage. **13**(1), 51–68 (2020)
11. D. Kryscynski, C. Reeves, R. Stice- Lusvardi, M. Ulrich, G. Russell, Analytical abilities and the performance of HR professionals. Hum. Resour. Manage. **57**(3), 715–738 (2018)
12. E. Kossek, Human resource management innovation. Hum. Resour. Manag. J. **6**, 71–92 (1987)
13. E. Lawler, A. Levenson, J. Boudreau, HR metrics and analytics - uses and impacts (2004)
14. E. E. Lawler III, J. W. Boudreau, *Global trends in human resource management: A twenty-year analysis* (Stanford University Press, 2015)
15. A. Levenson, Harnessing the power of HR analytics. Strateg. HR Rev. **4**(3), 28–31 (2005)
16. A. Levenson, Using targeted analytics to improve talent decisions. People Strat. **34**(2), 34–43 (2011)
17. W.Y.M. Momin, K. Mishra, HR analytics as a strategic workforce planning. Int. J. Acad. Res. **1**(4), 258–260 (2015)
18. S. Mondore, S. Douthitt, M. Carson, Maximizing the impact and effectiveness of HR analytics to drive business outcomes. People Strat. **34**(2), 20–27 (2011)
19. P. Madhusanan, *The rise of HR Analytics to improve employee engagement*. (2017). Retrieved from https://www.peoplematters.in/article/hr-analytics/the-rise-of-hr-analytics-to-improve-employee-engagement-16438
20. D.B. Minbaeva, Introduction to the special issue. J. Organ. Eff.: People Perform. **4**(2), 110–118 (2017)
21. J. Pfeffer, R.I. Sutton, Evidence-based management. Harvard Bus. Rev. **84**(1), 62 (2006)
22. J. Pfeffer, J. Veiga, Putting people first for organizational success. Acad. Manag. Exec. (1993–2005), **13**(2), 37–48 (1999)
23. J. Paauwe, HRM and performance: Achievements, methodological issues and prospects. J. Manage. Stud. **46**(1), 129–142 (2009)
24. People analytics: recalculating the route. Deloitte Insights (2017). https://www2.deloitte.com/uk/en/insights/focus/human-capital-trends/2017/people-analytics-in-hr.html
25. T. Rasmussen, D. Ulrich, Learning from practice: how HR analytics avoids being a management fad. Organ. Dyn. **44**(3), 236–242 (2015)
26. J. Smith, *20 incredible perks companies like Airbnb, Facebook, and Google offer their employees.* Business Insider. (2016). Retrieved from http://www.businessinsider.com/incredible-perks-companies-like-airbnb-facebook-andgoogle-offer-their-employees-2016–2

27. M.J. Ward, K.A. Marsolo, C.M. Froehle, Applications of business analytics in healthcare. Bus. Horiz. **57**(5), 571–582 (2014)
28. V. Wickramasinghe, N. Fonseka, Human resource measurement and reporting in manufacturing and service sectors in Sri Lanka. J. Hum. Resour. Costing Account. **16**(3), 235–252 (2012)

Part III
Marketing Analytics

Chapter 35
Applying Digital Technologies to Financial Product Marketing

Jiajun Li

Abstract This article listed some of the current challenges that are faced in the area of applying digital technologies in marketing of financial products. Possible solutions to these challenges are suggested as well as the results. The vision of the future of this area is also discussed at the end of this article.

Keywords Component · Marketing strategies · Data modeling · Big data · Financial products · Digital technologies

35.1 Introduction

As the society and economy grow, more and more marketing strategies have been developed and applied due to the tremendous improvements of informational technologies. According to a report by consulting company McKinsey&Comapny, big data is a great opportunity for marketing. Big data can put this scattered information into use then increase performance. Firms can also deduct additional valuable information of the customers based on the current information. Catching the opportunity of big data can generate considerable profits for anyone who puts it into tight use [1].

Data based marketing have already become the essential part of business for industry giants such as Youtube and Amazon [3].

Especially after the hit of COVID-19, more people started to get used to buy things online, that also includes buying investment products. Hence the importance of data driven marketing is self-evident [4].

Various industries have already started to use big data for precision marketing to different customers, since using data modeling to analyze detailed information of the current or potential customers can make the existing marketing strategy become more personalized hence more efficient. Data modeling is becoming more and more essential in nearly everything in modern society. The reason for that is because it can

J. Li (✉)
Degroote School of Business, Mcmaster University, Hamilton, ON, Canada
e-mail: li748@mcmaster.ca

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_35

use existing data to generate personal preferences of target group then lead the people into customers. From presidential campaigns to digital marketing, the importance of data modeling should not be neglected [6].

In this article we are going to focus on the intelligent marketing strategies that are used in investment product sales. Banks and investment product selling agencies have used some of the data modeling techniques to try to improve the selling performance of their products or services due to analysis based on financial conditions, previous investment history or income of their target customers. Though these attempts turned the idea into practice and have made some achievements. However, we believe there are some problems existing in these attempts.

Though digital technologies have already been used in marketing for a period of time, but we are still in early practice area, there are many challenges that interfered the actual performance of these technologies. Facing these challenges and conquer them can give firms competitive advantages [5].

Most of the current strategies do not take all valuable related information into consideration. Hence the results show that the fitting ability of their data modeling is not strong enough [8]. In other words, the current intelligent marketing strategies based on data modeling used in sales of investment products are not intelligent enough. Due to these problems, we have put forward a plan for the whole process.

The data that we used to make the analysis is from a competition organized by a bank, but based on the privacy policy, the name of the bank cannot be presented here.

35.2 Factors

Based on the past customer information of a specific bank in China, we have found out that age, gender, risk acceptance, income, trust in brands, past performance of the products and macroeconomic conditions are the most defining factors that will affect the buying decision of investment products (Figs. 35.1 and 35.2).

The two diagrams show that 53.2% of the customers are male and 46.8% of the customers are female. The peak of the age distribution appears in the age range between 25 years old to 35 years old, and then the customer proportion starts to decrease as the age increases.

When looking into the proportion of sales from the new customers of total sales of each month, we can see that the proportion is not stable and has differences from month to month (Fig. 35.3).

The proportion of sales from new customers in December is more than two times than in September and October. This may illustrate that the customer acquisition channel of the bank may be affected by seasonality and periodicity. If we can better characterize the cold start problem, then it will contribute to a better selling performance.

Fig. 35.1 Gender Distribution

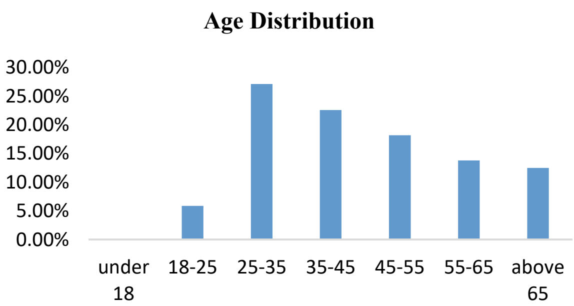


Fig. 35.2 Age Distribution

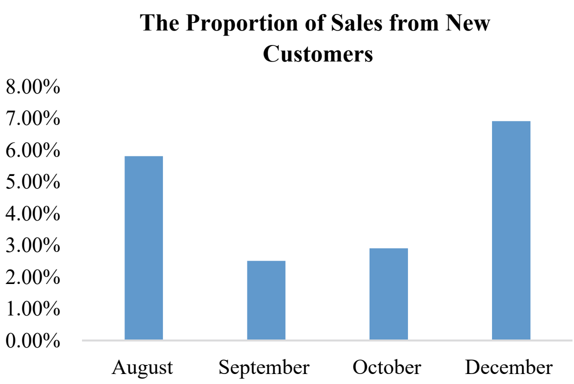
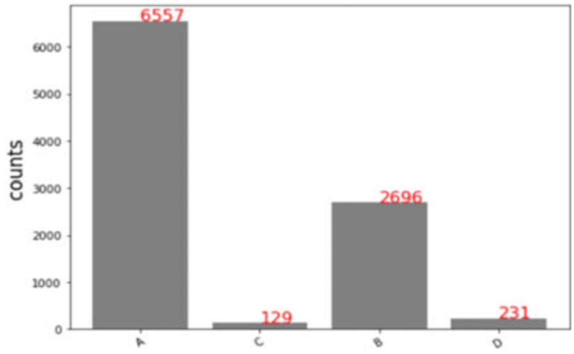


Fig. 35.3 Proportion of Sales from New Customers

35.3 Basic Information About the Products

After we have calculated the quantity distribution of the four product types of A, B, C and D, we can see that product type A accounted for 67% of the total sales and product type B follows (Fig. 35.4).

Fig. 35.4 Product Type Distributions



The diagram below shows the purchase rates and quantity of different products in different months. The purchase rate of product A fluctuates greatly with a large variance; it is 2.3% in July, but less than 1% in the following months. While the purchase rates of product B, C, and D are more stable and their variances are minor. As the number of product an accounts for about 67% of the total products, it can be seen that the fluctuation of product A is an essential factor affecting the inconsistency. In the subsequent feature engineering, differentiated feature combination is carried out based on the performance of product A, which reflects different users' preference degree and trading habits for product A. Characterizing the user portrait of product A is essential for the implementation of subsequent marketing strategies (Figs. 35.5 and 35.6).

Because products may also have the problem of cold start, we counted the number of the four new products A, B, C and D in the current month compared with the previous month. We found that there were a certain number of new financial products in all months, Most of them were product A. Product B did not have cold start products, product C and D both had a small number of cold start products (Fig. 35.7).

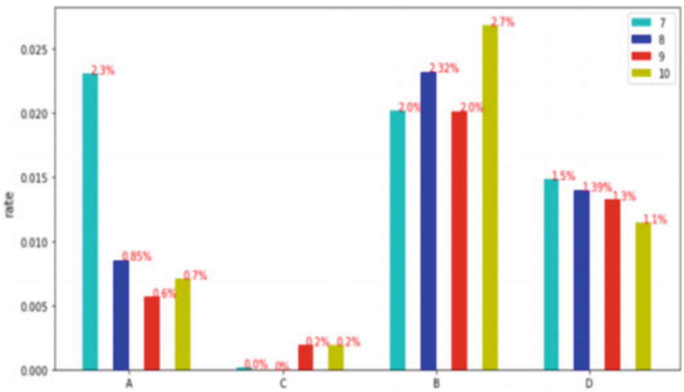


Fig. 35.5 Proportion of Sales of Different Types of Products in Different Months

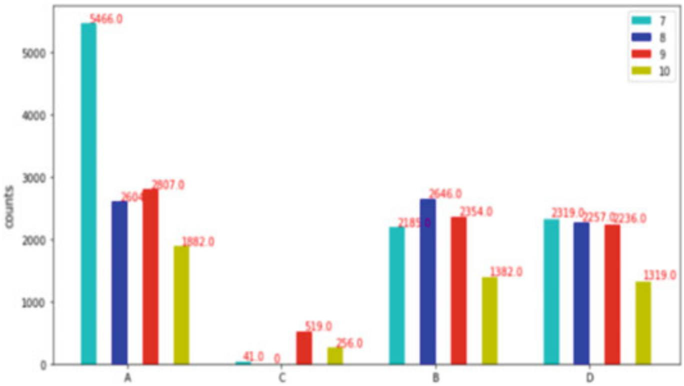


Fig. 35.6 Number of Sales of Different Types of Products in Different Months

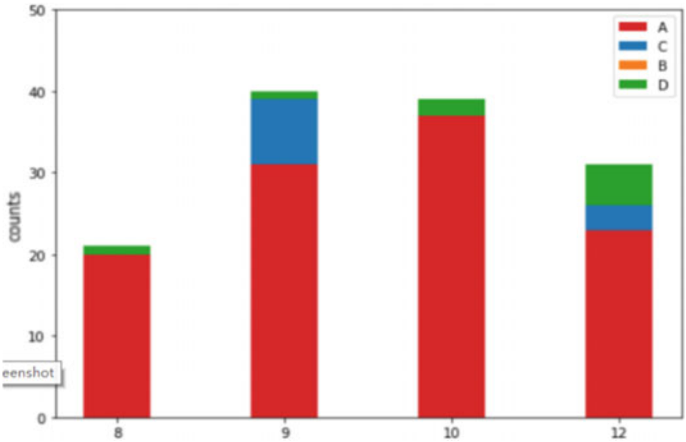


Fig. 35.7 Products Cold Start Problem

Based on the basic data exploration we have done, we found that the cold start problem exists on both the user side and the product side. In this scenario, we need to build the correlation between users' risk propensity with different types of financial products. Therefore, we need to build a model with stronger generalization ability by constructing a complete set of feature engineering to predict the purchasing ability of unknown users for unknown products.

35.4 Feature Engineering

35.4.1 User Side Feature Mining

The purchase behavior of our customers is caused by multiple factors, so it needs to carry out multi-feature cross combination. The influence of external factors like monetary liquidity and epidemic should also be taken into consideration.

The first user feature is age. We sorted the ages in groups according to the World Health Organization's age classification criteria (Fig. 35.8).

First, from the perspective of statistics, there are different distributions, and this characteristic index is effective for the model to distinguish user purchase behavior. Secondly, from the perspective of business understanding, the peak of the rate of purchase behavior occurs around the age of 30 and 60. These two groups of people have a high intention to buy financial products, but according to our research, the root causes of the buying behavior for these two different age groups are different. The first reason we speculate that people around the age of 30 buy a large amount of financial products is because the high inflation rate at the end of the twentieth century caused the stock market blue chips soared, and it lead to the trend for people to invest their savings in the fund and stock market. It made the age group around 30 start to have the awareness of the financial management. Another root cause for this age group is these people are doing the original accumulation of funds for the future of their own family and business. People around 60 years old buy financial products are mostly influenced by traditional ideas; the reason for them to buy is for the consideration of hedging and saving money for their future generations.

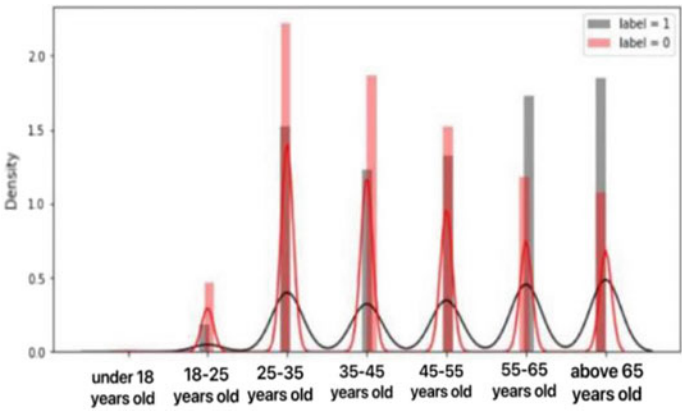


Fig. 35.8 Sales Generated from Different Age Groups

35.4.2 Product Side Feature Mining

By counting the occurrence times of products of the same type, we construct a one-dimensional feature based on frequency statistics to measure the popularity of products. For example, if a product P appears 1000 times in the data, the feature of product P is the continuous value of 1000. It can be seen from the image below that the purchase rate of products with high frequency is higher. The purchase rate of low-frequency products is lower. And that also makes intuitive sense. Popular products, in essence, are generally less risky investment or in line with current financial trends. For example, the blue chip fund buying wave at the end of 2020, it will be passed on by word of mouth and even put on the home page of mobile terminal products, thus generating positive feedback and further promoting the sales of hot products. Conversely, less popular products may receive less attention (Fig. 35.9).

The next factor we look into is the number of days products were held by consumers. As shown in the figure below, in addition to the products held for 180 days, the products held for short periods of 0–30 days have a very high user purchase rate. Relatively speaking, users in the short-term closed products have less risk. Whether the risk of financial products is high or low, users have a shorter decision-making cycle. There will also be users with a try mentality to buy products. An excessively long closing period, therefore, may affect a user's purchasing behavior, if other factors are excluded. However, as can be seen from the figure, there is still a good purchase rate for products with a long holding period. It is also possible that products with a fixed period have a guaranteed income, thus obtaining a good purchase situation (Fig. 35.10).

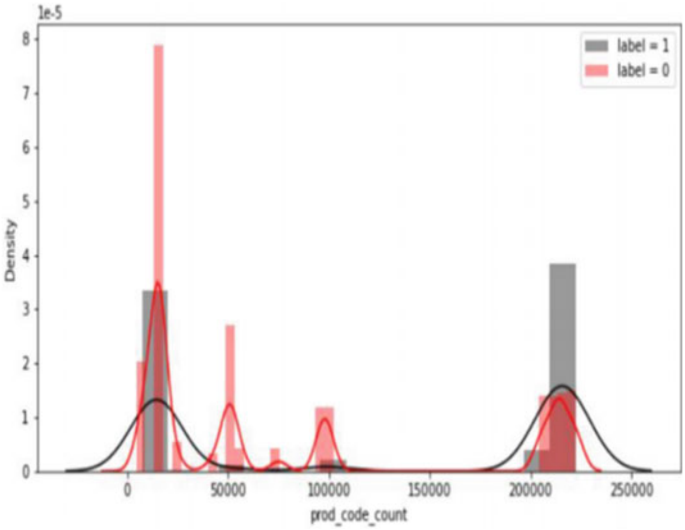


Fig. 35.9 Frequency of Occurrence and Sales

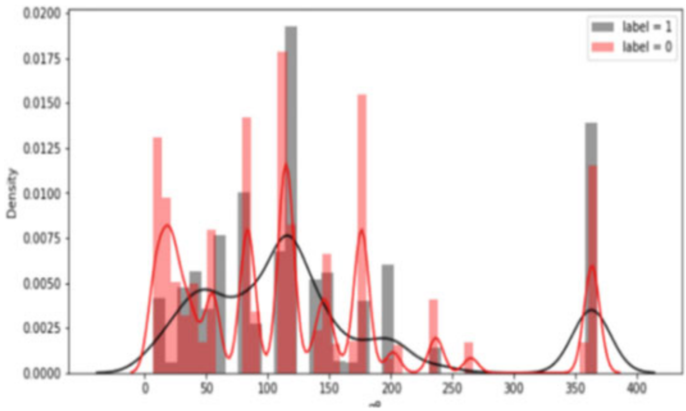


Fig. 35.10 Number of Days Held

35.4.3 Transaction Information Feature Mining

For users, users' trading preferences played a leading role, such as the time difference between now and the last click of users, and the time difference between users' trading and the last click of the product of the same type as the current product. In addition, from the feedback of feature importance, as time goes by, the importance of features of historical data gradually decreases, indicating that users' recent transaction behavior plays a dominant role in judging current users' purchase intention. This implies that we should pay attention to the types of products recently traded by users, as well as the revenue and expenditure of users' funds.

For the product, we found that the user portrait of the product being traded played a key role, such as the time difference when the chosen product was traded the last time, the time difference when the chosen product was last traded by the same user, the frequency of the chosen product being traded, and the age distribution of the users of the chosen products being traded. At the same time, the problem of cold start of the product is solved to some extent. This implies that, when promoting a product to a certain user, we can see the product preference of the user's age group through the user's social information, so that we can use the information to make a more accurate estimation of uses' purchasing behavior.

35.4.4 User Click Through Rate Feature Mining

When targeting at the user click information table and focusing on exploring users' interest points, we counted the number of days from the last click to the current time, the user click frequency and other characteristics. As you can see, users who click more frequently buy more. This finding shows that we should try to optimize

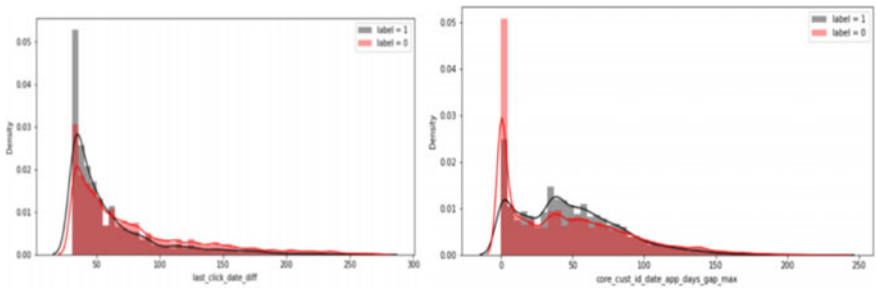


Fig. 35.11 Click Through Rate

the click through rate of the app, improve the daily activity of the app, and focus on improving the conversion rate of users that have clicked. Analyzing the statistics of users' click intervals for products, such as maximum time interval between two clicks and minimum time interval between two clicks, can reflect the degree of users' interest in a certain product and guide the purchase rate (Fig. 35.11).

35.4.5 User Borrowing Information Feature Mining

For the account transaction statement, detecting the user's credit risk should analyzing the data from both debit and credit perspectives. The statistics of the amount lent by the borrower and the statistics of the time interval of the borrower can reflect the capital capacity and risk tolerance of the user. The statistics of the amount borrowed by the lender user can reflect the how intensify user's demand for funds, and to some extent can reflect the risk level of the user, that is, people with good credit will be willing to borrow money (Fig. 35.12).

35.5 Model Construction

In order to ensure the interpretability of the model in the field of risk control, we only retained the features with business characteristics; a large number of redundant features were removed. We chose the LightGBM model to avoid the failure may happen when implemented in actual business scenarios and no practical explanatory significance when multiple models were integrated. The whole process is as follows.

1. Data cleaning. The nan value in the data is filled with -1 value, and the character of the string is encoded.

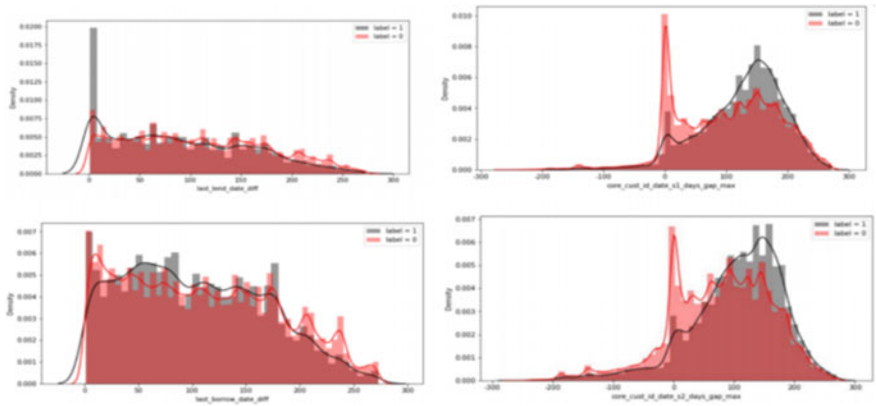


Fig. 35.12 User Borrowing Information

2. Feature engineering. Generating the data of November according to the tag construction rules. The feature types mainly include user-side feature, product-side feature, user click through rate feature, user borrowing information feature and user-product interaction feature, and the most important is user-product interaction feature. Through first order crossover, second order crossover and sliding window statistics, transaction data are counted in coarse and fine granularity to construct practical features that conform to business logic.
3. Model construction. In order to ensure the readability and completion of the model, only the LGB tree model is used. Since the sampling rules in November were controlled by us, there would be some sampling errors, so our modeling method adopted the idea of hierarchical modeling method. The first part of the model uses the data of July, August, September and October for modeling and the data of December for testing; the second part of the model uses the data of July, August, September, October and November for modeling and the data of December for testing. The final result is determined by both part of the model.

35.6 Innovation in Data Exploration

This article makes an in-depth exploration of the data set, analyzes the profound connection between the tags and the original features of the data. It also visualizes the connection between the features in the form of mind mapping. Based on the idea of recommendation algorithm, the article explores the interpretable and useful practical characteristics from three aspects: user, product and interaction between users and products. For example, from the perspective of users, subgroups are divided according to user level. Different subgroups have different product preferences in historical transactions (described by statistical values, such as frequently traded products, last transaction time, transaction frequency, etc.). On the contrary, from the

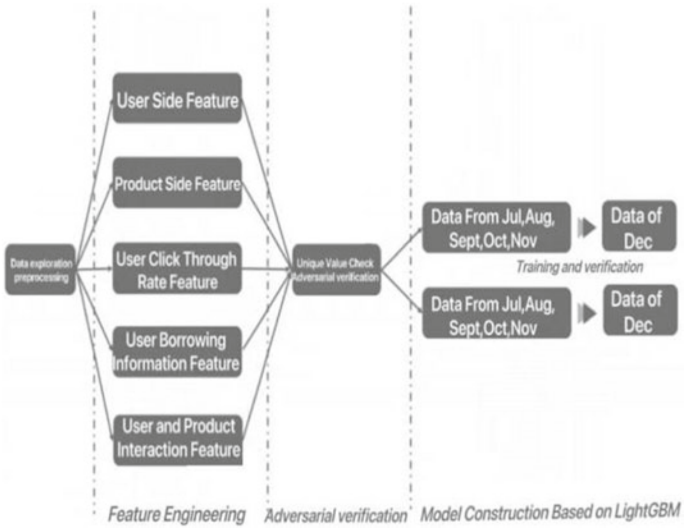


Fig. 35.13 Steps of Model Construction

perspective of products, different types of products (A,B,C,D) have different user groups (descriptions of statistical values, such as average age of users, average grade of users, etc.) in historical transactions. Through the recommendation understanding of the product transaction information table, a large number of cross features are derived, and the information contained in the data is fully extracted. This is also a feature engineering idea that we often use in real business. Secondly, we used user click through rate and user transaction data to build the Deepwalk network, and embedded user id and product id into low-dimensional representation, effectively solving the cold start problem of users and products.

35.7 Innovation in Model Construction

Due to the problem of insufficient memory caused by multi-model fusion in actual business scenarios, only LightGBM model is used in this attempt. Compared with more model fusion, it has a more practical landing scenario and interpretation significance. In addition, based on the findings of tag construction, we added the training data of November for training. However, due to sampling deviation, it cannot be consistent with the official sampling rules. In order to eliminate this deviation, we adopt the idea of hierarchical modeling. The first part of the model uses the data of July, August, September and October for model construction and uses the model to predict the data of December; the second part of the model uses the data of July, August, September, October, and November for model construction and uses the model to predict the data of December. The model is expected to learn the positive sample information from the data of November to make the results more reliable.

35.8 Vision of the Future

The tree model is widely used in the banking business, which has the characteristics of high interpretability and easy to deployment. However, with the development of new technologies, the future directions that can be further explored are: graph convolutional neural networks, causal inference and MLops deployment.

The transformation to digital marketing is imperative. Since last year, the share prices of listed banks have been in the doldrums, while quarterly earnings have beaten expectations. We believe that, at present, the domestic banking industry is not favored by investors, mainly because the current bank digital marketing is not developed enough. Although the banking industry is inseparable from people's daily life, its experience could be much better with the emergence of digital technologies.

Data mining technology will not only be applied in user portrait and specific behavior analysis, but also flexibly applied in specific marketing strategy. Digital and intelligent service can help banks to create an avant-forward and professional image for customers. In the short term, retail investors and loyal customers will be quickly drawn back from the haze of the epidemic impact, and in the long-term, a positive and reliable brand image will be established for users. Making preparation for the transformation in the field of financial digitalization in advance and reserving corresponding technologies will considerably help banks to remain competitive in the future technological competition.

The successful of digital marketing should be build on consumer trust to the brand. After the pandemic, firms have to reconsider how to build consumer loyalty in order to make digital marketing strategies more efficient. (O' Brien, 2021).

Though data mining for marketing has a bright future, but morale problem should also be considered. Overuse customers personal information may lead to contrary result [6].

References

1. D. Court, J. Perry, T. McGuire, J. Gordon, D. Spillecke, *Marketing & sales big data, analytics, and the future of marketing & sales* (McKinsey&Company, 2022). Retrieved December 15, 2022, from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Marketing%20and%20Sales/Our%20Insights/EBook%20Big%20data%20analytics%20and%20the%20future%20of%20marketing%20sales/Big-Data-eBook.ashx
2. A. Sundararajan, *Data modeling: A blueprint to your digital marketing business—blog. Xtract.io.* (2022). Retrieved January 4, 2023, from https://xtract.io/blog/data-modeling-a-blueprint-to-your-digital-marketing-business

3. K. Hosanagar, R. Iyenger, Marketing the future: How data analytics is changing. Knowledge at Wharton, (2020). Retrieved January 29, 2023, from https://knowledge.wharton.upenn.edu/article/marketing-future-data-analytics-changing/
4. T.I. Contributor, Forbes Insights: How data is fueling the future of marketing. Forbes, (2023). Retrieved January 30, 2023, from https://www.forbes.com/sites/insights-teradata/2020/12/22/how-data-is-fueling-the-future-of-marketing/?sh=919b4ca283f5
5. K. Plangger, D. Grewal, K. de Ruyter, C. Tucker, The future of digital technologies in marketing: A conceptual framework and an Overview. J. Acad. Mark. Sci., (2022). SpringerLink. Retrieved January 30, 2023, from https://link.springer.com/article/https://doi.org/10.1007/s11747-022-00906-2
6. Y.K. Dwivedi, E. Ismagilova, D.L. Hughes, J. Carlson, Setting the future of digital and social media marketing research: Perspectives and Research Propositions. Int. J. Inf. Management., (2020). Retrieved January 30, 2023, from https://www.sciencedirect.com/science/article/pii/S0268401220308082
7. C. O' Brien, *The future of marketing after covid-19* (Digital Marketing Institute, 2021). Retrieved January 30, 2023, from https://digitalmarketinginstitute.com/blog/the-future-of-marketing-after-covid-19
8. D. Trillo, The biggest marketing data challenges enterprises face and how to overcome them. Mesh- AI (2022). Retrieved January 30, 2023, from https://www.mesh-ai.com/blog-posts/biggest-marketing-data-challenges-enterprises-face-and-how-to-overcome-them
9. C. Forsey, *The top 10 marketing challenges expected globally in 2023*. HubSpot, (2022). Retrieved January 30, 2023, from https://blog.hubspot.com/blog/tabid/6307/bid/33820/5-major-challenges-marketers-face-and-how-to-solve-them.aspx
10. R. Page,*Handle with care: The data challenges facing marketers*. Raconteur. Retrieved January 30, 2023, from https://www.raconteur.net/marketing-sales/handle-with-care-the-data-challenges-facing-marketers/

Chapter 36
Empirical Analysis of the Impact of Internet Financial Products on the Operation of Commercial Banks in China

Qian Li and Haoran Zhang

Abstract With the rapid maturity of the Internet technology, people feel that the effect of the network era will sweep the whole society, the industry has started to integrate with the network, for the sustainable development of the industry to constantly explore a new way out. The gradual maturity of internet finance has had an unprecedented impact on the commercial banks in the financial field, and the traditional financial services of commercial banks have not been able to support their better development in the future. In the literature and their own understanding of the internet on the concept of financial products, the characteristics of a brief summary of the study of official news and reports on its development status, it mainly describes the specific business of commercial banks affected by the development of Internet wealth management products and the extent of the impact, and finally it is to help commercial banks to improve the measures to deal with the impact of the development of Internet wealth management products.

Keywords Business activity · Finance industry · Internet finance · Internet financial products · Commercial banks

36.1 Introduction

This paper mainly discusses the relevant official data of the ten largest commercial banks in our country during the period of 2017Q1–2019Q4, as well as the relevant operation data of the internet wealth management products represented by the Internet Money Fund, then the model was built to verify whether the internet wealth management products are related to the performance of commercial banks, and the

Q. Li (✉) · H. Zhang
Haojing College of Shaanxi University of Science and Technology, Xi'an, China
e-mail: 872614907@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_36

software reviews 10.0 was used to analyze the degree of correlation between the relationship and the results.

On the basis of the existing results, the paper further studies the impact of Internet financial products on the business performance of commercial banks. This paper selects the Internet financial products with the most choices and the most familiar as the main research object to explore their impact on the development of commercial banks. Secondly, based on the perspective of commercial banks, this paper explores the specific impact on commercial banks based on data results and empirical analysis [1]. Finally, the countermeasures for commercial banks to cope with the development of Internet financial products should be improved.

36.2 The Influence of Internet Financial Products on the Management of Chinese Commercial Banks

36.2.1 The Influence of Internet Financial Products on Debt Business of Chinese Commercial Banks

The creditor's business of commercial banks is also called deposit business. The debt source is the deposit of enterprises and individuals. With the rapid development of the Internet financial management market, the market share of Internet financial products keeps rising, attracting more and more customer resources, and achieving success in a short time. In the era of e-commerce, the rise of third-party payment has an impact on the debt business of commercial banks, and also changes the debt structure of commercial banks. With the rapid development of third-party payment platforms, third-party account banks have gained a large amount of funds. Although the deposits in the banking system do not decrease, the amount of reserve fund deposits is mostly concentrated in the banks selected by the third party, among which there is a great difference in the time benefit of funds [2]. As a profit-making institution, it can deposit the customer's reserve fund into the bank in time deposit or other ways with higher returns after meeting the funds needed for daily payment business in order to seek profits. Since the interest rate of bank demand deposit is the deposit mode with the lowest return in the society, it will choose the time deposit mode of commercial banks for deposit, which undoubtedly increases the liability cost of commercial banks.

36.2.2 The Influence of Internet Financial Products on the Assets Business of Chinese Commercial Banks

With the development of Internet information technology, P2P online lending is more and more recognized by people. Its loan approval time is short, and its flexibility is high. The main loan objects are small and medium-sized enterprises and individuals. The operation of loan business has a direct impact on the profits of commercial banks. Internet finance is no longer strange. Small and medium-sized enterprises and individuals begin to raise funds through Internet platforms to meet their own capital needs. Traditional commercial banks mainly make loans by absorbing deposits from the masses and gain profits through the difference between deposit and loan rates, which rob commercial banks of part of the profit source. Average return on total assets is an important index to measure the profitability of commercial banks' assets. As can be seen from the above data, the average return on total assets of the six major commercial banks has shown a downward trend in the past three years, which also indicates that the asset profitability of commercial banks is gradually declining.

36.2.3 The Influence of Internet Financial Products on Operating Income of Chinese Commercial Banks

In view of the convenience and speed of Internet finance, which is very in line with the current fast-paced social development mode, users are more willing to invest in Internet finance, and Internet finance also brings good benefits to consumers. In this virtuous circle process, commercial banks' financial returns are decreasing. In addition, in order to cope with the rapid expansion of Internet finance, commercial banks have to take the initiative to increase the yield of their financial products, forcing the cost of bank expenditure to increase. All these reasons make commercial banks' business income decreasing [3]. The online loan impact of P2P platform is increasing the credit burden of commercial banks. The amount of commercial bank deposits declined, loan growth slowed down, and interest margin narrowed further. Internet financial products rely on big data technology to fully meet the diversified needs of customers and provide accurate basis for product pricing. The pricing advantage of commercial banks is gradually weakened, and the transaction cost is also increasing, which has a huge impact on its own development.

36.3 Sample Selection and Variable Design

36.3.1 Sample Selection

The main data in this article are from the official websites of the People's Bank of China and major commercial banks, the Bank of China, China Construction Bank, Agricultural Bank of China, China Merchants Bank, China Merchants Bank, Everbright Bank, Pudong Development Bank, Bank of communications, China CITIC Bank and Ping an bank were the four major state-owned commercial Industrial and Commercial Bank of China during the period from 2017 Q1 to 2019 Q4, through the data empirical analysis of the internet financial products to our commercial banks operating impact. Due to the lack of data of internet financial management products, the data used in this paper comes from financial 360 data and observable analysis.

36.3.2 Variable Design

Through the review of relevant literature and the study of my own professional knowledge, the indicators mainly used to judge the business performance of commercial banks include return on assets, return on equity, profit rate, etc.

(1) Dependent variable
Return on assets (ROA). Return on assets can directly represent the performance of commercial banks in the process of development, and is also an indicator to measure the net income per unit of assets. The data interval of this paper is set as quarter, so the quarterly return on assets is selected as the independent variable. Quarterly return on assets is the ratio of quarterly net income to quarterly average total assets.

(2) Independent variables
Logarithm of Internet Money Fund size (ICF). The variety of Internet financial products has been continuously enriched, occupying a large number of market shares, which has brought a certain impact on the asset business and liability business of commercial banks. The main component of Internet financial products is Internet money fund. Since it is difficult to obtain data on the total scale of Internet financial products, the size of Internet money fund is selected as the independent variable in this paper. In order to eliminate the interference of heteroscedasticity, the logarithm of the size of Internet money fund is taken as the independent variable.

(3) Control variables
The logarithm of third-party Internet payment transaction size (TIP). The development of Internet finance has weakened the payment intermediary role of commercial banks, brought great obstacles to the development of commercial banks, and accelerated the financial disintermediation of commercial banks. From the direct impact point of view, the third-party payment directly affects the bank's payment and settlement system; From the perspective of indirect impact, third-party payment constantly optimizes its own financial services, facilitates the optimization of customer groups, grabs the customer resources of commercial banks, diverts the demand deposits of commercial banks, and increases the cost of bank liabilities. In order to verify the analysis results better and eliminate the interference of heteroscedasticity, it was selected as the control variable.

Cost-income ratio (CIR). Operating compensation and the ratio of management compensation to operating income. It can represent the operating performance of commercial banks. The smaller the value, the higher the return on bank assets will be.

(4) Random variables
The random error term μ has an effect on the dependent variable in the model, but it is not the main factor.

36.4 Model Construction

By consulting relevant literature and researching existing achievements, the article selects model construction to study the impact of Internet financial products on the business performance of commercial banks in China. The model formula is shown as follows:

$$\text{ROAit} = \beta 0 + \beta 1\text{LNICFit} + \beta 2\text{LNTIPit} + \beta 3\text{CIRi},\ \text{t} + \mu\text{it}$$

ROAit The explained variable indicates the return on assets of the bank in year t i; β 0 is the intercept term; LNICFitIs an explanatory variable, used to represent the scale of Internet finance; LNTIPit, CIRitIs a control variable; μitIs the random interference term. The variables were independent of each other, satisfying the zero mean and the same variance.

36.4.1 Analysis Process

Perform ADF unit root tests on all sequences using reviews 10.0 software. LNTIP is a time series that performs only the unit root test. From the difference results, we can see that there is a stationary sequence between variables. The results are as follows (Table 36.1).

Next, do the co-integration test on the above data. The test results show that the P value is less than 0.05, the co-integration test is passed, and the original hypothesis is rejected. Therefore, there is indeed a cointegration relationship between variables.

Table 36.1 Variable stationarity test

Variable	Differential order	ADF (t-test value)	ADF (p-value)	LLC, and the test values	LLC (p-value)
LnTIP	1	168.5840	0.0000		
LnICF	1	304.0780	0.0000		
ROA	0	178.5240	0.0000	−14.5728	0.0000
CIR	0	210.3240	0.0000	−10.7566	0.0000

Table 36.2 Panel data-of panels

Method of calibration	Null hypothesis	Statistical quantity name	Statistical value (p-value)
Kao	H0: P = 1	ADF	0.0000 (−3.5721)

Table 36.3 For panel data regression results

Variable	Coefficient	t-statistic	Prob.
C	0.036725	0.225536	0.8024
LnICF	−0.005742*	−1.750608	0.0603
LnTIP	−0.006723**	−2.536038	0.0201
CIR	−0.013227***	−5.379421	0.0000
R^2	0.659021	F-statistic	26.45392
Adjusted R^2	0.625705	Prob (F-statistic)	0.0000

We know that non-stationary time series also have a common trend of change, even if there is no causal relationship between them in economic behavior. This paper selects the common test method in economics, puts forward the suitable hypothesis, then uses the software to carry on the data processing, obtains the desired result (Table 36.2).

Through econometrics learning, we have come to realize that it is very important to test the co-integration of variables in building econometrics models. Moreover, the data base of selecting the variables of the model is firm and the statistical properties are good. Then, using the mixed model regression, get the panel data regression results (Table 36.3).

After data processing, get panel data regression results. The *** symbol in the upper-right corner of the table indicates significance at 1% confidence level, ** indicates significance at 5% confidence level, and * indicates significance at 10% confidence level.

36.5 Summary

The logarithmic effect of the size of internet money funds (LNICF) on the return on assets (Roa). According to the regression results of the above-mentioned models, when the confidence level is 10%, the T statistic value of the variable coefficient corresponds to a p value of 0.0603, indicating that the results passed the significance test. The variable factor is negative and the result is −0.005742, which indicates that there is a negative correlation between the size of Internet Money Fund and asset yield. In other words, the internet money fund weakens the profitability of commercial banks by diverting the deposits of commercial banks, robbing the customers of commercial banks and raising the cost of funds of commercial banks [4]. From the numerical point of view, the variable coefficient is still very small, indicating that as a new thing, economic characteristics do not play their due role.

The logarithmic effect of the size of third-party internet payment transactions (LNTIP) on return on assets (Roa). From the above regression results, it can be found that the t statistic value of the variable coefficient corresponds to the p value of 0.0201 at the confidence level of 5%, indicating that it has passed the significance test. The variable coefficient is negative, and the result is −0.006723, which proves that there is a negative correlation between the size of the third-party internet payment transaction and the rate of return on assets. The role of the bank as a payment intermediary is not only weakened by the third-party internet payment, but also affected by the internet money fund it has launched [5]. The third-party internet payment robs the market funds originally belonging to the commercial banks, the commercial banks have to increase their investment in order to take deposits, which leads to the increasing cost of funds, at the same time, the potential customers who belong to the commercial banks are also losing.

The impact of the current quarterly cost-to-income ratio (CIR) on return on assets (Roa). From the above regression results, it can be found that at the confidence level of 1%, the T statistic corresponding to the variable coefficient has a p value of 0.0000, indicating that the result has passed the significance test. The variable coefficient is −0.013227, which shows that there is a negative correlation between the rate of return on cost and the rate of return on assets. In the study of expertise, we find that the lower the cost-to-income ratio and the higher the unit cost, the higher the return on assets and assets.

36.5.1 Improve the Countermeasures of China's Commercial Banks to Deal with the Internet Financial Products

This chapter mainly revolves our country commercial bank to be the center point, proposes our country commercial bank how to deal with the Internet wealth management product development to bring the influence some measures, consummates our country commercial bank to deal with the obstacle factor the theory system, help our commercial banks to achieve high-quality development.

36.5.2 Make Full Use of the Huge User Group of Internet Finance

At present, we are familiar with the large Internet companies have been involved in the Internet financial management. Many mobile internet users will be attracted by internet wealth management [6]. Commercial banks should take the initiative to strengthen cooperation with large internet companies and build their own wealth management products based on e-commerce and social software platforms, grasp the opportunity in the tide of Internet financing, and help our commercial banks further develop.

36.5.3 To Maximize the Advantages of Internet Financial Management and Network Technology

Under the background of big data era, we should not only rely on the huge user group to support development, but also understand the needs of customer groups in detail. Commercial banks can make use of big data technology to analyze the ability of consumers to purchase wealth management products, reasonably divide the types of customers, provide targeted financial services for different types of users, and fully tap potential customer resources [7]. Take our familiar Alipay, wechat software, the use of these software user consumption data, capital flows and other information will help commercial banks to develop wealth management services, and then help commercial banks to enhance the level of intermediary business capacity.

36.5.4 Simplify Financial Management and Information Collection Methods

To achieve development, commercial banks need to have more customer resources and fully understand the information of financial clients. The collection of customer information is often troublesome, which brings obstacles to the development of commercial banks. Commercial banks should take the initiative to provide customers with the necessary information and related financial knowledge, to solve the Information asymmetry problems to customers, and to pull the commercial banks closer to the customers themselves [8]. To help customers analyze financial products, and then make customers easily choose the most suitable for their own financial products. To help commercial banks better maintain customer relations, for commercial banks to contribute to the sustainable development of wealth management products market.

36.5.5 Jointly Promote the Healthy Development of the Wealth Management Market

The growth of Internet finance has brought obstacles to the normal operation of commercial banks, but it also helps the integration of commercial banks and Internet finance to promote their development of new businesses [9]. The development prospect of internet finance in recent years urges commercial banks to take seriously the restrictive factors brought by internet wealth management products, integrate with network actively, and develop financial management products with their own characteristics, we will actively maintain the relationship between commercial banks and their clients, expand their influence in financial services, promote the sustainable development of commercial banks, and work together with internet financial management platforms to create a healthy financial market.

36.6 Conclusion

Internet wealth management products are a lot richer than before, it also continues to affect the commercial bank's business development. Including the gradual loss of credit resources of commercial banks due to the impact of internet wealth management products, changes in the structure of debt, and the acquisition of market share of debt by internet wealth management products, which increased the cost expenditures of commercial banks, and continue to narrow the profit margin of commercial banks [10]. The development model of Internet financing has forced commercial banks to change the traditional profit model that relies on the difference between deposit and loan interest rate to obtain income, because the financing cost of commercial banks is rising steadily, but the profitability is very low. Internet financial products are more profitable than commercial bank financial products, and the profitability of commercial bank financial services has gradually declined, restricting the growth of commercial bank operating performance.

References

1. Y. Chen, J. Pang, W. Zhang, A study of volatility and externality compensative return of internet financial products in the case of Yuebao. Emerg. Mark. Financ. Trade **54**(4) (2018)
2. J.M. Zhang, S.Z. Zhu, W. Yan, Z.P. Li, The construction and simulation of internet financial product diffusion model based on complex network and consumer decision-making mechanism. Inf. Syst. e-Bus. Manag. **2018** (prepublish)
3. Design and research of bank internet financial product pricing model. Cluster Comput. **22**(6) (2019)
4. Y. Wang, Analysis on the development of chinese commercial banks from the perspective of internet finance. Econ. Manag. Dig. (10), 1–2 (2020)
5. Y. Gao, Research on the influence of internet financial products on the financial sales performance of a commercial bank (Xi'an University of Technology, Xi'an, 2020)
6. B. Liu, Analysis of the impact of Internet finance on bank financial products. Bus. News (17), 95–97 (2020)
7. T. Li, Research on the innovation and development of financial products of commercial banks under the background of Internet. Modern Market. (next issue) (09), 46–48 (2020)
8. K. Chen, An internet financial platform and method. China Patent. CN1,098,40,84,1A (2019)
9. J. Liu, Research on innovation advantages and development of Internet financial products. Time Financ (15), 7–8 (2019)
10. P. Lu, The influence of Internet finance on commercial banks and countermeasures: a case study of "Change Pass". Rural Econ. Technol. **303**(14), 46–47 (2019)

Chapter 37
A Text Mining Approach to Identify Key Sustainability Reporting Trends and Issues on Twitter

Anand Kumar, Pradip Kumar Bala, and Rajat Kumar Behera

Abstract The objective of this study is to use real-life social media data to examine the incentives and important topics surrounding sustainability reporting in a natural context. Predominantly, businesses communicate their performance and impacts on a broad variety of sustainability topics, encompassing environmental, social, and governance dimensions, through sustainability reporting. Therefore, this study analyzes user conversations on Twitter, a social media platform where people share common interests. The Latent Dirichlet Allocation (LDA) method was used to extract conversation topics on Twitter that were related to sustainability reporting. As a result, 28 themes for conversation topics were identified. Consequently, reporting structure was found to be the most discussed topic. The results suggested that members of the Twitter community shared their motives for adopting sustainability reporting and cooperatively discussed relevant issues and problem-solving methods to enhance their practices.

Keywords Sustainability reporting · Latent Dirichlet allocation · Communities of practice

A. Kumar (✉) · P. K. Bala
Indian Institute of Management, Ranchi, India
e-mail: anand.kumar20ph@iimranchi.ac.in

P. K. Bala
e-mail: pkbala@iimranchi.ac.in

R. K. Behera
Kalinga Institute of Industrial Technology, Bhubaneshwar, India
e-mail: rajat_behera@yahoo.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_37

37.1 Introduction

The idea of sustainability was initially focused on environmental issues but has since expanded to include social and economic dimensions. It aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. The frequent occurrence of catastrophes over the past few years impacting society, the environment, and the economy prompted research on sustainability [1]. This has been reflected in the sustainable development goals (SDGs), which cover a wide range of issues and were adopted by the United Nations General Assembly in 2015 [2]. However, little is known about the motivations behind the shared interests of global stakeholders discussed in socially mediated communities of practice. Examining the type of social media communication approaches can provide organizations with valuable insights into how they engage with their stakeholders.

In continuation, if organizations use social media to foster a two-way conversation with stakeholders, it not only allows them to listen to their stakeholders' voices but also helps them understand the issues that are significant to their stakeholders. In addition, this approach offers organizations a chance to directly address their stakeholders' concerns [3]. This strategy could indicate that organizations leverage social media's interactive and participatory features to create networks facilitating learning and relationship-building with their stakeholders [4]. Drawing upon the community of practice approach [5] as the theoretical framework, this study explored conversation topics reflecting on online members who share their motivations to learn about sustainability reporting and interact with other users to learn about and reciprocate their practice on Twitter. Consequently, the following research question (RQ) has been framed, i.e.,

RQ: What are the popular topics on sustainability reporting that users have posted in socially mediated communities of practice?

37.2 Related Work

Digital transformation supports sustainability and fosters business action [7]. Pilař [6] identified six topics from Twitter, namely: innovation, environment, climate change, corporate social responsibility, technology, and energy, as key hashtags in the field of sustainability. 'Risk management', 'infrastructural development', 'sustainable thinking', and 'transparency' are widely discussed sustainability themes [10]. The Global Reporting Initiative (GRI) reports in a typical way to make sustainability reporting transparent to stakeholder groups [8]. Many CSPSEs in India are opting for BRSR [9]. A global standard has been established for GHG reporting [11]. The sustainability reporting standards vary across companies due to the lack of a globally accepted standard, and the company can choose voluntarily [8]. Thus, sustainability reporting is an emerging area with no global standard like financial reporting. These are some of the research topics discussed in the literature.

37.3 Data Collection

We used the Twitter application programming interface (API) key and the secret to collect data from Twitter from November 13, 2007, to March 23, 2023. Yang [13] suggested random sampling as the gold standard in their research. This study employed random sampling to handle biases in Twitter data. A total of 75,443 tweets were scrapped, and after random sampling, preprocessing, and filtering out tweets of less than twenty words, 5,265 tweets were considered for further analysis. We extracted all posts and their top-level comments into one document to ensure data integrity.

37.4 Methodology

37.4.1 Data Preprocessing

In this study, Twitter posts were pre-processed using Python 3.10.11 to remove punctuation, integers, non-English content, special and accent characters, and stop words using the Natural Language Toolkit (NLTK). The text data was then tokenized, and N-grams (i.e., sequences of two or three adjacent items) were used to denote semantic units represented by tokens. The tokens representing functional terms were removed by part-of-speech taggingsince they were considered trivial enough to represent the document's content.

37.4.2 Topic Modeling

After preprocessing automated content analysis using topic modeling, Latent Dirichlet Allocation (LDA) [12] was done to explore the discussion topics and identify overarching topics without prior knowledge of the corpus. LDA's fundamental principle relies on the document-topic and term-topic matrices to determine the underlying topic structure. The LDA method assumes that documents can be represented as a mixture of different latent topics, each defined by a probability distribution over terms. In short, LDA determines topic clusters within a given document, such as a Twitter post, based on an unordered set of topical terms with different frequencies [5]. Under the Bag-of-Words assumption, the order of terms in each document is ignored, leading to a loss of specific contextual information about the semantic associations between words. However, this assumption can be helpful in exploring general topic clusters in document collections. The user needs to input the number of topics for LDA, which is a challenging task because a smaller number of topics will lead to an under-representation of themes, while a large number leads to redundant themes. The coherence score represents the human interpretability of topics, and its high value leads to better interpretability of topics. The coherence score is found to be the maximum for 28 topics. The below table describes the keywords obtained for each topic from the LDA model and the name given by the authors (Table 37.1).

37.5 Results and Discussion

Themes such as climate, environment, and corporate social responsibility (CSR) are found in a previous study by Pilař [6]. Digital transformation [7], global reporting initiatives (GRI) [8], and sustainability reporting standards [8] are described in the existing literature. Apart from these themes study finds several other topics of discussion. Thus, answering the research question.

The study proposes that the following sustainability reporting themes can be classified into four broad groups, namely (1) target variable (e.g., climate, environment, social housing, CSR, investor interest) is the area where the company wants to perform better in terms of contributing to sustainability. (2) Standards (e.g., GRI, CRSD, KPMG Report, EU Directives) represents various suggestions and directives given by consulting and governing body (3) Implementation (e.g., ESG data solution, digital transformation, policy, and strategy) represents company measures to implement. (4) Knowledge update (e.g., podcast, conference, webinar, Asia summit) represents a form of media to stay updated on sustainability development. Based on these groups, the study proposes a framework to guide sustainability reporting in an organization, as shown in Fig. 37.1. Information and knowledge about each step can be updated with freely available social media data. Therefore, it represents steps to dynamically guide sustainability reporting using social media data.

37.6 Conclusion

The study found 28 topics of discussion related to sustainability reporting and proposed a sustainability reporting guiding framework for organizations based on the grouping of these topics. Among these most frequent topics is reporting structure, which accounts for 5% of total tweets. Since there is no globally accepted standard for sustainability reporting, this may be the reason for its most frequent occurrence in Twitter discussions. These topics help the business to understand the interest of stakeholders and to make appropriate business decisions.

Table 37.1 Interpretation of topic

Topic	Terms per topic
Framework update	Framework, world, industry, provide, effort, sustainable, leading, chief, policy, major
SDG implementation workshop	Amp, sdgs, secretariat, workshop, link, forum, build, sustainable_development, pm, implementation
ESG podcast	ESG, carbon, article, service, full, partner, landscape, demand, growing, podcast
Sustainability reporting standard	Global, standard, international, accounting, initiative, issb, standard_board, IFRS, IFRS_foundation, chair
Emission reporting	Company, information, emission, report, year, large, gt, compliance, increase, start
ESG data solution	Data, make, goal, solution, metric, measure, analysis, process, decision, progress
Conference	Future, today, session, expert, great, conference, discussion, join, panel, speaker
Webinar	Join, register, event, webinar, discus, communication, week, place, online, live
Public sector	Step, board, public_sector, sdg, brsr, open, india, important, business_responsibility, opportunity
CRSD	Corporate, EU, requirement, CSRD, regulation, directive_csrd, directive, legislation, law, effect
KPMG report	Company, key, support, good, trend, survey, requirement, issue, kpmg, insight
CEO message	Amp, director, CEO, leader, DR, engagement, agenda, strategic, long_term, netzero
Sustainability research	Management, public, assurance, project, amp, research, audit, clear, client, area
Green reporting	Finance, green, member, meet, lead, state, government, bank, commitment, story
Investor interest	Investor, stakeholder, energy, level, group, europe, benefit, info, include, high
Policy & strategy implementation	Amp, performance, strategy, learn, improve, organization, system, platform, business, policy
Corporate social responsibility (CSR)	Gri, training, day, standard, program, CSR, upcoming, principle, register, miss
Social housing	Standard, investment, sector, UK, news, ESG, november, social_housing, capital, economy
Climate	Disclosure, climate, financial, role, action, important, play, climate_related, sustainable_finance, sec
Consultation listed company	Part, based, sustainable, approach, regulatory, guideline, series, listed_company, manager, aim
EFRAG standard	Standard, european, efrag, financial, set, ESR, org, draft, call, published

(continued)

Table 37.1 (continued)

Topic	Terms per topic
Company sustainability team	Today, work, share, team, topic, insight, view, develop, related, apply
EU directive	Corporate, directive, eu, proposal, rule, non_financial, directive_csrd, council, csrd, adopted
Environment	Impact, risk, social, environmental, focus, issue, climate_change, opportunity, assessment, including
Global reporting standard (GRI)	ESG, CSR, TCFD, climatechange, RT, responsible, sasb_cdp, gri_sasb, netzeroemissions_ corporategovernance, djsi_tcfd
Singapore Asia summit	Award, asia, year, summit, report, integrated, singapore, top, proud, communication
Materiality information	Read, development, latest, challenge, update, smes, blog, tool, recent, materiality
Digital transformation	Transparency, market, time, stakeholder, plan, building, change, taxonomy, real, digital

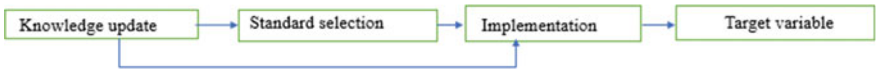


Fig. 37.1 Proposed framework (Author's own conceptualization) for guiding sustainability reporting in an organization

References

1. W. Qian, C. Tilt, A. Belal, Social and environmental accounting in developing countries: contextual challenges and insights. Account. Audit. Account. J. **34**(5), 1021–1050 (2021)
2. A. Sianes, A. Vega-Muñoz, P. Tirado-Valencia, A. Ariza-Montes, Impact of the sustainable development goals on the academic research agenda. A scientometric analysis. Plos One **17**(3), e0265409 (2022)
3. J. Moll, O. Yigitbasioglu, The role of internet-related technologies in shaping the work of accountants: new directions for accounting research. Br. Account. Rev. **51**(6), 100833 (2019)
4. S. Lodhia, A. Kaur, G. Stone, The use of social media as a legitimation tool for sustainability reporting: a study of the top 50 Australian stock exchange (ASX) listed companies. Medit. Account. Res. **28**(4), 613–632 (2020)
5. J. De Wilde, G. Cavalli, S. Fuller, Online communities of practice for academic practice and a sense of belonging, in *Online Communities for Doctoral Researchers and their Supervisors* (Routledge, 2021), pp. 83–94
6. L. Pilař, L.KvasničkováStanislavská, J. Pitrová, I. Krejčí, I. Tichá, M. Chalupová, Twitter analysis of global communication in the field of sustainability. Sustainability, **11**(24), Article 24 (2019)
7. N. Chatzistamoulou, Is digital transformation the Deus ex machina towards sustainability transition of the European SMEs? Ecol. Econ. **206**, 107739 (2023)
8. M.C. Machado, V.S. Correa, M.M. de Queiroz, G.C. Costa, Can global reporting initiative reports reveal companies' green supply chain management practices? J. Clean. Prod. **383**, 135554 (2023)

9. R. Mahajan, Measuring sustainability in india: a comparative assessment of frameworks and key challenges, in *Measuring Sustainability and CSR: from Reporting to Decision-Making*. (Springer International Publishing, Cham, 2023), pp.179–195
10. G. Valenza, R. Damiano, Sustainability reporting and public value: evidence from port authorities. Utilities Policy **81**, 101508 (2023)
11. R. Kasperzak, M. Kureljusic, L. Reisch, S. Thies, Accounting for carbon emissions—Current state of sustainability reporting practice under the GHG protocol. Sustainability **15**(2), 994 (2023)
12. M. Poongodi, T.N. Nguyen, M. Hamdi, K. Cengiz, Global cryptocurrency trend prediction using social media. Inf. Process. Manag. **58**(6), 102708 (2021)
13. K.C. Yang, P.M. Hui, F. Menczer, How Twitter data sampling biases US voter behavior characterizations. PeerJ. Comput. Sci. **8**, e1025 (2022)

Part IV
Business Analytics

Chapter 38
Design and Implementation of Intelligent Analysis and Management Platform for Urban Economic Statistical Data Under the Background of Information Age

Xiaobing Deng

Abstract After entering the 21st century, the rapid development of China's social economy shows a high dependence on energy resources. China is facing a severe test of whether the energy demand brought by the rapid development of social economy can be supplied accordingly. Under this background, the state has repeatedly emphasized the establishment of a resource-saving society to achieve the coordinated development of economy and energy. Establishing a macroeconomic basic database has become the main measure of government work. However, because of the rapid development of various industries, the difficulty of statistical work is relatively high. If you want to guarantee the efficiency and accuracy of statistical work, you should actively adjust and reform in accordance with the development trend of the times, scientifically and reasonably apply computer technology and Internet technology to ensure the intelligent development of statistical economic work. Therefore, this paper discusses the relationship between urban economy and market economy, and analyzes the role of urban economic statistics on market economy and urban construction in combination with urban development.

Keywords Information age · Urban economy · Data intelligence · Platform management

X. Deng (✉)
Nanchang Institute of Technology, Nanchang, China
e-mail: 17091790@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_38

38.1 Introduction

With the convergence and integration of information technology and human production and life, the Internet is rapidly popularized, and global data is characterized by explosive growth and massive aggregation [1]. IDC predicts that the global data circle will increase from 33ZB in 2018 to 175ZB in 2025, and the storage capacity of all media types will exceed 22ZB. According to IBM's research, 90% of all the data obtained by the whole human civilization were produced in the past two years. By the end of 2020, the scale of data generated by the world will reach 44 times of the current level. Modern urban operation is characterized by complexity [2]. From the perspective of participation role, the constituent roles of urban operation are played by government, enterprises and free people; From the perspective of composition space, urban operation covers the communication between people such as business, transportation, logistics and residence. From the perspective of operation management, the operation of the city includes public infrastructure, transportation, social security and other management [3].

The safe, healthy and operational development of the city requires not only the cooperation of all industries, and reasonably allocate urban resources, the city needs to establish a complete urban operation evaluation system; And build a city operation management platform based on the operation evaluation. The contradiction between economy and resources, environment and development is increasingly prominent [4]. Local governments have also formulated annual energy conservation plans and emission reduction targets, and measures such as eliminating outdated production capacity and promoting energy-saving transformation have achieved remarkable results. Strengthening economic statistics in the process of building a conservation-oriented economic society is the need for us to implement the scientific concept of development and build a resource-conserving and environment-friendly society. It is also an important starting point for transforming the development mode and taking the new road of industrialization. It can also be said that statistical economy is an important way that people need to use in the process of understanding the market, and its role is irreplaceable [5].

Under the background of the rapid development of information technology, how to obtain comprehensive and real economic data, besides taking the market development situation as the basis, also needs to make up for the defects in the current statistical approach, and analyze and sort out the data from a holistic perspective [6]. Introducing informatization as a new management mode into energy conservation and consumption reduction is a research hotspot and focus in the field of energy conservation and consumption reduction. Taking information technology as a new means to promote energy-saving work can provide a platform for energy consumption data statistics and monitoring, help statistical departments to obtain statistical data in time and accurately, and combine all units with the overall goal of energy-saving work formulated by the government, thus promoting the construction of an environment-friendly and resource-saving "two-oriented society" and making China's social and economic sustainable development faster and better [7].

Based on the above principles, this paper proposes a multivariable statistical model based on the artificial intelligence parameter estimation method, which includes the prediction model based on the combination of RBF and LASSO based on the artificial intelligence parameter estimation method and the prediction model based on the combination of RBF and Hard-ridge based on the artificial intelligence parameter estimation method.

38.2 Intelligent Construction Methods of Statistical Economy in the Information Age

38.2.1 Actively Improve the Original Statistical Economic Work Model

At present, in the process of statistical economic work in China, statistical data, because it is directly related to the performance evaluation results of local government staff, so local governments generally adjust the data generated in the process of social and economic development in their own regions. Under this background, the information data obtained by statistical departments are not very true, and the accuracy of information is difficult to be guaranteed, which will have a certain impact in the process of formulating national economic policies, thus the adaptability of various macro-control measures implemented by the state is not strong [8]. In order to ensure the speed of intelligent construction of statistical economy, it is necessary to construct a professional data analysis and management mechanism under the background of integrating all kinds of necessary statistical economic data. For example, in the information age, we can use all kinds of intelligent terminals with strong adaptability and build a standardized statistical and economic data center, so as to ensure the professionalism of the data sources of securities and ensure that the causes of various data problems can be found according to the data sources [9]. With the popularization of statistical methods, not only statisticians can do statistical analysis, but also workers from all walks of life can use statistical methods for statistical analysis. Statistical analysis is closely related to economic analysis, accounting analysis, enterprise management analysis and other analytical research activities, and there is often an inclusive relationship between them [10].

In a sense, the provision of high-level statistical analysis report is the final product of the deep processing of statistical data, the full display of the organic combination of the overall functions of statistical information, consultation and supervision, and the highest achievement of the statistical department to play its unique advantages and provide high-quality services for enterprise leaders and decision-making departments. It is an indispensable and important basis for them to analyze the economic operation situation, make macro decisions and formulate long-term plans. Data statistics is a part of information statistics. The development trend of data or information statistics is to use computer and network statistical methods,

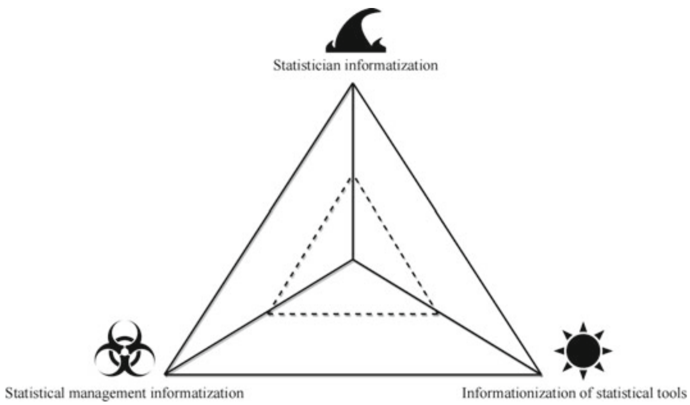


Fig. 38.1 Elements of statistical informatization

that is, statistical informatization. Statistical informatization refers to the application of informatization in the whole process of collecting, classifying, processing and publishing statistical information, and the analysis, prediction and evaluation of statistical results with the help of computer technology, so as to realize the deep processing of statistical information. The core of statistical informatization is to use advanced information technology to improve the traditional way of information statistics. The essence is that the statistical staff are proficient in relevant technologies, improve the management level of statistical work, and achieve better operation and application of statistical data information. In terms of connotation, statistical informatization should include: informatization of statistical tools, informatization of statisticians and informatization of statistical management. As shown in Fig. 38.1.

Statistics is a knowledge that combines natural science and social science, and it is also a rigorous and meticulous work. From the collection of basic data to comprehensive processing, from the analysis and research of data to the ultimate service to society, all links are closely linked, which will affect the whole body. The system covers and expands such aspects as strengthening the organizational construction of statistical teams, establishing statistical information automation systems, prospering statistical scientific research and providing statistical quality services. Therefore, the establishment of data source subsystem is the most basic and important part of modern statistical system. Specifically, on the basis of consolidating and strengthening the statistical institutions of cities and counties, it is important to establish statistical organizations of data sources at the grassroots level, such as towns, villages, enterprises and institutions, and all relevant departments at the same level must also establish their own statistical organizations, thus forming an organizational network that runs through from top to bottom, criss-crossing, complete and efficient statistical data collection.

38.2.2 Business Statement of Intelligent Analysis Platform for Urban Economic Statistical Data

There are three kinds of conventional data statistical analysis solutions: paper reports, EXCEL forms and customized software. Among them, paper reports are the most common, and most domestic manufacturing enterprises with low degree of production automation or less computer application adopt this form. According to the usual business needs, the statistics department manually draws a series of paper reports, binds them into volumes and distributes them to various production workshops or departments. The production managers fill in all the index data and then return them to the statistics department at one time.

Some heads of enterprises and units do not pay enough attention to economic statistics. Enterprises focus on tax burden, environmental protection, safe production and other issues. They do not pay enough attention to economic statistics. Indicators such as coal consumption and electricity consumption of enterprises are not filled in according to actual consumption. The statistical department cannot obtain real data, which has affected historical data to some extent, and also caused individual enterprises to file with the development and reform department in the future annual technical reform, The development and reform department needs to record according to the ability evaluation of the enterprise in the previous years, so that the enterprise can wake up to the fact that the project cannot be started on schedule and the cost exceeds the budget. If the enterprise reports according to the actual situation at the beginning of the statement, such events will not occur. For example, the proportion of secondary indicators under a certain indicator, the comparison between different economic indicators in the same city, and the comparison between the same indicators in different cities are convenient for users to analyze the data changes and understand the economic development trend. The data generated by the query can be downloaded in Excel form, which is convenient for users to process. The difference between economic data and other kinds of data is that economic data stores all relevant attributes of a specific indicator, including indicator name, start and end time, current month's value, cumulative value, current month's ratio, cumulative ratio, same period's ratio, unit, etc. Based on the above indicator attributes, this platform designs database tables to store economic data. The above business process is the operation process of the intelligent analysis platform of urban economic statistics data in an ideal situation. However, in practical application, the function of data news extraction cannot be carried out normally due to the changes in the page structure of major websites. In this case, the platform needs to give an alarm in real time and handle anomalies in time. The activity diagram of information collection function of intelligent analysis platform is shown in Fig. 38.2.

Different data extraction is required for different formats of data. Finally, the extracted data is stored in the corresponding table of the database. The format of news stored in different websites is the same, so the news in different websites can be processed in the same way to get the news content. After the news is extracted, it needs to be filtered, and the qualified news will be stored in the database for display to

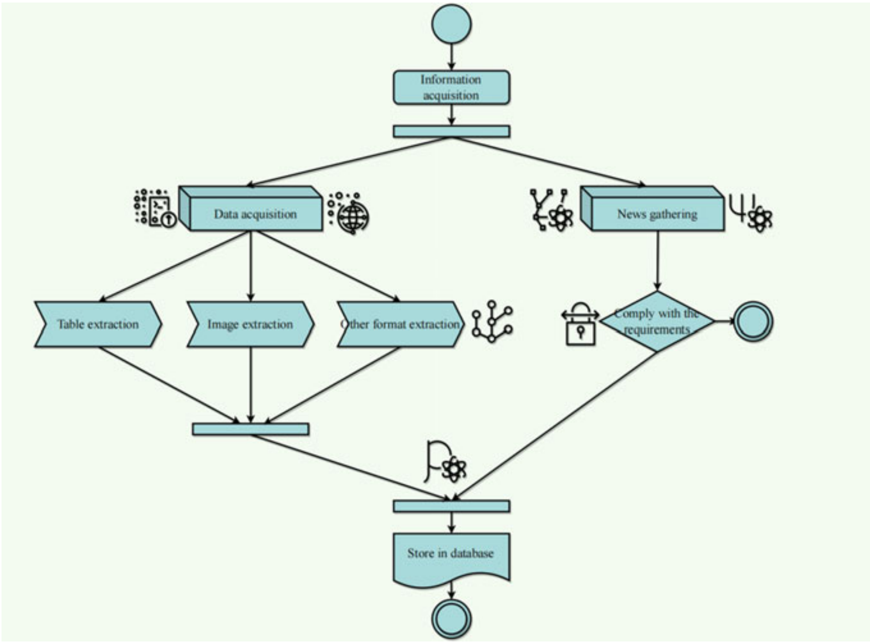


Fig. 38.2 Information collection activity diagram of intelligent analysis platform

users. At the same time, the customized recommended news for users will be based on the user's viewing and search records.

38.3 Multivariable Statistical Model Based on Artificial Intelligence Parameter Estimation Method

38.3.1 Data Analysis Model

In the real world, a social phenomenon is often related to more than one reason, and it is also related to many other social phenomena. Data mining algorithms can go deep into the data and find some relevant data in massive data. In linear regression model, if there are too many independent variables, it will lead to collinearity problems, and if there are too few independent variables, it will make the explanation of the model insufficient. However, variables are not necessarily linear. Apriori association rules can mine the correlation between massive data, and generate strong association rules by generating association rules that are greater than the set minimum support and minimum confidence. Based on the results of Pearson correlation coefficient analysis, the Apriori association rule is established to find the strong correlation among given variables, dependent variables. It is not difficult to find that the effect of traditional parameter estimation method K-means clustering method is not very good. In order to determine the optimal parameter value, we still use three artificial intelligence optimization algorithms: differential evolution algorithm, grouped ant colony algorithm and cuckoo algorithm to estimate the central parameters and scale parameters of the model, thus establishing a complete prediction model based on artificial intelligence parameter estimation method combining RBF with Lasso and a prediction model based on artificial intelligence parameter estimation method combining RBF with hard-ridge. Although we can visually see whether there is a linear relationship between the two variables from the scatter plot, it is a rough representation, and the correlation coefficient can be calculated to find the linear relationship between the two variables.

$$r = \frac{\sum_{i=1}^{n} (x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \overline{x})^2 \sum_{i=1}^{n} (y_i - \overline{y})^2}} \tag{38.1}$$

where, x and y represents the value of the two variables, $\overline{x}$ and $\overline{y}$ represents the average value of the two variables, and n represents the number of samples. If $|r|$ is >0.8, then there is a strong linear correlation between them; if $|r|$ is <0.3, then there is a weak linear correlation between them.

The Akaike Information Criterion (AIC) criterion is used to select the adjustment parameters in formula (38.2)λ.

$$df(\lambda) = tr(L) = tr\left[\psi(\psi^T\psi + \lambda I_{qt})^{-1}\psi^T\right] = \sum_{j=1}^{q_1} \frac{\lambda_j}{\lambda_j + \lambda} \tag{38.2}$$

where q_1 is the number of hidden layer nodes selected after adding the penalty function, $tr(\cdot)$ is the trace of $(\cdot)$, $\{\lambda_j, k = 1, 2, ..., q_1\}$, $\psi^T\psi$, $L = \psi(\psi^T\psi + \lambda I_{q1})^{-1}\psi^T$.

The AIC criteria are:

$$AIC = n\log(SSE/n) + 2df \tag{38.3}$$

where $SSE = \|y - \psi\theta\|_2^2$ is the mean square error, and df represents the degree of freedom in shrinkage estimation.

Based on the excellent performance of Hard-Ridge, in this section, $l_0 + l_2$ penalty function is added to the parameter linearization model of RBF neural network, and a prediction model is established, which is abbreviated as Hard-Ridge-RBF model. Similar to lass 0-RBF model, the prediction model established at this time does not select the number of independent variables, but selects the hidden layer nodes of RBF neural network, and reduces the number of hidden layer nodes to achieve dimensionality reduction, thus obtaining a simple model with high prediction accuracy.

Based on the above analysis, the optimization problem named hard-ridge-RBF can be transformed into:

$$\overset{\wedge}{\theta}_{Hard-ridge} = \arg \min_{\beta\theta \in R^q} \{\|y - \psi\theta\|_2^2 + \sum_{j=1}^{q} P_{Hard-ridge}(\theta_j; \lambda, \eta)\} \tag{38.4}$$

According to our experience, the estimated value of η is not very sensitive, so the small grid of η-path can be set to 0.5, 0.05 and 0.005.

38.3.2 Analysis of Experimental Results

China Statistical Yearbook is an informative annual publication compiled by the National Bureau of Statistics, which comprehensively reflects the economic and social development of the People's Republic of China. A statistical yearbook of a certain year contains a large number of economic and social statistical data of the whole country and all provinces, autonomous regions and municipalities directly under the Central Government in the previous year, as well as major statistical data of the whole country in important historical years and nearly 20 years. It is published by the National Bureau of Statistics every year and is the most comprehensive and authoritative comprehensive statistical yearbook in China. For summary forms that need to extract data from other reports, first select the slave table (that is, the data source table) to extract data, then select the data source cells of the slave table and the main table cells in turn, and then define the summary formula between tables. All these formulas are defined in a visual graphical interface, which is intuitive and clear. When the table is summarized, the data values we need are calculated according to these predefined summary formulas. The function of the data processing management module is to analyze the data or data files exchanged from the commission office, and through certain data processing (such as extraction, loading, verification, etc.), define the corresponding data filtering rules and other cleaning configuration information, complete the filtering of the exchanged data according to the definition of the cleaning configuration, and store the data provided by the commission office in the system database. It includes the transformation process management sub-module and the transformation task management sub-module.

Based on the variable selection feature of Hard ridge, it is introduced into the parameter linearization structure of RBF neural networks, and a Hard ridge RBF model is established. By selecting an appropriate number of hidden layer nodes, a concise model is obtained. The ant colony algorithm calculates the pheromone concentration of the contemporary ant location, calculates the pheromone concentration of the optimal ant in each sub region, and then calculates the pheromone concentration of the global optimal ant to determine the location of the optimal ant. After each iteration, ordinary ants in each sub region perform size step search based on the location of the optimal ant, and then update and judge the new positions searched by the ants in each sub region. Based on the new positions of the ants, the current optimal solution can be obtained; By applying the characteristics of Hard ridge selection variables, an ACO hard ridge RBF model is established, and an appropriate number of hidden layer nodes is selected to obtain a concise model; Considering the characteristics of Hard ridge selection variables, this paper establishes a CS hard ridge RBF model, which simplifies the model by selecting an appropriate number of hidden layer nodes.

In order to verify the superiority and effectiveness of the proposed model, the solar radiation from January 2019 to December 2010 is predicted and compared with RBF neural network and hard-ridge-RBF model. It is easy to find that the number of nodes in the hidden layer of RBF neural network has not changed in the prediction process, while the hard-ridge-RBF model realizes sparsity by increasing the hard-ridge penalty, that is, the model is simplified by reducing the number of nodes in the hidden layer. Through many simulation experiments, the optimal number of hidden layer nodes in the model with hard-ridge penalty is 16. Figures 38.3 and 38.4 present the real values of solar radiation at two stations and the predicted values of five models based on Hard-Ridge. These two figures also have a big picture and six sub-pictures, in which the sub-picture in the upper right corner represents the legend, and the other five sub-pictures respectively represent the scatter charts of the predicted values of five models (the abscissa and ordinate are both real values). If the scatter points are closer to a straight line, the prediction effect of the model is better. It is not difficult to find that the scatter points of DE-hard-ridge-RBF, ACO-hard-ridge-RBF and CS-hard-ridge-RBF are closer to a straight line than RBF and hard-ridge- RBF.

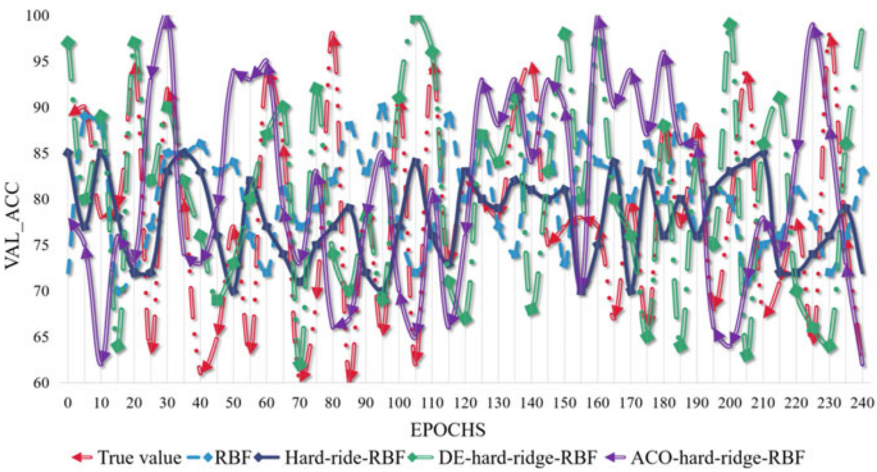


Fig. 38.3 Comparison between the predicted values and the real values of five models based on hard-ridge (**a**)

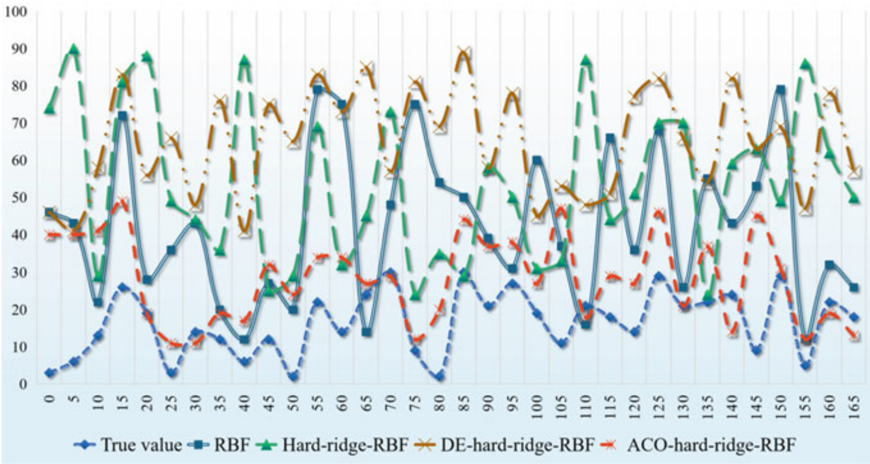


Fig. 38.4 Comparison between the predicted values and the real values of five models based on hard-ridge (**b**)

Two statistical evaluation indicators MAPE and RMSE are still used here to show that the optimization model with Hard-ridge penalty is superior to the traditional model. In order to carry out comparative research, this paper selects the prediction value of the number of hidden layer nodes from 50 to 16 and from 50 to 10. The experimental results show that the single variable statistical distribution based on artificial intelligence parameter estimation method is superior to traditional statistical distribution, the model is more simplified, and has higher prediction accuracy, especially the multivariate statistical model combining RBF and Hardridge based on artificial intelligence parameter estimation method.

38.4 Conclusion

In recent years, the country has put forward policy objectives such as sustainable development, the construction of a resource-saving and environment-friendly society, which has opened the prelude to energy conservation and emission reduction nationwide. In the information age, the role of data has shown a trend of gradual enhancement. In the process of collecting data and applying and analyzing data, intelligent terminals and Internet technology should be used. This is an important trend in the development of the era and an inevitable requirement in the development of the information age. This paper analyzes the technical system of macroeconomic data management system for smart cities and discusses the key technologies, and on this basis, initially designs and implements the macroeconomic data management system, which has carried out more effective preliminary research and exploration for the large-scale application of macroeconomic data. In this paper, the artificial intelligence optimization algorithm is used to make a series of extended analysis and research on the parameter estimation problems encountered in the practical application of the prediction model, which makes the prediction model based on the artificial intelligence parameter estimation method more applicable and more accurate. Compared to traditional methods, the model is more simplified and has higher prediction accuracy.

Acknowledgements Project Name: Science and Technology Research Project of Jiangxi Provincial Department of Education (Fund number: GJJ2202706).

References

1. X. Lv, M. Li, Application and research of the intelligent management system based on internet of things technology in the era of big data. Mob. Inf. Syst. **15**(6), 12 (2021)
2. L. Zheng, X. Zhang, Optimization design of automatic filing system of financial management information under the background of information technology development. J. Intell. Fuzzy Syst. **38**(9), 12 (2019)
3. K. Sun, Analysis of production and organisational management efficiency of Chinese family intelligent manufacturing enterprises based on IoT and machine learning technology. Enterp. Inf. Syst. **14**(7), 20 (2020)
4. S. Chandra, R. Arya, et al., Reliability and age of information analysis of 5G IoT for intelligent communication. Comput. Electr. Eng. **55**(10), 4 (2022)
5. Y. Lyu, Y. Zhang, Y. Liu et al., Analysis of potential disruptive technologies in the electronics and information field towards the intelligent society. Engineering **44**(6), 12 (2021)
6. S. Chen, I. Sanweng, Economic information analysis and its application in decision-making under the background of big data. Mob. Inf. Syst. **36**(7), 36 (2021)
7. B. Guo, Research on the construction of logistics information platform for coastal ports under the background of electronic commerce. J. Coast. Res. **43**(11), 48 (2020)
8. Q.A. Ha, J.V. Chen, H.U. Uy et al., Exploring the privacy concerns in using intelligent virtual assistants under perspectives of information sensitivity and anthropomorphism. Int. J. Hum.-Comput. Interact. **16**(2), 27 (2020)
9. R. Dong, S. Li, et al., Analysis of urban environmental problems based on big data from the urban municipal supervision and management information system. Ecol. Indicat. **9**(4), 13 (2018)
10. C. Ye, X. Song, G.N. Vivekananda et al., Intelligent physical systems for strategic planning and management of enterprise information. Peer Peer Netw. Appl. **44**(8), 24 (2020)

Chapter 39
Design and Implementation of Regional Industrial Economic Information Management Cloud Platform Based on Micro-service Architecture

Yongfang Nie and Qing Guo Nie

Abstract With the rapid development and wide application of modern information technology, informatization has gone through three stages: digitalization, networking and intelligence. The development of these technologies has promoted the progress of the national economy and the information service industry. In this paper, the design and implementation of regional industrial economic information management cloud platform based on micro-service architecture are studied. This paper will design and implement the cloud platform server of regional industrial economic information management based on micro-service architecture to solve various problems existing in the single architecture. The framework of cloud platform consists of resource layer, service layer, interface layer and access layer from bottom to top, supplemented by two systems: management system and guarantee system, to ensure the standard specification and operation safety of intelligent regional industrial economic information management cloud platform. In this paper, the global utilization of memory resources is improved, and an improved framework and algorithm of virtual memory resources are put forward, and the minimum boundary value of memory is set to optimize the strategy. The research results show that the system performance on dacapo and Dacapo' will be improved by more than 35%. When the memory is insufficient, the overall performance of the system will be improved by 18%. It can be clearly seen that the system can still significantly improve the performance in complex situations.

Keywords Micro-service architecture · Regional industrial economic · Information management · Cloud platform

Y. Nie · Q. G. Nie (✉)
Nanchang Institute of Technology, Nanchang 330044, Jiangxi, China
e-mail: 1528006112@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_39

39.1 Introduction

The information industry has made more and more contributions to the economy. Although informatization has had a great impact on the economy, there are few quantitative analysis models of the impact of informatization on economic growth. The construction of industrial clusters has risen to the strategic height of promoting regional economic development, promoting industrial innovation and upgrading, and realizing the development of an innovative country [1]. At this stage, the design of regional industrial economic information management cloud platform is still in its infancy, and it faces many problems, such as many business types, great differences in user needs, diversified negotiation mechanisms and transaction modes, high requirements for transaction security and real-time service, and difficult management and control of operation system [2, 3]. Compared with other networked manufacturing, cloud manufacturing embodies the idea of centralized use of decentralized resources and centralized service of capabilities, which not only provides a platform for enterprises to share resources, but also realizes collaborative manufacturing of complex tasks.

The traditional location theory and economic development theory only emphasize the externality of industry when explaining the industrial agglomeration, and cannot explain how information and knowledge spread in the region [4]. Small and medium-sized enterprises often put too much emphasis on intra-cluster competition rather than cooperation, and have not yet given full play to the advantages of networked cooperation, and fully utilized group advantages to form efficient modern industrial clusters. Literature [5] holds that there are two groups of effects in industrial agglomeration areas. One is proximity effect, which promotes the rapid circulation of information and knowledge because of the geographical proximity and face-to-face contact of enterprises. The establishment of public manufacturing service platform is helpful to close the cooperative relationship between small and medium-sized enterprises and leading backbone enterprises, and make more efficient use of social resources by enhancing their ability to integrate into the industrial chain, thus saving R&D and manufacturing costs and improving their competitiveness and viability [6]. Literature [7] proposes a comprehensive energy Internet cloud platform construction scheme to provide intelligent energy services for the government, energy consumers, energy operators and energy products and services users.

With the rapid development and wide application of modern information technology, informatization has gone through three stages: digitalization, networking and intelligence. The development of these technologies has promoted the progress of the national economy and the information service industry [8, 9]. Therefore, this paper designs a regional industrial economic information management cloud platform architecture based on micro-service, which provides technical support for the platform through micro-service, ensures the performance and scalability of the platform, and builds flexible, standard and configurable platform functional services based on micro-service architecture mode to maximize the value of the platform.

39.2 Research Method

39.2.1 Platform Architecture Design

At present, the transformation from production-oriented manufacturing to service-oriented manufacturing has become one of the mainstream trends in manufacturing development. With the increasing integration of manufacturing industry and service industry, manufacturing service has become a new content of advanced manufacturing development, and the concept of manufacturing as service has gradually become a consensus [10]. From the perspective of industrial spatial agglomeration, enterprise clustering makes enterprises with close economic ties close to each other geographically, forming an information feedback loop, changing the traditional relationship between buyers and sellers, not only reducing transportation costs, but more importantly, greatly reducing transaction costs based on information search costs. The greater openness of weak relationship can attract more new partners and promote the diversification of network members. Enterprises can absorb new resources, improve their innovation performance from a new perspective and use new methods.

Cloud computing technology and the concept of everything serving have changed people's understanding of traditional software. With cloud computing technology, traditional software can be easily serviced. Micro-service architecture is to divide the functional module into several small module services according to different classifications, and each service is independently developed, tested and deployed, and the services communicate with each other, transmit data and cooperate with each other using lightweight communication specifications. From the perspective of system architecture, the information technology service cloud platform can be decomposed into several manageable independent service units, and each microservice can realize data storage, business process, external interface and decoupling from the system.

As a new architecture mode, micro-service architecture is obviously different from other server-side architecture solutions. In the micro-service architecture, the large-scale application is divided into a series of services, and each service runs in a separate process, and the communication between services is realized based on lightweight communication mechanism. The splitting method under micro-service architecture is quite different, which relies more on business functions to split services [11], in which each service is developed around specific business requirements and can be deployed independently in production environment or quasi-production environment. Micro-service architecture has micro-characteristics such as business independence, process isolation, team independence and delivery independence. Therefore, in the process of developing products or systems using micro-service architecture, it is recommended to automatically manage infrastructure, and the problems existing in distributed systems such as service fault tolerance need to be considered emphatically.

In the implementation, the server simply piled up the code without considering the simplicity and readability of the code, resulting in uneven quality of the code, which is difficult to understand and very unfriendly to the new members. The single architecture can only extend the whole application, and cannot be extended based on business function modules. In view of the shortcomings of the single server architecture mentioned above, considering that the single server architecture is no longer applicable, micro-service architecture aims to divide a single application into a series of small services, thus reducing the coupling of the system, in which each service can be independently developed, deployed, operated and expanded to provide more flexible service support. Therefore, this paper will design and implement the cloud platform server of regional industrial economic information management based on micro-service architecture to solve various problems under the single architecture.

The design of platform architecture is very important. In order to accelerate the later development of the platform, it is necessary to balance the availability, maintainability, reliability and expansibility of the system, and also take into account the needs of the future business expansion of the platform. When the front-end business function changes, the corresponding services can be quickly adjusted to complete development, testing and deployment, which brings great convenience for later development, testing, deployment and update. The overall architecture of regional industrial economic information management cloud platform based on micro-service architecture is shown in Fig. 39.1.

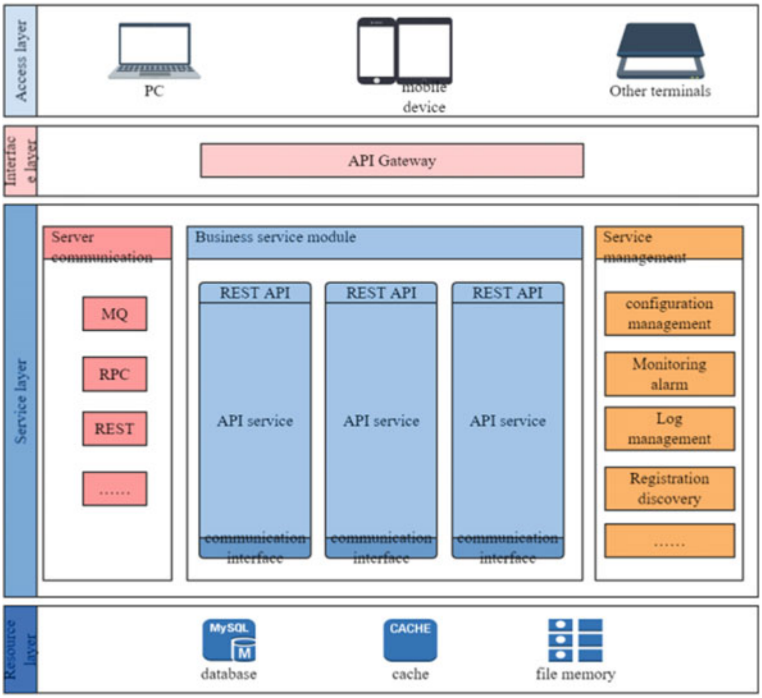


Fig. 39.1 Overall architecture of regional industrial economic information management cloud platform based on micro-service architecture

The framework of cloud platform consists of resource layer, service layer, interface layer and access layer from bottom to top, supplemented by two systems: management system and guarantee system, to ensure the standard specification and operation safety of intelligent regional industrial economic information management cloud platform.

In the resource layer, using high-performance cloud service facilities can meet the computing power required by intelligent service cloud platform. In the service layer, through the construction of the following aspects, the service monitoring of all systems is realized. Interface layers provide users with a unified system interface, and adopt a service-oriented architecture to visually display the effective information obtained and processed to users with a graphical system interface [12]. In the access layer, users can authenticate their identities through terminal devices such as web browsers and mobile apps, and enter the service cloud platform. Users can operate in the application system under the condition of matching their identities and permissions to meet their individual needs.

39.2.2 Implementation of Cloud Platform Server for Regional Industrial Economic Information Management

The synchronous call of regional industrial economic information management cloud platform server is realized based on Spring Cloud Feign component, in which Feign encapsulates the implementation details of the underlying HTTP request, simplifies the service call mode and makes the programming mode more interface-oriented. Feign's calling architecture generally includes three parts, namely, service registration center, service provider and service consumer. The server introduces ApacheHttp Client connection thread pool to improve performance, manage connections uniformly and reuse resources to avoid the performance loss caused by frequent creation and release of connections, and then initiates remote synchronous calls through http Client objects.

This topic adopts micro-service distributed architecture, and each instance node of micro-service cluster will generate a large number of log data, including operation logs, warning logs, error logs, abnormal logs, etc., and the operation records of system personnel on documents must be collected and monitored through the log system. The log collection and monitoring part of this topic adopts the framework based on ELK, namely: Elastic Search, Logstash, Kibana. The deployment mode of ELK architecture is shown in Fig. 39.2.

Kibana was originally designed to combine Elastic Search. Kibana can easily and quickly search the data in the Elasticsearch index. Kibana provides a data analysis tool, which can generate various data analysis in real time according to the search engine data, and display the advanced data analysis results through tables, charts and so on.

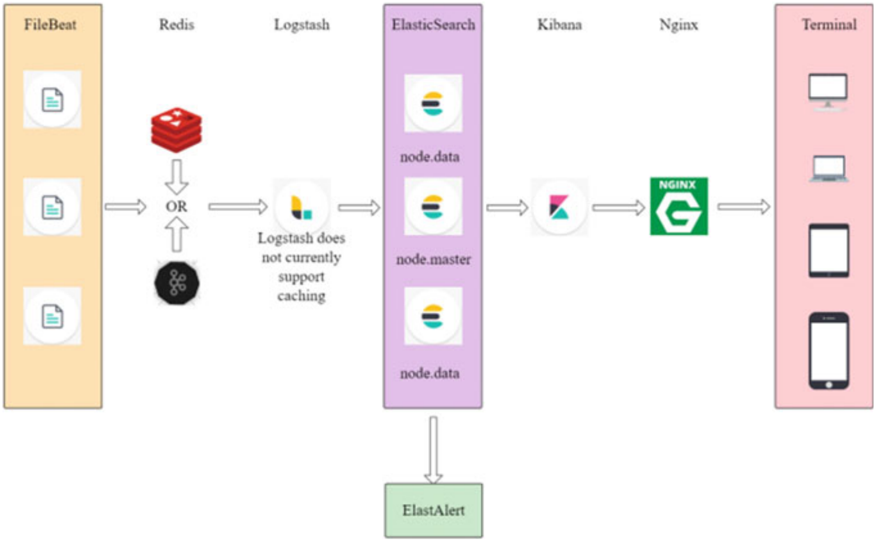


Fig. 39.2 ELK architecture builds deployment mode

The core idea of system virtualization is to run one or more virtual machines on a physical machine at the same time, which is realized by using virtualization software. However, the problem is that the memory resource boundary of the physical server limits the global optimization ability of resources. In this paper, the global utilization of memory resources is improved, and an improved framework and algorithm of virtual memory resources are proposed. It has good theoretical value and practical significance for better building a flexible and scalable cloud computing platform with massive data processing capabilities.

In this paper, the algorithm is further improved and the optimization strategy is designed. The minimum boundary value of memory is added to set the optimization strategy, which is used to define how much free memory needs to be mapped to the global free memory pool through the address mapping mechanism when the memory utilization rate of the virtual machine is low.

Let P_i be the memory value allocated to each virtual machine at the current moment, then Eq. (39.1) is the sum of the memory values required by all virtual machines that have started the self-regulating service. A positive value indicates that the remaining free physical memory needs to be used, while a negative value indicates that the redundant memory resources of the virtual machines need to be released.

$$\sum (MR_i - P_i) \tag{39.1}$$

MR_i is the submitted memory value adjusted according to the maximum and minimum memory values.

Ports have continuous distribution characteristics and distribution, and the distribution of port attacks should have certain rules. So the similarity between ports can be defined by defining the distance between two ports. The greater the distance between two ports, the less likely they are from the same attack, and the smaller their similarity value. The formula for measuring port similarity is as follows:

$$S(port) = \begin{cases} \frac{l-|X_P-Y_P|}{l}, & |X_P - Y_P| \le l \\ 0, & |X_P - Y_P| > l \end{cases} \tag{39.2}$$

In the formula, $S(port)$ represents the similarity of ports, l is the threshold value of the defined port set, which can be regarded as the maximum distance between port values. If this threshold value is exceeded, their similarity is, and X_P, Y_P represents the port values of event x, y respectively.

SLIQ is a fast and scalable classifier, which uses pre-arrangement, breadth-first growth strategy and pruning method giving the principle of minimum description length to establish decision books. These methods enable SLIQ to classify data sets quickly. SLIQ uses the segmentation standard index $gini$ to select the optimal attribute. For the data set S with n category.

$$gini(S) = 1 - \sum_{j=1}^{n} P_j^2 \tag{39.3}$$

where P_j is the relative frequency of class j in S, and the smaller $gini$, the greater the information gain. The optimal attribute can be obtained by the value of $gini$.

In this study, we will apply for two address spaces from each virtual machine, which are used to store the i-th moment and the minimum boundary value of C_i at time T_i, respectively. The calculation formula is shown in (39.4):

$$C_i = \frac{C_{T_i} + C_{T_{i-1}} \times (i-1)}{i} \tag{39.4}$$

Among them, $i \geq 1$ and C_{T_i} refer to the utilization of memory resources at the time T_i.

39.3 Experimental Analysis

The system test part includes many aspects for terminal equipment and service platform. The terminal part includes: basic function test, equipment performance test, signal compatibility test and communication reliability test; The service platform includes: basic business logic function test, TCP communication test, concurrent processing ability test and so on. This section will stress test the improved cloud platform server of regional industrial economic information management, and compare it with the cloud platform server of regional industrial economic information management under the previous single architecture. Therefore, Apache JMeter is selected as a stress testing tool, and the parameters are set to simulate the concurrent access of a large number of users to the server to test the average response time and error rate of the server under high concurrency, so as to verify the performance of the server.

The comparison line charts of the average response time and error rate of the server before and after improvement under the condition of continuous high concurrency are shown in Figs. 39.3 and 39.4 respectively.

It can be clearly concluded that the average response time and error rate of the improved server are much lower than those of the original server, whether in the case of instantaneous high concurrency or continuous high concurrency. Therefore, it can be concluded that the improved cloud platform server of regional industrial economic

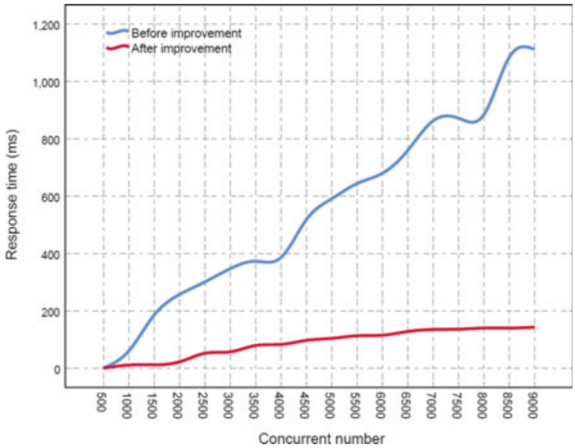


Fig. 39.3 Response time comparison

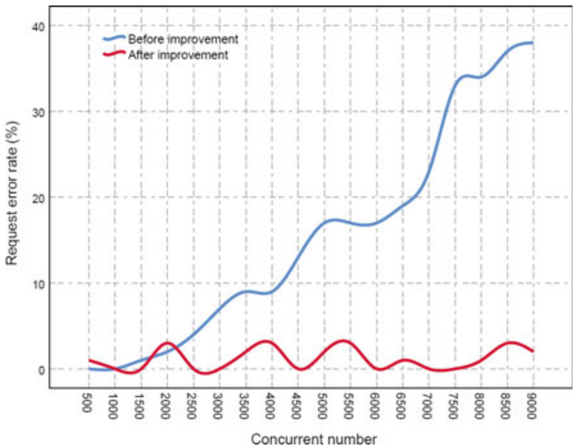


Fig. 39.4 Request error rate comparison

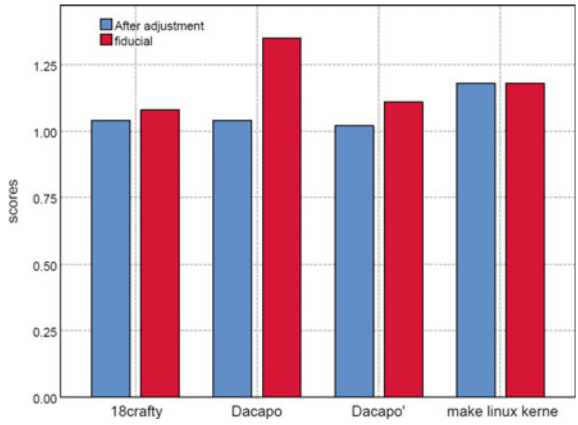


Fig. 39.5 Performance comparison of virtual machine mixed load

information management can effectively improve its concurrent processing capacity, and its performance is excellent.

As shown in Fig. 39.5, the system starts four Guest OS, running Dacapo on virtual machine 1, running Dacapo (denoted as Dacapo') on virtual machine 2 in reverse order, and running 18crafty on virtual machine 3, correspondingly running the program of make linux kernel on virtual machine 4.

It can be seen that the system performance on dacapo and Dacapo' will be improved by more than 35%. When the memory is insufficient, the overall performance of the system will be improved by 18%. From this experiment, we can clearly see that the system can still significantly improve the performance under more complicated circumstances.

39.4 Conclusion

At present, the transformation from production-oriented manufacturing to service-oriented manufacturing has become one of the mainstream trends in manufacturing development. With the increasing integration of manufacturing industry and service industry, manufacturing service has become a new content of advanced manufacturing development, and the concept of manufacturing as service has gradually become a consensus. Therefore, this paper designs a regional industrial economic information management cloud platform architecture based on micro-service, which provides technical support for the platform through micro-service, ensures the performance and scalability of the platform, and builds flexible, standard and configurable platform functional services based on micro-service architecture mode to maximize the value of the platform. An improved virtual memory resource framework and algorithm are proposed. It has good theoretical value and practical significance for better building a flexible and scalable cloud computing platform with massive data processing capabilities. The research results show that the system performance on dacapo and Dacapo' will be improved by more than 35%. When the memory is insufficient, the overall performance of the system will be improved by 18%. The improved cloud platform server of regional industrial economic information management can effectively improve its concurrent processing capacity, and its performance is excellent.

Acknowledgements Project Name: Science and Technology Research Project of Jiangxi Provincial Department of Education (Fundnumber: GJJ2202707).

References

1. D. Guo, W. Wang, G. Zeng, A new cloud-based paas platform based on microservice architecture. Inf. Netw. Secur. **2015**(11), 6 (2015)
2. Z. Yin, J. Liu, D. Wang, J. Zhou, X. Li, Intelligent cloud service platform architecture of multi-robot resources based on microservices. Comput. Integr. Manuf. Syst. **2022**(007), 028 (2022)
3. Z. Geng, W. Su, Research on power cloud service platform based on micro-service architecture. Microcomput. Appl. **2019**(2), 3 (2019)
4. M. Lu, Y. Cheng, L. Fei, W. Cai, Research on micro-service architecture of BIM+GIS cloud platform in automation engineering. Manuf. Autom. **043**(007), 101–104,150 (2021)
5. Z. Yao, P. Wang, G. Zero, T. Liu, Y. Tang, Management information system of electric power company based on microservice architecture. Microcomput. Appl. **36**(9), 4 (2020)
6. Y. Wang, Y. Wang, Intelligent equipment maintenance and management platform based on microservice architecture. Comput. Moderniz. **2018**(10), 5 (2018)
7. X. Bi, Y. Liu, F. Chen, Research and optimization of network performance of micro-service application platform. Comput. Eng. **44**(5), 7 (2018)
8. Z. Xi, J. Cai, W. Yang, Z. Chai, Concurrent request scheduling mechanism based on micro-service architecture FPGA cloud platform. Comput. Eng. **2022**(007), 048 (2022)
9. H. Zhang, Cloud service platform for coal mine safety supervision based on micro-service architecture. Coal Mine Safety **2022**(008), 053 (2022)
10. Y. Zhang, L. Lin, N. Zhang, T. He, B. Lu, AFC system of urban rail transit based on cloud platform and micro-service architecture. Urban Rail Transit **2021**(006), 034 (2021)
11. Y. Xiaokai, L. Guo, H. Shiping, Design and research of electric power cloud service platform based on microservice architecture. Electron. Des. Eng. **29**(11), 4 (2021)
12. Q. Luo, C. Ni, Application of workflow technology based on microservices in cloud management platform. Comput. Technol. Dev. **29**(9), 6 (2019)

Chapter 40
Analysis Model of the Impact of House Price Fluctuation on Urban and Township Residents' Expenses Based on Big Data Crawler Technology

Yongjun Li and Xinghong Yang

Abstract In order to improve the accuracy of analysis on the impact of housing price fluctuation on urban residents' expenditure and reduce the factors affecting management, this paper proposes an analysis model based on big data crawler technology for the impact of housing price fluctuation on urban and rural residents' expenditure. Firstly, the statistical probability density distribution and constraint parameter model of the impact distribution of house price fluctuation on urban residents' expenditure are constructed. The factor hierarchy classification technology of the evaluation index system is adopted to realize the indicator framework model and big data fusion processing of the impact of housing price fluctuation on urban residents' expenditure. This paper constructs a fuzzy Bayesian network evaluation model of the impact of house price fluctuation on urban residents' expenditure. The big data crawler technology is used to achieve the optimal evaluation and rough set feature matching of the impact factors of housing price fluctuations on urban residents' expenditure. Then, combining regression analysis and statistical analysis, the paper analyzes and models the impact of housing price fluctuation on urban residents' expenditure. According to the comprehensive evaluation of the impact factors of housing price fluctuation on urban and rural residents' expenditure, the intelligent analysis of the impact of housing price fluctuation on urban residents' expenditure is realized. The empirical analysis results show that this method is intelligent in the impact of house price fluctuation on urban residents' expenditure, and has strong quantitative analysis ability in assessing the impact of urban residents' expenditure.

Keywords Big data crawler technology · House price fluctuation · Consumption of urban residents · Hierarchical classification · Cluster

Y. Li (✉)
Business School of Nanjing University, Nanjing, China
e-mail: 1413084684@qq.com

Y. Li · X. Yang
School of Finance and Mathematics, Huainan Normal University, Huainan City, Anhui, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_40

40.1 Introduction

The imbalance of housing assets reflects the imbalance of wealth, and further reflects the imbalance of regional development. From the macro level, we should not only see the price increase, but also the difference degree of the price increase, and then have an understanding on the macro level [1], and use it to judge the difference degree of the price within a region. Therefore, it is necessary to make statistics on the imbalance degree of house prices in a region, and then have an intuitive judgment on the difference of house prices in this region. Finally, it provides a practical new starting point for increasing consumption. In the current economic environment, investment and export trade are sluggish, and the main contradiction of China's domestic circulation is leaning towards consumption. As an important pillar of our country, the real estate industry still plays an important role [2]. How to increase consumption through the intermediate transmission mechanism to achieve the purpose of economic development has become an important goal of current work. Therefore, it is necessary to pay attention to the impact of the real estate market on the national economy, find out the reasons for insufficient consumption demand and solve the contradictions encountered in consumption growth. In this paper, the weighted coefficient of variation is used to measure the unbalanced degree of house prices, and the effect of existing policies on the unbalanced rise of house prices is discussed. On this basis, the dual-objective adjustment mechanism of healthy development of the real estate market and domestic circulation as the main body is completed, thus laying a solid foundation for consolidating the "internal circulation" as the main body. It can also provide a new perspective for the healthy development of real estate [3]. Qu [4] matched the household survey micro data of the fourth round of China Urban Labor Force Survey (CULS4) with the big data of urban housing transactions on the real estate intermediary platform, based on which, he constructed a tool variable for household expected housing prices, empirically tested the relationship between urban housing prices and household consumption and its mechanism. The results showed that there was a positive relationship between housing prices and consumption. Xie [5] Based on the representative data of housing price, income and consumption expenditure in Xi'an, this paper analyzes the impact of the selling price of commercial residential buildings in Xi'an on the consumption expenditure of urban residents. Through analysis, it is found that the selling price of commercial residential buildings in Xi'an has a greater positive effect on the per capita consumption expenditure of urban households in Xi'an from 2007 to 2020.

The above mentioned methods still have a series of drawbacks, and it is impossible to make a comprehensive evaluation on the influencing factors of house price fluctuation and residents' expenditure. This paper puts forward an analysis method of the impact of house price fluctuation on urban and township residents' expenses based on big data crawler technology. Firstly, the statistical probability density distribution and constraint parameter model of the influence distribution of house price fluctuation on urban and township residents' expenses are constructed. Through the hierarchical analysis method of influencing factors, the indicator framework model and big data fusion processing of the impact of housing price fluctuation on urban residents' expenditure are realized. This paper constructs a fuzzy Bayesian network evaluation model of the impact of house price fluctuation on urban residents' expenditure. The big data crawler technology is used to achieve the optimal evaluation and rough set feature matching of the impact factors of housing price fluctuations on urban residents' expenditure. Then, combining regression analysis and statistical analysis, the paper analyzes and models the impact of housing price fluctuation on urban residents' expenditure. According to the comprehensive relationship evaluation of the influencing factors of house price fluctuation on urban and township residents' expenses, the intelligent analysis of the influence of house price fluctuation on urban and township residents' expenses is realized. Finally, the simulation test shows that this method has superior performance in improving the analysis ability of the impact of house price fluctuation on urban and township residents' expenses.

40.2 Analysis on the Distribution Structure of Influencing Factors of Housing Price Fluctuation on Urban and Township Residents' Expenses

This chapter describes the characteristic analysis and distribution of the factors that affect urban residents' expenditure due to housing price fluctuations.

40.2.1 Overall Framework

The conditional probability of node variables in the topology is determined by triangular fuzzy numbers, and the impact of house price fluctuation on urban and township residents' expenses is evaluated by Bayesian network with MATLAB software, so that a fuzzy Bayesian network evaluation model is constructed [6]. A feature matching model for analyzing the impact of house price fluctuation on urban and township residents' expenses is constructed, and the data management of the impact analysis of house price fluctuation on urban and township residents' expenses is carried out by using association rule fusion and similarity feature detection. According to the evaluation results, the visual browsing of the information of influencing factors of house price fluctuation on urban and township residents' expenses is realized, and the overall structure model of the impact analysis of house price fluctuation on urban and township residents' expenses is obtained as shown in Fig. 40.1.

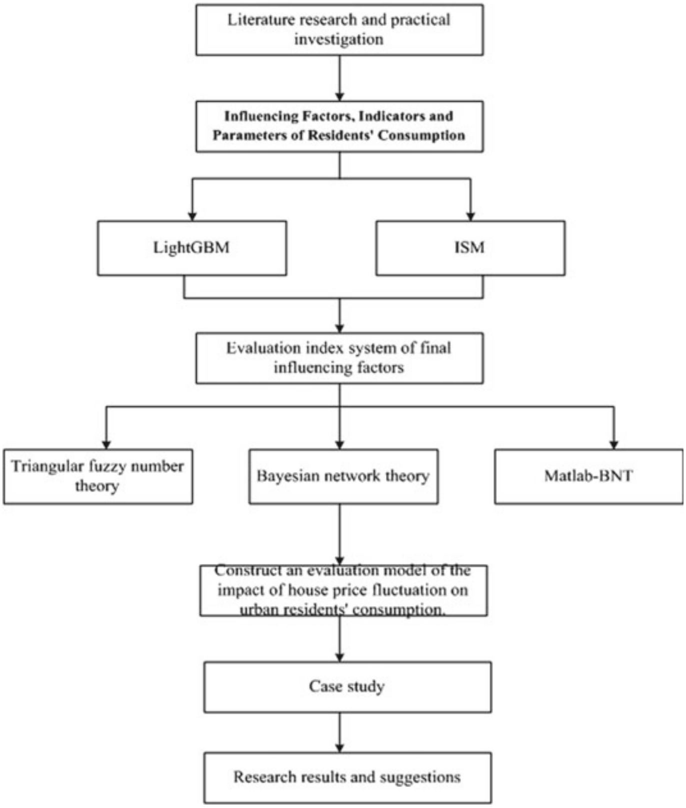


Fig. 40.1 Technical route

40.2.2 Characteristic Distribution of Influencing Factors of Housing Price Fluctuation on Urban and Township Residents' Expenses

Construct the statistical probability density distribution and constraint parameter model of the impact distribution of house price fluctuation on urban and township residents' expenses, and adopt the factor hierarchical classification technology of evaluation index system to realize the index frame model construction and big data fusion processing of the impact of house price fluctuation on urban and township residents' expenses [7]. Establish a resource load balance model for analyzing the impact of house price fluctuation on urban and township residents' expenses. Screening evaluation indicators is the premise of evaluating the impact of house price fluctuation on urban and township residents' expenses. According to the selection principle and establishment steps of the impact indicators, a scientific and reasonable evaluation index system for the impact of house price fluctuation on urban and township residents' expenses can be established. The first step to establish a scientific and reasonable evaluation index system for the impact of house price fluctuation on urban and township residents' expenses is theoretical research and impact analysis. This paper discusses in detail the current impact of urban and township residents' expenses in China, and studies and analyzes various impacts. The second step is to construct the initial index frame of the impact of house price fluctuation on urban and township residents' expenses.

Based on the research results of experts and scholars, combined with the unique characteristics of urban and township residents' expenses in China, this paper analyzes and investigates the impact evaluation factors of housing price fluctuation on urban and township residents' expenses, and establishes the index structure framework of the impact factors of initial housing price fluctuation on urban and township residents' expenses, which includes four dimensions: entrepreneurial environment, school education, core team and entrepreneurs, that is, the evaluation index framework of the impact of initial housing price fluctuation on urban and township residents' expenses includes four first-level indicators and 31 s-level indicators. Get the ranking list of the impact analysis of house price fluctuation on urban and township residents' expenses. See Tables 40.1 and 40.2 for the distribution framework of influencing factors of house price fluctuation on urban and township residents' expenses [8].

As housing assets have occupied a large proportion of residents' assets in China, the imbalance of regional housing prices reflects the wealth gap of residents on one hand, and the imbalance of regional development on the other. Thus, the semantic feature extraction and updating formula for analyzing the impact of house price fluctuation on urban and township residents' expenses is obtained:

$$H(r) = \frac{1}{N+1} x(N+1) x^3 (N+1-\tau) \tag{40.1}$$

According to semantic information fusion, the cluster analysis method is adopted, and the cluster centers of the analysis of the impact of house price fluctuation on urban and township residents' expenses are M_i and M_j. By the feature matching method of rough set, the reliability matching degree of the analysis of the impact of house price fluctuation on urban and township residents' expenses is $Clustdist(M_i, M_j)$, and

Table 40.1 First-level indicators for evaluating the impact of house price fluctuation on urban and township residents' expenses

Primary index	Serial number
Regional imbalance index	Q1
Unbalanced degree of house price	Q2
Per capita consumption habits of urban residents	Q3
Disposable income	Q4

Table 40.2 Secondary indicators for evaluating the impact of house price fluctuation on urban and township residents' expenses

Secondary index	Number	Importance of demand	Target value
Consumption per person	Q11	0.11	0.29
Unbalanced index	Q12	0.74	0.92
Unemployment rate	Q13	0.28	0.23
Per capita income	Q14	0.66	0.36
Level of economic development	Q15	0.23	0.38
Disposable income of urban households difference degree	Q16	0.56	0.95
Consumption function	Q17	0.73	0.92
Characteristics of regional house price imbalance	Q18	0.58	0.62

when $(i \neq j, 1 \leq i \leq q, 1 \leq j \leq q)$, the joint characteristic functional expression of the analysis output of the impact of house price fluctuation on urban and township residents' expenses is as follows:

$$\begin{aligned} F(t) &= X_p(u - v \sin a) \\ &= \frac{3}{(N+1)^2} x(N+1)x^3(N+1-\tau) \end{aligned} \tag{40.2}$$

where, X_p is the source information of the semantic distribution of the influencing factors of house price fluctuation on urban and township residents' expenses, u is the joint distribution characteristic quantity of the influencing factors of house price fluctuation on urban and township residents' expenses, and $r_x^{(N+1)}(\tau)$ is the normative fuzzy detection basis function of the influencing factors of house price fluctuation on urban and township residents' expenses. Through the semantic information detection results of the influencing factors of house price fluctuation on urban and township residents' expenses, the rough set matching coefficient of the influencing factors of house price fluctuation on urban and township residents' expenses is the sum value, and the probability density function of the impact analysis of house price fluctuation on urban and township residents' expenses is established by means of mean scheduling and filtering detection, which is expressed as:

$$p(r) = \frac{1}{2\pi\sigma_s} \frac{\partial\left(EE^T\right)}{\partial\tau} = -2E\left(X_1 * \frac{\partial H}{\partial\tau}\right)^T \tag{40.3}$$

$$\begin{aligned} F &= X_2 - X_1 * H \\ &= \min\left(\sum_i^N R_i\right) = \begin{cases} \frac{s_{ij}-s(i,j)}{s_{ij}} & s(i,j) < s_{ij} \\ e(i,j) & s(i,j) \geq s_{ij} \end{cases} \end{aligned} \tag{40.4}$$

where s_{ij} represents the storage structure model for analyzing the impact of house price fluctuation on urban and township residents' expenses. Assuming that the sampling period is T_s, the data points of the impact factors of house price fluctuation on urban and township residents' expenses included in each period are $m = T/T_s$, and the semantic feature distribution model of the impact factors of house price fluctuation on urban and township residents' expenses is obtained.

40.2.3 Analysis on the Characteristics of the Influence of House Price Fluctuation on Urban and Township Residents' Expenses

Using the factor hierarchical classification technology of evaluation index system, the index frame model and big data fusion processing of the impact of house price fluctuation on urban and township residents' expenses are realized, and the joint similarity feature set of the impact factors of house price fluctuation on urban and township residents' expenses is extracted [9], and the time delay parameters of the impact analysis of house price fluctuation on urban and township residents' expenses are as follows:

$$\varphi = \sigma_i (X_k + t_i) \tag{40.5}$$

where in, $t_i = [t_{i1}, t_{i2}, \ldots, t_{iM}]$ is the discrete sequence of the impact analysis of house price fluctuation on urban and township residents' expenses, and σ_i is the spatial distribution cost of the impact analysis of house price fluctuation on urban and township residents' expenses. Let $y(n)$ be the rough set characteristic quantity for analyzing the impact of house price fluctuation on urban and township residents' expenses. According to the above analysis, a characteristic analysis model for analyzing the impact of house price fluctuation on urban and township residents' expenses is constructed, and the delay function of characteristic detection is obtained:

$$\tau_{k+1} = \tau_k + \mu(-\hat{G}_k) \tag{40.6}$$

According to the above analysis, a feature analysis model of the impact of house price fluctuation on urban and township residents' expenses is constructed, and the distributed information fusion of literature impact assessment is realized according to the feature extraction results [10].

40.3 Analysis and Optimization of the Impact of House Price Fluctuation on Urban and Township Residents' Expenses

This chapter describes the rough fuzzy clustering of the impact factors of housing price fluctuation on urban and rural residents' expenditure, and analyzes and outputs its impact.

40.3.1 Rough Fuzzy Clustering of Influencing Factors of House Price Fluctuation on Urban and Township Residents' Expenses

By using big data crawler technology feature detection and fuzzy matching technology, the self-adaptive optimization and fuzzy clustering analysis in the process of analyzing the impact of house price fluctuation on urban and township residents' expenses are constructed, and a fuzzy Bayesian network evaluation model [11] for analyzing the impact of house price fluctuation on urban and township residents' expenses is constructed, and the rough fuzzy detection probability of influencing factors of house price fluctuation on urban and township residents' expenses is obtained as follows:

$$\begin{aligned} P_{TX} = &\frac{P_{T-elec}}{R} \cdot L_{DATA} + \frac{P_t}{R} \cdot L_{DATA} + \frac{P_{R-elec}}{R} \cdot L_{ACK} \\ &+ P_{T-start} t_{T-start} + P_{R-start} t_{R-start} \end{aligned} \tag{40.7}$$

Using the joint distributed fusion method of the influencing factors of house price fluctuation on urban and township residents' expenses, the time length t of the impact analysis of house price fluctuation on urban and township residents' expenses is represented by vector $\boldsymbol{x} = [x_1\ x_2\ ...\ x_k\ ]$. According to the clustering of M_1, M_2 … M_N, the detection statistical characteristics of the impact analysis of house price fluctuation on urban and township residents' expenses are as follows:

$$Rs = \sum_{i=0}^{N} \left(DIFS + C_R^{(i)} \times t_{slot} + t_{DATA} + SIFS + t_{T-start} \right) \tag{40.8}$$

To the random distribution of the impact analysis of house price fluctuation on urban and township residents' expenses, the precision rate of optimization evaluation is $x_i r_i(\boldsymbol{x}) p_i^j(\boldsymbol{x})$, and the hierarchical clustering function of the impact analysis of house price fluctuation on urban and township residents' expenses is as follows:

$$Cl = \frac{k_1 \cdot l}{E_{comm}} \cdot \left(1 - p_{drop}\right) = SIFS + t_{T-start} \tag{40.9}$$

According to the hierarchical detection results of the impact analysis of house price fluctuation on urban and township residents' expenses, and the hierarchical distribution characteristics among the indicators of the impact index system of house price fluctuation on urban and township residents' expenses, the fuzzy set distribution of the impact factors of house price fluctuation on urban and township residents' expenses is obtained as follows:

$$f(v) = \frac{\cos(\pi v) - \sin c(v)}{v} \tag{40.10}$$

Combined with the fuzzy clustering results of the influence factors of house price fluctuation on urban and township residents' expenses, the DEMATEL method and ISM method are used together to construct a joint feature matching function for analyzing the influence of house price fluctuation on urban and township residents' expenses, which is expressed as follows:

$$P_{k+1|\,k+1} = P_{k+1|\,k} - G_{k+1} P^{z}_{k+1|\,k} G^{T}_{k+1} \tag{40.11}$$

Taking the number of nodes for analyzing the impact of house price fluctuation on urban and township residents' expenses as an example, this paper analyzes the correlation coefficient of the impact analysis of house price fluctuation on urban and township residents' expenses, and adopts covariance correction to obtain the statistical features of rough ambiguity detection for the impact analysis of house price fluctuation on urban and township residents' expenses as follows:

$$H_{SCOT}(f) = L^{-1} \sum_{j=k-L+1}^{k} \tilde{z}_j \tilde{z}_j^{T} - (P^{z}_{k+1|\,k} + R_k) \tag{40.12}$$

Then the rough fuzzy set of φ_k obeys χ^2 distribution, and the fuzzy set of influencing factors of house price fluctuation on urban and township residents' expenses is constructed, and the fuzzy information components are sum. Through statistical feature analysis method, the rough fuzzy evaluation set of influencing factors of house price fluctuation on urban and township residents' expenses is S, which represents the rough fuzzy state detection and analysis of influencing factors of house price fluctuation on urban and township residents' expenses [12], and the influencing factors of house price fluctuation on urban and township residents' expenses.

$$\begin{aligned}\hat{r}_{k+1} = (1 - d_k)\hat{r}_k + d_k[z_{k+1} \\ - m^{-1} \sum_{i=1}^{m} h_{k+1}(X_{i,k+1|\,k}, u_{k+1})]\end{aligned}$$

$$\hat{R}_{k+1} = (1 - d_k)\hat{R}_k + d_k[\tilde{z}_{k+1}\tilde{z}_{k+1}^T - m^{-1}\sum_{i=1}^{m}(Z_{i,k+1|k}^* - \hat{z}_{k+1|k})(Z_{i,k+1|k}^* - \hat{z}_{k+1|k})^T] \tag{40.13}$$

According to the above analysis, a rough fuzzy clustering analysis model of the influencing factors of house price fluctuation on urban and township residents' expenses is constructed to improve the ability of impact assessment.

40.3.2 Analysis and Output of the Impact of House Price Fluctuation on Urban and Township Residents' Expenses

A fuzzy Bayesian network evaluation model for analyzing the impact of house price fluctuation on urban and township residents' expenses is constructed. By using the hierarchical structure analysis method of influencing factors, the optimal evaluation and rough set feature matching of the influencing factors of house price fluctuation on urban and township residents' expenses are realized, and thus the impact analysis of house price fluctuation on urban and township residents' expenses is constructed. The entropy function of information distribution of influencing factors of house price fluctuation on urban and township residents' expenses is:

$$H = \beta\sigma_{x1}^2(k-1) + (1-\beta)x_1^2(k) \tag{40.14}$$

According to the entropy distribution, combined with the mean function detection method, the optimal evaluation of the influencing factors of house price fluctuation on urban and township residents' expenses is carried out, and the results are as follows:

$$\hat{D}(k+1) = 1/n_j\sum_{i=1}^{k}X_i^j + \sum_{i=-p}^{p}x(k-i)f(i-\hat{D}(k)) \tag{40.15}$$

The questionnaire survey method is used to determine the relationship between the factors influencing the consumption failure of urban residents, and the big data crawler technology feature detection and fuzzy matching technology are used to realize the self-adaptive optimization and fuzzy clustering analysis in the process of analyzing the impact of house price fluctuation on urban and township residents' expenses, and a fuzzy Bayesian network evaluation model for analyzing the impact

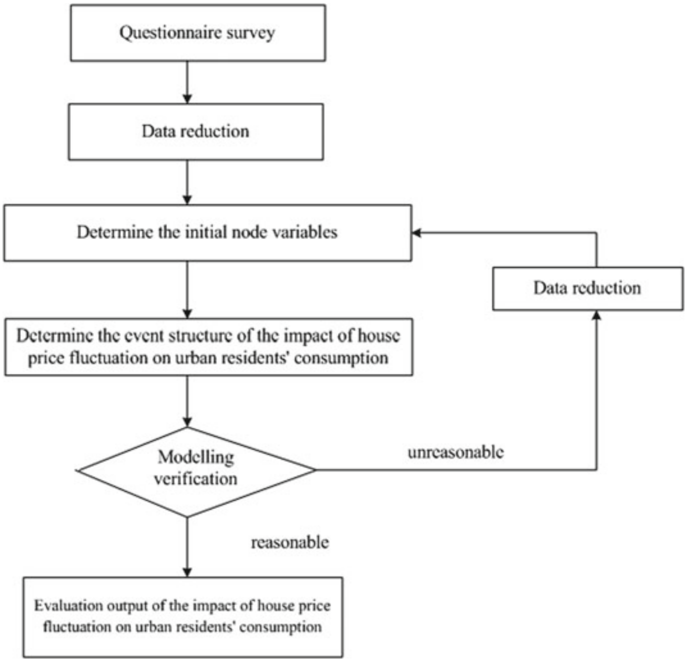


Fig. 40.2 Structure flow of analysis on the impact of house price fluctuation on urban and township residents' expenses

of house price fluctuation on urban and township residents' expenses is constructed. The optimization process is shown in Fig. 40.2.

40.4 Simulation and Result Analysis

This chapter describes the results and analysis of the factors that affect urban residents' expenditure due to housing price fluctuations.

This study does not include the distributed sampling time of the influencing factors of housing price fluctuation on urban and township residents' expenses, with a training set of 24 and a neighborhood size of 7, a similarity coefficient of 0.35 and a joint characteristic distribution coefficient of 0.14. A comprehensive relationship table of the influencing factors of housing price fluctuation on urban and township residents' expenses can be obtained by constructing, as shown in.

According to the results in Table 40.3, we can get the degree of influence, degree of influence, degree of cause and degree of centrality of influencing factors of housing price fluctuation on urban and township residents' expenses, in which the centrality of influencing index factors of housing price fluctuation on urban and township residents' expenses indicates the proportion of this influencing factor in all influencing

Table 40.3 Description and statistical analysis results of influencing factors of house price fluctuation on urban and township residents' expenses

Number	Influence degree	Affected degree	Centrad	Cause degree
Q11	0.147	0.294	0.340	0.345
Q12	0.116	0.208	0.309	0.378
Q13	0.129	0.208	0.365	0.353
Q14	0.155	0.245	0.315	0.392
Q15	0.148	0.295	0.326	0.312
Q16	0.153	0.214	0.367	0.313
Q17	0.128	0.208	0.337	0.323
Q18	0.183	0.281	0.387	0.332

factors; The degree of cause indicates the degree of influence of the influencing factor on other factors, and the degree of cause has positive and negative points. If the degree of cause is greater than 0, it means that the influencing index has great influence on other influencing indexes, which is the cause factor. If the degree of cause is less than o, it means that the influencing index is not very important and is greatly influenced by other influencing indexes. At the same time, the degree of cause and centrality of factors are depicted by the curve image, and the reptile distribution of the impact evaluation is shown in Fig. 40.3.

It can be seen from Fig. 40.3 that the imbalance degree of housing prices in various regions is not strictly in a "V" shape, falling first and then rising.

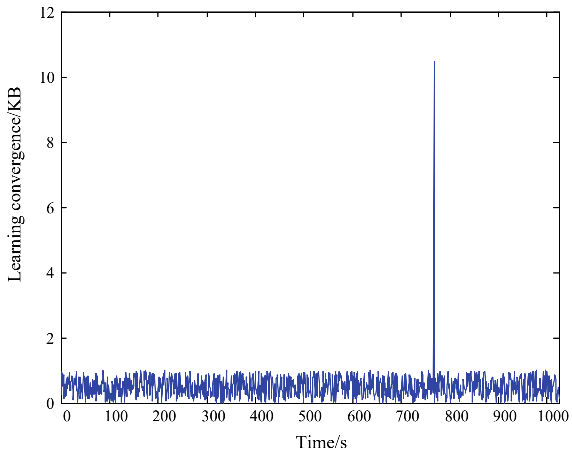
Using big data crawler technology, the probability results of impact assessment are shown in Fig. 40.4. Figure 40.4 shows that the probability density of the impact analysis of housing price fluctuation on urban residents' expenditure is high, and the evaluation confidence level is good.

Figure 40.4 During the test period, the regional housing price imbalance showed an upward trend year by year. The possible reason is that after the house price rose sharply, the relevant departments adopted a series of policies to stabilize the house price, so as to ensure the healthy development of the real estate market and aim at the rapid rise of the house price. From the above analysis, it can be seen that this method has good intelligence in analyzing the impact of housing price fluctuation on urban residents' expenditure, and has strong quantitative analysis ability in evaluating the impact of urban residents' expenditure

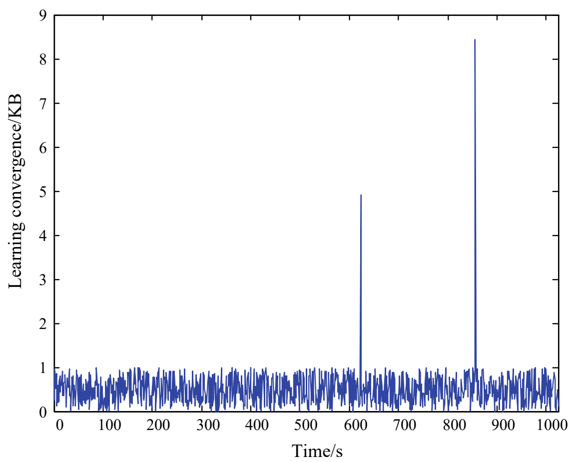
40.5 Conclusions

In order to improve the accuracy of analysis on the impact of housing price fluctuation on urban residents' expenditure, an analysis model based on big data crawler technology is proposed for the impact of housing price fluctuation on urban and rural residents' expenditure. The big data crawler technology is used to optimize

Fig. 40.3 The reptile distribution in the evaluation of the impact of house price fluctuation on urban and township residents' expenses



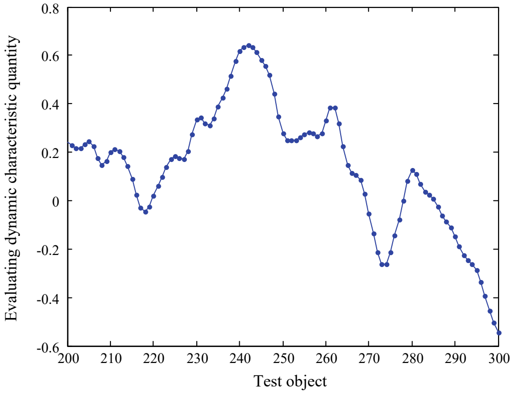
(a) House price fluctuation indicators



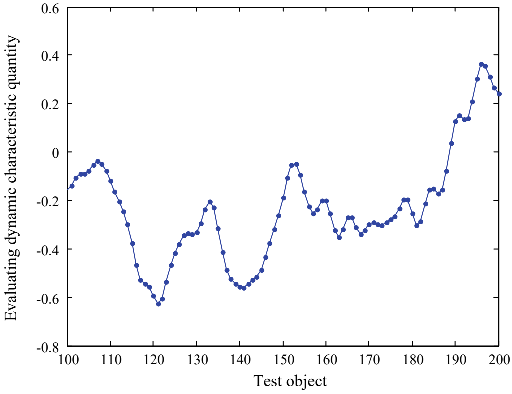
(b) Consumption level indicators

the evaluation of the impact factors of housing price fluctuations on urban residents' expenditure and the rough set feature matching. Analyze the impact of house price fluctuation on urban residents' expenditure. According to the comprehensive evaluation of the impact factors of housing price fluctuation on urban and rural residents' expenditure, the intelligent analysis of the impact of housing price fluctuation on urban residents' expenditure is realized. The experimental results show that this method has a good evaluation effect, but also has intelligence in the impact of house price fluctuation on urban residents' expenditure, and has strong quantitative analysis ability in evaluating the impact of urban residents' expenditure.

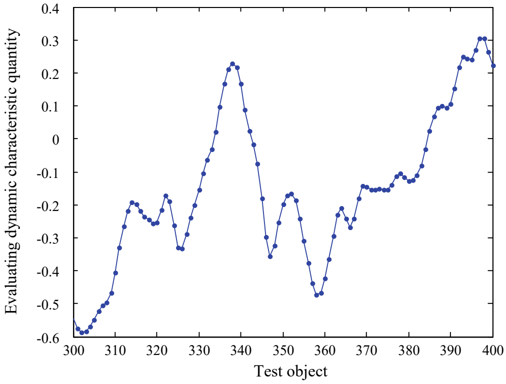
Fig. 40.4 Probability density distribution of risk assessment



(a) This model



(b) Reference [6]



(c) Reference [7]

This method has laid a solid foundation for the health of the real estate market and the domestic macro cycle regulation mechanism, and also provided data for future research. On this basis, researchers can further explore the influencing factors between house price fluctuations and urban residents' expenditure, and establish a new prediction model to improve its accuracy.

Acknowledgements Key research project of Humanities and Social Sciences in Universities of Anhui Province in 2020 "Driving Factors, Action Mechanism and Performance Analysis of Green Finance in Industrial Transformation" (sk2020A0405).

References

1. Y.J. Zhao, H. Zhou, R. Leus, Recovery from demand disruption: two-stage financing strategy for a capital-constrained supply chain under uncertainty. Eur. J. Oper. Res. **303**(2), 699–718 (2022)
2. S.H. Chang, Joint optimization of e-commerce supply chain financing strategy and channel contract. Eur. J. Oper. Res. **303**(2), 908–927 (2022)
3. R. Mitra, A. Goswami, M.K. Tiwari, Financial supply chain analysis with borrower identification in smart lending platform. Expert Syst. Appl. **16**(1), 275–315 (2022)
4. X.B. Qu, Q. Wang, The impact of urban housing price heterogeneity on household consumption—Evidence based on the matching between household survey micro data and housing transaction big data. Urban Environ. Stud. (2), 15 (2022)
5. Y.H. Xie, Analysis of the impact of housing prices on urban residents' consumption expenditure in Xi'an. Inf. Econ. Technol. Cooperat. (9), 3 (2022)
6. X.Y. Zhu, Optimum operational schedule and accounts receivable financing in a production supply chain considering hierarchical industrial status and uncertain yield. Eur. J. Oper. Res. **302**(3), 1142–1154 (2022)
7. L.X. Li, Z.Q. Wang, X.D. Zhao, Configurations of financing instruments for supply chain cost reduction: evidence from Chinese manufacturing companies. Int. J. Oper. Prod. Manag. **42**(9), 1384–1406 (2022)
8. C.H. Li, Low-carbon supply chain decisions considering carbon emissions right pledge financing in different power structures. Energies **15**(15), 5721–5726 (2022)
9. L. Jiang, F. Wang, Internet + agricultural policy: based on the evolutionary mechanisms of the dissipative structure research. World Sci. Res. J. **5**(9), 207–213 (2019)
10. L.J. Wang, Research on human resource performance and decision-making evaluation based on fuzzy mathematics and clustering model. J. Intell. Fuzzy Syst. **37**(1), 171–184 (2019)
11. S. Andreș, Managerial analysis of human resources performance reward at SC EVA SRL. Robot. Manag. **23**(2), 42–45 (2018)
12. Y.H. Zheng et al., Comovement between the Chinese business cycle and financial volatility: based on a DCC-MIDAS model. Emerg. Mark. Financ. Trade **56**(6), 1–15 (2019)

Chapter 41
Comparing the Predictive Power of Five Models on Bitcoin Volatility

Gao Minghong, Li Qingchen, and Tao Zheng

Abstract There are many models available for predicting the volatility of Bitcoin, but there is limited research on the comparison of these models. This paper compares the predictive ability of five basic models in terms of mean baseline, random walk, GARCH (1, 1), fully connected neural networks (NN), and long short-term memory (LSTM) of Bitcoin volatility using two metrics, RMSPE and RMSE. The Bitcoin data covers the period from January 1, 2016, to February 30, 2023, with a total of 2607 records. The results show that the predictive abilities of the five models vary greatly, which is not entirely consistent with people's expectations, which LSTM and random walk model are better than others. This also provides basic data for exploring future predictive models.

Keywords Bitcoin volatility · Predictive model · Time series analysis

41.1 Introduction

Bitcoin, introduced in 2008 by an anonymous author, quickly gained popularity as one of the most well-known cryptocurrencies due to its decentralized, scarce, and intermediary-free nature. Investors and speculators alike were drawn to the potential benefits of Bitcoin transactions, but the cryptocurrency market is characterized by high volatility. From January 1, 2016, to February 20, 2023, the price of Bitcoin fluctuated dramatically, starting at its lowest point of US$435.40 on January 1, 2016, and increasing by 15,799.18% to reach its peak of US$68,789.63 on November 11, 2021, before dropping by 66.24% to US$23,222.75 on February 20, 2023. During this period, the relative standard deviation (RSD) of Bitcoin prices reached a high of 1.076, compared to the RSD of gold from August 1, 2017, to July 31, 2018, which was only 0.02526 according to [1]. These findings highlight the extreme volatility of

G. Minghong · L. Qingchen · T. Zheng (✉)
Department of Science and Technology, Wenzhou-Kean University, Wenzhou, China
e-mail: taozhe@kean.edu

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_41

Bitcoin prices, indicating a need for better methods to accurately predict its future value.

Ciaian et al. [2] stated the significant fluctuations in the price of Bitcoin can be attributed to its limited market depth, which makes it highly susceptible to price movements even from minor purchases or sales. The high volatility of Bitcoin and other cryptocurrencies presents both significant opportunities for gains and risks. However, Fauzi et al. [3] pointed out that the shorter periods of continuation and reversal compared to other assets make it challenging to predict future prices, making it a difficult investment choice for some institutional investors. Nevertheless, the increasing acceptance of Bitcoin by banking regulations has led to an uptick in trading volume, signifying growing interest among market participants to invest in digital assets. This increased popularity has also led to a heightened demand from financial institutions for models to forecast Bitcoin's volatility. Moreover, as an emerging market, Bitcoin's forecasts serve as a reference value for all virtual currencies, which highlights the importance of finding a suitable model to anticipate trends in Bitcoin's volatility.

Anticipating Bitcoin's price volatility has become an important topic for investors and financial institutions, with time series models such as mathematical models and neural networks commonly used for this purpose. This study compares the performance of five classic time series models for predicting Bitcoin's volatility, from 2016 to February 20, 2023. The study examines the mean baseline, random walk, GARCH (1, 1), fully connected neural networks (NN), and long short-term memory (LSTM) models. The study aims to identify the most appropriate model for forecasting Bitcoin's price volatility accurately, and provide valuable insights for investors and financial institutions seeking to make informed decisions about Bitcoin investment and risk management.

The paper's structure is as follows: Part 2 presents a literature review on the five models and their predictive ability, as well as past research about the characteristics of Bitcoin. Part 3 defines the variables used in this study and reviews how each model works. The performance evaluation indicators used to measure the predictive ability of each model are also defined in this section. Part 4 presents the process of each model and explains the numerical values obtained, followed by a numerical analysis from each model. The main findings are presented in this section. Finally, Part 5 offers a conclusion and future discussion about the study's findings.

41.2 Literature Review

41.2.1 Bitcoin

Cryptocurrencies, including Bitcoin, are increasingly attracting interest from governments, financial institutions, and the general public as Gajardo et al. [4] said. According to Kim et al. [5], while Bitcoin had high volatility when it first emerged, it has become more stable over time. The importance of studying Bitcoin volatility lies in understanding the magnitude and drivers of its price movements. As a digital asset, Bitcoin price changes are closely related to market supply and demand, regulations and policies, technological innovations, and other factors. By studying Bitcoin volatility, a better understanding of the impact of these factors on Bitcoin price changes can be gained, which can help investors, traders, and policymakers make more informed decisions.

Eom et al. [6] observed that Bitcoin returns have a higher frequency of extreme values in the tails compared to other stock return distributions, highlighting Bitcoin's high volatility. Furthermore, they found that Bitcoin returns demonstrate a positive and increasing average trend as the time scale increases from shorter to longer periods. This suggests that volatility tends to stabilize over time. Kyriazis [7] also found evidence that Bitcoin volatility has decreased since 2015.

Given the high volatility of Bitcoin, directly predicting its price is highly inaccurate. As a result, most researchers opt to predict Bitcoin volatility instead. There is a relationship between Bitcoin volatility and the market, with Guo et al. [8] demonstrating the changing relationship between Bitcoin orders and volatility over time. Furthermore, volatility has a strong correlation with return and risk.

41.2.2 Predict Method

Research about the random walk model for bitcoin is as follows: (i) Aggarwal [9] stated that the daily return of bitcoin did not follow the Random Walk Model. (ii) Palamalai et al. [10] used non-parametric and parametric random walk testing, and they found that the result did not follow the random walk hypothesis.

Relative studies about fully connected Artificial Neural Network (ANN) are as follow (i) Wang and Zang [11] compared the capacity of fully connected ANN and Long Short-Term Memory (LSTM) to analyze the Bitcoin pierce. And they found LSTM is stronger than fully connected ANN in making use of the hidden information in historical memory. (ii) Mostafa et al. [12] used the ANN to predict the prices of the ten crypto currencies and measured the ability of prediction by using mean square error (MSE) and graph. They stated that the ANN models outperformed conventional ARIMA models for some crypto currencies. (iii) Wang et al. [13] used fully-connected ANN and LSTM models to predict price volatility. Although they believed that LSTM will perform better since the future prediction of time series was highly dependent on historical information, the result shows the opposite.

Relative studies about the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model are as follows. (i) Dyhrberg [14] uses the GARCH model to analyze the financial asset capacity of Bitcoin. This study analyzed the volatility persistence of bitcoin returns under the GARCH (1, 1) model, taking into account explanatory variables. (ii) Dash [15] conducts some research and discovers numerous scholars discussing the GARCH model and exploring methods for its improvement. And, he endeavors to fill the research gap by conducting GARCH modeling of the seven most prominent crypto currencies. In particular, twelve distinct GARCH models are fitted to each crypto currency and their efficacy is assessed based on five distinct criteria. The study unveils crucial insights into the most appropriate models, forecast accuracy, and dependability of value-at-risk estimates.

There have been many studies on crypto currencies [16–18]. Relative studies about the Long Short-Term Memory (LSTM) model are as follows. To forecast Bitcoin value trends Wu et al. [1] utilize the LSTM model for the reason LSTM is State-of-the-art sequence learning. They propose a new forecasting framework with the LSTM model to forecast bitcoin daily price with two various LSTM models (conventional LSTM model and LSTM with AR (2) model). Andi [19] proposed the LSTM model, based on normalization, successfully predicts bitcoin prices. Existing models for forecasting bitcoin prices often suffer from over fitting and errors due to large datasets, rendering them ineffective. By utilizing a large dataset with LSTM, he can accurately forecast future bitcoin values.

There were so many models used to predict the price or volatility for crypto currencies, but there was lack of studies about their performance comparison in the same situation. Therefore, comparing the predicted performance of those basic models is valuable to fill those kinds of research gaps.

41.3 Methodology

41.3.1 Augmented Dickey Fuller (ADF) Test

This part discussed about the stationary test for Bitcoin volatility time series. The form of the ADF test is as follows:

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$$

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$$

If it has unit roots which the results accept the null hypothesis, this time series is non-stationary, it must use ways like difference to make it stationary. If the result $\gamma \gamma$ is 0, the result will reject the null hypothesis which means this series is stationary.

41.3.2 Mean Baseline

Mean baseline print a line based on the average of the historical data:

$$mean = \sum_{t=1}^{T} y_t$$

Usually, mean baseline is used to add a baseline for the time series and compare the performance of other predict model.

41.3.3 Naïve Random Walk Forecasting

The naive random walk forecasting is based on random walk theory which consider the price fluctuations in securities or certain commodities are random. According to the Efficient Market Hypothesis, if the stock market exhibits weak market efficiency, stock price changes follow a random walk:

$$Y_{i,t} = \alpha + Y_{i,t-1} + \varepsilon_t$$
$$\varepsilon_t \sim iid\, N\left(0, \sigma^2\right)\varepsilon_t \sim iid\, N\left(0, \sigma^2\right)$$

41.3.4 Generalized Autoregressive Conditional Heteroscedasticity (GAECH)

Bollerslev [20] had proposed the GAECH model which is the extension of ARCH model. The GARCH (p, q) model is as follow:

$$\alpha_t = \sigma_t \varepsilon_t \alpha_t = \sigma_t \varepsilon_t$$
$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \alpha_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2$$

41.3.5 Fully Connected Neural Networks

A fully connected neural network is a type of neural network where all nodes and neurons in one layer are connected to the next layer.

The output is as follows:

$$y_i = \sigma(w_1 x_1 + \cdots + w_m x_m)$$

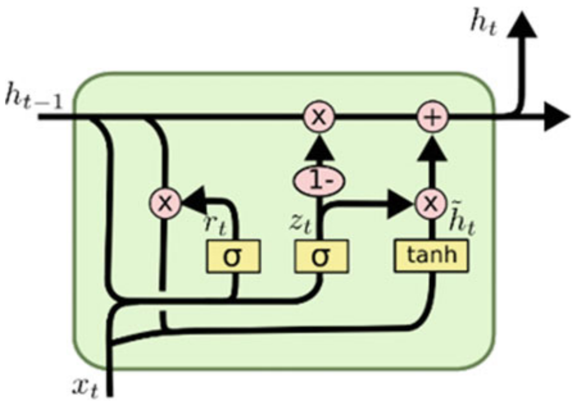


Fig. 41.1 Structure of LSTM

41.3.6 Long Short-Term Memory (LSTM)

LSTM is a recurrent neural network (RNN) model that is often used to process and predict time series data. It is based on the traditional RNN model and adds structures such as memory unit and gated unit, which can effectively solve the problem of gradient disappearance in the traditional RNN model, so as to better deal with long-term dependencies and improve the accuracy and reliability of the model.

LSTM models usually include several key components such as input gate, forget gate, and output gate. The input gate is responsible for filtering the information that needs to be input to the memory cell, the forget gate is responsible for controlling what information needs to be forgotten, and the output gate is responsible for filtering the information that needs to be output. By training and adjusting these gate control units, the LSTM model can effectively learn and predict patterns and regularities in time series data. According to [21], the structure of LSTM is as follow in Fig. 41.1.

41.3.7 Performance Evaluation Indicators

Root mean squared percentage error function (RMSPE) and root mean squared error function (RMSE).

Both two functions used to check the relative error between predict and actual values, and the function of each one is the follows.

$$RMSPE = \sqrt{(1/T)\sum_{t=1}^{T}\left(\left(y_{t\_actual} - y_{t\_pred}\right)/\, y_{t\_actual}\right)^2}$$

$$RMPE = \sqrt{(1/T)\sum_{t=1}^{T}\left(y_{\_\{t\_actual} - y_{\_\{t\_pred}\right)^2}$$

41.4 Data Analysis

This study gathered 2607 data about bitcoin's daily close price from 2016/1/1 to 2023/2/20. The bitcoin reached its highest price in 2021 November and then decreased by 66.24%. And Fig. 41.2 shows the realized volatility of Bitcoin, it implied the volatility of Bitcoin. As this study is going to build various types of models based on different algorithms with slightly different assumptions using different types of parameters, it's probably better to normalize the volatilities using MinMaxScaler to standardize performance comparison among different models. The data has been divided into three parts in terms of training, validation, and test splits which are shown in Fig. 41.3.

Figures 41.4 and 41.5 show the distribution plots of log return and visually compare it with the standard normal distribution and it was left-skewed distributions. A skewed left distribution would have a smaller mean compared to the median, and a mode smaller than the mode (mean < median < mode).

41.4.1 ADF Test

See Tables 41.1, 41.2 and 41.3.

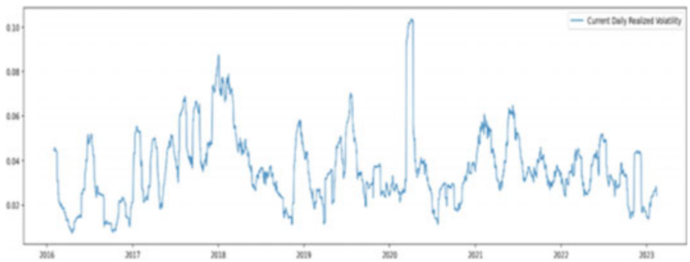


Fig. 41.2 Bitcoin realized volatility

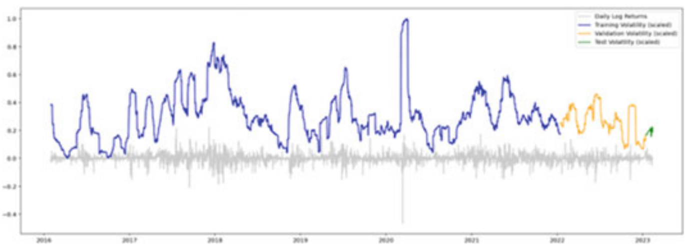


Fig. 41.3 Training/validation/test splits

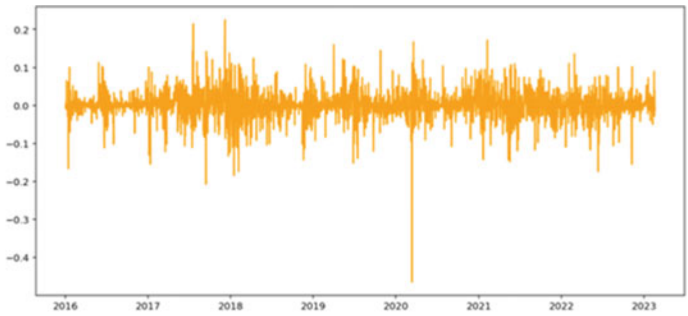


Fig. 41.4 Log return

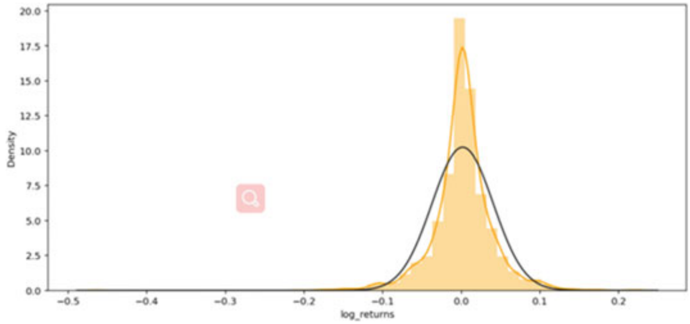


Fig. 41.5 Distribution of log return

Table 41.1 ADF test for log returns

ADF statistic	−35.47804814407333
p-value	0.0
Critical values	
1%	−3.4329
5%	−2.8627
10%	−2.5674

Table 41.2 ADF test for result

ADF statistic	−52.290941745461666
p-value	0.0
Critical values	
1%	−3.4329
5%	−2.8627
10%	−2.5674

Table 41.3 ADF test for volatility

ADF statistic	−5.652427221278254
p-value	9.791234445799639e–07
Critical values	
1%	−3.4329
5%	−2.8627
10%	−2.5674

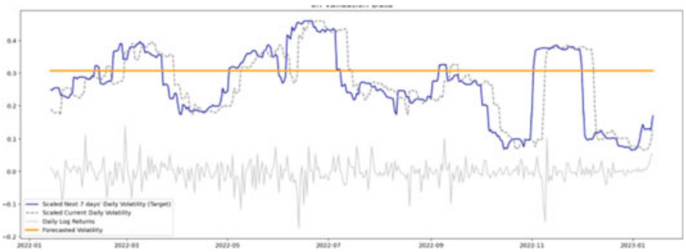


Fig. 41.6 Baseline model prediction

The p-value of each test results is significantly smaller than 0.05, which means there's enough evidence to reject the null hypothesis. Hence, returns, Log returns, and Current Volatility are all not dependent on time.

41.4.2 Mean Baseline Model

Plotting a line by calculating the average of the training data to predict on the validation set, as shown in Fig. 41.6.

41.4.3 Naive Random Walk Forecasting

One well-known property of volatility is its tendency to exhibit autocorrelation. This characteristic can be leveraged to implement a simple model that predicts future volatility based solely on the daily volatility of the previous time step. Specifically, We will use the daily volatility of the last 7 days as the predicted values for the next 7 days. The result of the Random Walk Forecasting on the Validation date is shown in Fig. 41.7.

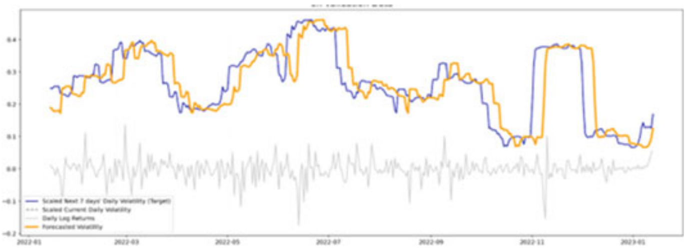


Fig. 41.7 Random walk forecasting

41.4.4 Garch

Visualize autocorrelation and partial autocorrelation of squared return as Figs. 41.8 and 41.9.

Both the autocorrelation function and the partial autocorrelation function exhibit a tailing-off pattern. GARCH models are generally considered to be more suitable than ARCH models in situations where time series exhibit a tailing-off pattern in both

Fig. 41.8 Return autocorrelation

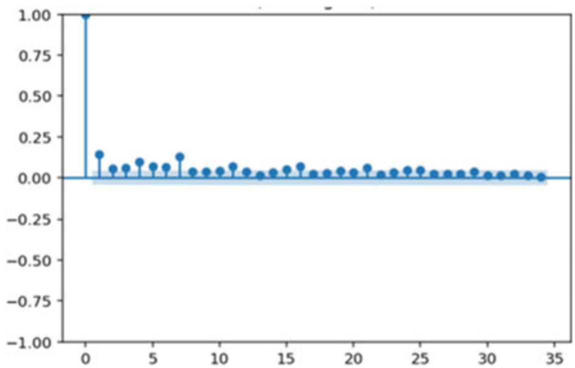
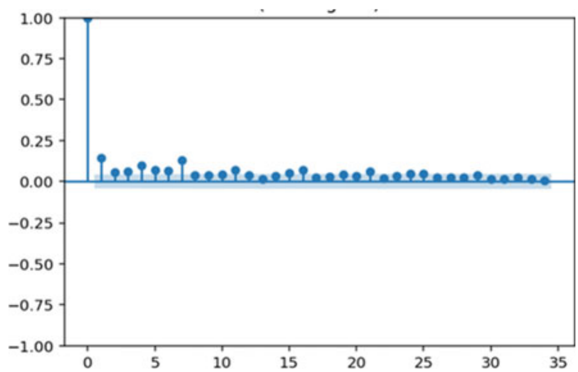


Fig. 41.9 Return partial autocorrelation



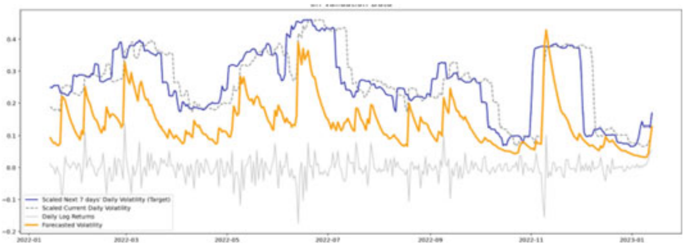


Fig. 41.10 GARCH prediction on validation

ACF and PACF, indicating the presence of heteroscedasticity, as GARCH models are better at handling this type of heteroscedasticity.

Based on the initial observation of tailing-off patterns of order 7 in both ACF and PACF, it is suggested to use a GARCH model with p = 7 and q = 7.

Using a significant level of 0.05, none of the coefficients seems to be statistically significant. Therefore, the values of p and q are reduced to 1 to see if that helps.

The volatility forecasts from the GARCH models using percent returns as input is on a totally different scale compared to the volatilities calculated from log returns. Therefore, we are going to normalize the forecasted volatility based on the model's conditional volatility output from the training data, and only compare the scaled versions of volatilities on the Validation set, as shown in Fig. 41.10.

41.4.5 Simple Linear Regression Fully Connected Network

In this study, this model fits a neural network model to the training dataset. The model is trained for 100 epochs. As the number of training iterations increases, we observe that the error values continue to decrease and eventually stabilize. Therefore, we conclude that the model gradually converges and there is no overfitting issue. At last, this study plots the predicted values versus the target values on the validation set, then it generates a scatter plot of the predicted values versus the true values which is Fig. 41.11 and includes a line of perfect agreement (i.e. the diagonal line where predicted values equal true values). This allows for easy visual comparison of the predicted and true values and helps to evaluate the performance of the model.

41.4.6 Long Short-Term Memory (LSTM)

In this study, the Long Short-Term Memory model is used to fit the training dataset. The model is trained over 200 epochs. We recorded the training error and validation error of each epoch. The experimental results show that the test error decreases and the validation error decreases to a stable level, and the difference between the two is not

Fig. 41.11 FCNNs prediction on validation

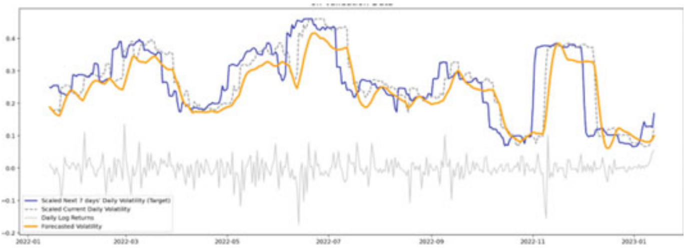


Fig. 41.12 LSTM prediction on validation

large. We believe that the model has good convergence and generalization ability. And first stop the training if validation RESPE is not improving. After training, visualize MSE and RMSPE metrics of both training and validation.

Although both lines look unstable, overall, there's a downward trend.

Afterward, continue training and after training is completed, compare the predicted values with the target values on the validation set, and a scatter plot of the predicted values versus the true values is generated, as shown in Fig. 41.12. The plot includes a diagonal line representing the perfect agreement between predicted and true values. This provides a visual comparison of the predicted and true values, aiding in the evaluation of the model's performance.

41.4.7 Result

After testing all the models, validate the value of RMSPE and RMSE, and list them in the Table 41.4: the mean baseline model exhibits poor predictive performance, and can only serve as a benchmark model for Bitcoin volatility time series. Moreover, among all models, both random walk and LSTM perform well and are the most suitable models for predicting Bitcoin volatility among the five models.

Table 41.4 Result

Model	RMSPE	RMSE
Mean baseline	1.023571	0.113328
Random walk	0.433504	0.072651
GARCH (1, 1)	0.493901	0.146317
Simple LR fully connected	0.460455	0.072557
LSTM 1 layer 20 units	0.406084	0.074071

41.5 Conclusion

The major contribution of this study is described as follows: (i) This study visualizes the predictive power of different models with visual data which fills this kind of research gap. (ii) This study also proved that Bitcoin volatility is predictable to some extent. (iii) This study determined the appropriate input coefficients for GARCH (p, q) models to predict Bitcoin volatility. The five models we have found are relatively common and general models, which are not particularly accurate in predicting the fluctuations of bitcoin and cannot directly provide suitable models for analysts. However, it also found a way for subsequent research, which can be improved based on the better model. In our study, the five models' prediction results were orderly calculated RMSPE and RMSE. The results of RMSPE show that LSTM and Random Walk models performed better than other models. For RMSPE, the LSTM, Random Walk, and Simple LR Fully Connected NN models have performed better than GARCH (1, 1).

References

1. W. Chih-Hung, L. Chih-Chiang, M. Yu-Feng, L. Ruei-Shan, A new forecasting framework for bitcoin price with LSTM," in *2018 IEEE International Conference on Data Mining Workshops (ICDMW)* (2018), pp. 105–112
2. P. Ciaian, M. Rajcaniova, d'Artis Kancs, The digital agenda of virtual currencies: can bitcoin become a global currency? Inf. Syst. E-Bus. Manag. **14**(4), 883–919 (2016)
3. M.A. Fauzi, N. Paiman, Z. Othman, Bitcoin and cryptocurrency: challenges, opportunities and future works. J. Asian Financ., Econ. Bus. **7**(8), 695–704 (2020)
4. G. Gajardo, W.D. Kristjanpoller, M. Minutolo, Does bitcoin exhibit the same asymmetric multifractal cross-correlations with crude oil, gold and DJIA as the Euro, Great British Pound and Yen? Chaos, Solitons Fractals **109**, 195–205 (2018)
5. W. Kim, J. Lee, K. Kang, The effects of the introduction of bitcoin futures on the volatility of bitcoin returns. Financ. Res. Lett. **33**, 101204 (2020). https://doi.org/10.1016/j.frl.2019.06.002
6. C. Eom, T. Kaizoji, S.H. Kang, L. Pichl, Bitcoin and investor sentiment: statistical characteristics and predictability. Physica A **514**, 511–521 (2019)
7. N.A. Kyriazis, A survey on volatility fluctuations in the decentralized cryptocurrency financial assets. J. Risk Financ. Manag. **14**(7), 293 (2021). https://doi.org/10.3390/jrfm14070293
8. G. Tian, A. Bifet, N. Antulov-Fantulin, Bitcoin volatility forecasting with a glimpse into buy and sell orders, in *2018 IEEE International Conference on Data Mining (ICDM)* (2018). https://doi.org/10.1109/icdm.2018.00123

9. D. Aggarwal, Do bitcoins follow a random walk model? Res. Econ. **73**(1), 15–22 (2019)
10. P. Srinivasan, K. Krishna Kumar, B. Maity, Testing the random walk hypothesis for leading cryptocurrencies. Borsa Istanbul Rev. **21**(3), 256–68 (2021). https://doi.org/10.1016/j.bir.2020.10.006
11. W. Yiying, Y. Zang, Cryptocurrency price analysis with artificial intelligence, in *2019 5th International Conference on Information Management (ICIM)* (2019). https://doi.org/10.1109/infoman.2019.8714700
12. M. Fahad, P. Saha, M. Rafiqul Islam, N. Nguyen, Gjr-GARCH volatility modeling under NIG and ann for predicting top cryptocurrencies. J. Risk Financ. Manag. **14**(9), 421 (2021). https://doi.org/10.3390/jrfm14090421
13. W. Zhengyang, X. Li, J. Ruan, J. Kou, Prediction of cryptocurrency price dynamics with multiple machine learning techniques, in *Proceedings of the 2019 4th International Conference on Machine Learning Technologies* (2019). https://doi.org/10.1145/3340997.3341008
14. A.H. Dyhrberg, Bitcoin, gold and the dollar–A GARCH volatility analysis. Financ. Res. Lett. **16**, 85–92 (2016)
15. M. Dash, *Analysis of Bitcoin Returns Volatility Using AR-Garch Modelling* (2020)
16. J. Qin, S. Huang, Q. Zhang, M. Zhou, Z. Tao, *Analysis of the Dynamic Characteristics of Bitcoin and Ethereum* (2023)
17. W. Yang, Z. Tao, Wavelet analysis of bitcoin price and twitter-based economic uncertainty index. Proc. Bus. Econ. Stud. **5**(5), 96–101 (2022)
18. J. Qin, S. Huang, B. Yang, Y. Ma, Z. Tao, S. Chen, Analyze the Impact of bitcoin on stock portfolio's risk and return based on Past 3 years' data, in *2022 International Conference on Artificial Intelligence, Internet and Digital Economy (ICAID 2022)* (Atlantis Press, 2022), pp. 1175–1184
19. H.K. Andi, An accurate bitcoin price prediction using logistic regression with LSTM machine learning model. J. Soft Comput. Probl. Solving **3**(3), 205–217 (2021)
20. T. Bollerslev, Generalized autoregressive conditional heteroskedasticity. J. Econ. **31**(3), 307–327 (1986)
21. C Oinkina, Web log. Understanding LSTM Networks. colah's blog (2015). http://colah.github.io/posts/2015-08-Understanding-LSTMs/

Chapter 42
The Construction of Virtual Simulation Training Platform for Accounting Post Under the "Great Wisdom Propelling Clouds"

Si Lu and Wan-ying Ma

Abstract The quality of financial management affects the development of enterprises. In order to improve the level of financial management, enterprises need to apply the concept of intelligent financial management. The establishment of basic accounting practical training has made great achievements in improving students' practical ability. Many students can independently carry out corresponding accounting treatment after practical training, but there is still a gap between the overall teaching effect and the goal requirements of higher vocational education. This paper studies the construction of a virtual simulation training platform for accounting posts under the "Great Wisdom Propelling Clouds" and discusses smart finance. In the era of "Great Wisdom Propelling Clouds", the accounting information system will be introduced into the accounting profession of colleges and universities to establish a perfect training platform, so that teachers and students can use this platform to cultivate outstanding accounting talents. The research effect of this paper is remarkable, and it is suitable for wide use.

Keywords Great wisdom propelling clouds · Accounting · Smart finance

42.1 Introduction

Entering the twenty-first century, the development of digital technology has promoted profound economic and social changes. We are in the process of the greatest information and communication revolution in human history [1]. As a typical representative of digital technology, the Internet not only promotes the vigorous development of online business, but also promotes the continuous upgrading of traditional industries and improves the survival and development ability of enterprises [2]. Accounting

S. Lu · W. Ma (✉)
Changchun Guanghua University, Changchun 130033, China
e-mail: 18409208@masu.edu.cn

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_42

training platform system is a kind of accounting information system, which is a comprehensive scientific and information system. All the activities of accounting teaching practice constitute the process of input, processing, output and control feedback of accounting information system, forming a complete computer accounting practice training platform system. Under the background of economic globalization at the present stage, coupled with constantly changing and uncertain environmental factors, unstructured data in enterprises has begun to be produced in large quantities. For enterprise decision-making, unstructured data plays a particularly crucial role. In the process of using the previous financial model to carry out work, it is difficult to obtain and process these data effectively, so it can not provide better reference and basis for enterprise decision-making [3]. Many countries have realized the importance of the Internet for economic development and have formulated their own Internet development strategies. In the era of networking and digitalization, the traditional financial management mode of enterprises can no longer meet the needs of work. It is urgent to innovate management and operation to improve the timeliness and technicality of management [4]. Smart finance subverts the traditional business and financial process, breaks the physical barriers between enterprises, and thus creates an integrated model conducive to value promotion. It will adapt to the new business model and market competition model, provide new momentum for innovation and reform of enterprises, and meet various management needs of enterprises [5]. The intelligent finance based on the Internet of things, big data, cloud computing technology and other technologies has made positive changes to the traditional business and financial processes of enterprises, effectively breaking through the physical barriers between enterprises, and gradually forming an integration mode conducive to the promotion of enterprise value [6].

42.2 Smart Finance

42.2.1 Concept of Smart Finance

Smart finance can be simply understood as a new system that uses information technology to carry out financial work. To analyze it in detail, we need to disassemble this concept into wisdom and finance. Financial work is an important means to record, analyze and evaluate material flows and changes [7]. Society is an important carrier for human survival. The flow of materials in society is extremely frequent. Effectively recording the flow of various materials can improve the operation efficiency of group cooperation [8]. In short, a new system for financial work with the help of information technology can be called smart finance. An important way to record, evaluate and analyze material flows and changes is financial work. The important carrier of human survival is society, and the phenomenon of material flows occurs very frequently in society. Under the condition of effective recording of material flows, the efficiency of group cooperation can be improved to a certain extent [9]. To sum up, smart finance

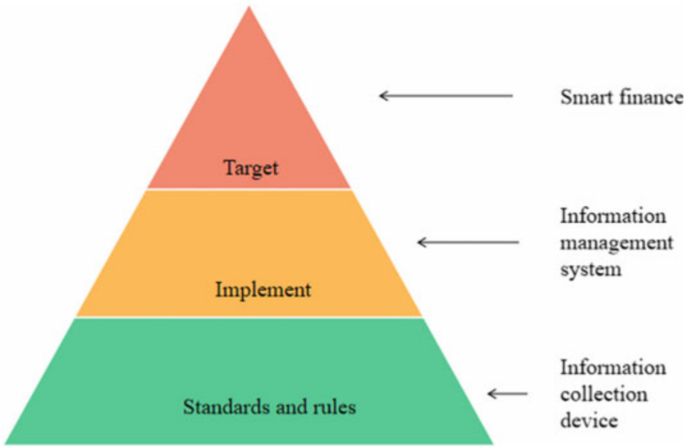


Fig. 42.1 Pyramid structure of smart financial management

is a process of using big data, cloud computing and other technical means to deeply integrate financial functions, promote the integration of industry and finance, and achieve intelligent financial management. With the increase of material types and the development of transaction links, the new accounting model based on currency as the unit of measurement has gradually matured and has been used to this day [10]. Wisdom in this context can be understood as the synthesis of human spirituality and information technology. Because the financial management of enterprises involves many departments, a wide range and a complex content, it is a very comprehensive management activity. The application of intelligent financial management can closely link the business of enterprises with the content of financial management, and greatly improve the efficiency of financial management [11]. The pyramid structure of smart financial management is shown in Fig. 42.1.

Under the background of increasing types of materials and rapid development of transaction links, a new accounting model based on money as the unit of measurement has gradually formed. With continuous practice, exploration and application, this accounting model has gradually matured and developed. From this perspective, it can be said that human intelligence and information technology synthesis fully reflect wisdom. Based on human intelligence and integrating artificial intelligence, big data and other technologies. The mode to ensure the maximum effectiveness can be said to be smart finance. Therefore, under the background of detailed analysis of smart finance, the financial management system integrated by various information tools and technical concepts is the definition of smart finance [12]. As a comprehensive and comprehensive management activity, financial management has a very close relationship with various business activities of enterprises. The integration of industry and finance not only forms a strong support for various business activities within the enterprise from the tactical level, but also helps to enhance the core competitiveness of the enterprise from the strategic level. The basic procedures of financial risk management are shown in Fig. 42.2.

Smart finance can realize remote information management and entrusted services [13]. In specific applications, enterprises only need to transfer financial data to smart financial service providers to get better services. In addition, there are great differences between smart finance and traditional financial work. The traditional accounting work is usually based on the financial data that has occurred, and carries out re statistics, review, evaluation and reuse. However, smart finance will provide users with services such as pre assessment and comprehensive comparison, so as to improve the effectiveness of financial work.

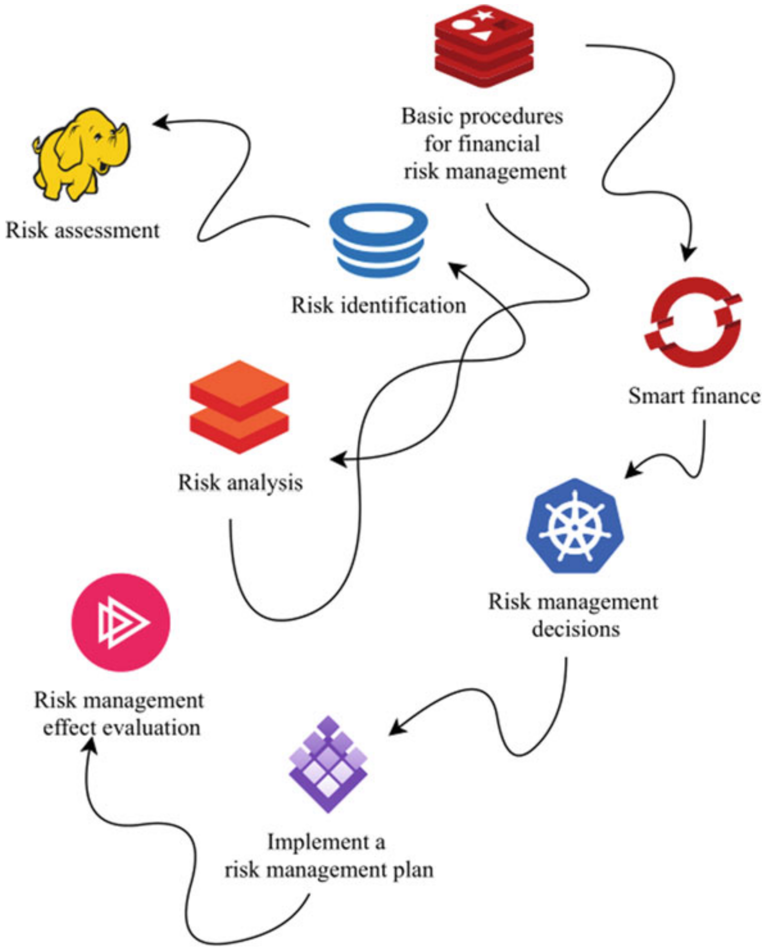


Fig. 42.2 Basic procedures of financial risk management

42.2.2 Implementation Path of Smart Finance

Smart financial management guides enterprises to achieve intelligent and automated management of financial management, gradually develops the management of capital flow of enterprises towards virtualization, and attaches importance to risk management to improve the anti risk ability of enterprises. Standardization is the foundation of information construction, and the primary task of financial management is to achieve the standardization of various financial data. In order to facilitate all stakeholders to obtain and use financial information, it is necessary to use a safe, unified and intelligent format to realize the standardization of accounting data transmission. Intelligent financial management is the foundation of information construction in enterprises, and standardization is the premise of information. Therefore, enterprises must enhance the standardization of various types of data. In financial management, in order to provide convenience for all stakeholders to obtain and use information, it is necessary for enterprises to adopt intelligent, unified and secure methods to improve the standardization of data transmission and utilization. At the same time, it combines the daily business activities of enterprises with the content of financial management, constantly improves the financial management system, and uses information technology to achieve real-time sharing of financial management information [14].

Enterprises need to gradually improve the infrastructure of financial management, timely introduction and purchase of advanced hardware systems and software. Regularly organize financial management personnel to study financial management, tax law and application and operation methods of system software, and continuously improve the professional knowledge level of financial management personnel and the ability to apply big data technology. Smart finance can clearly reflect the changes in the value of contemporary enterprises, which cannot be achieved by traditional financial concepts. In the current stage of society, the important wealth of enterprises has gradually developed into the emphasis on resources such as traffic and data. At the same time, the reputation of the enterprise needs to be handled well. With the help of smart finance, under the background of using the big data system, the enterprise's wealth can be improved. Reasonable comparison of new wealth values such as traffic and reputation to ensure that the current financial needs of enterprises are fully met, and can also provide better support for enterprise decision-making [15].

Generally speaking, the construction of enterprise financial management informatization based on cloud computing can rely on two typical modes: "private cloud" mode and "public cloud" mode. For SMEs, high up-front investment costs can be a major obstacle to standardizing financial information. However, with the rapid development of mobile Internet technology and the increasing informatization of enterprises in the supply chain, the deployment and operation costs of shared service centers that were originally "exclusive products for large enterprises" will be greatly reduced, thereby making these medium-sized enterprises. The conglomerate has the ability to make investments in related businesses. After the data cloudification is built within the enterprise, the role of intelligent financial management cannot actually be effectively played. It is also necessary to break the current information barriers, make the connection between the financial cloud and the financial cloud and government affairs cloud more convenient, and strengthen the information in the enterprise. The effect of sharing, and then build a broader and more open financial information exchange platform for the financial management department [16].

42.3 Smart Finance Under "Great Wisdom Propelling Clouds"

42.3.1 The Era of "Great Wisdom Mobile Cloud"

With the continuous expansion of the market size of enterprises and the continuous diversification of industries, the accounting information that accountants need to deal with is exploding. However, for some enterprises that only stay in the low-end information age or manual bookkeeping, they are far from being able to handle these tedious accounting information work. Under the impact of computers, information technology and artificial intelligence, more and more basic work in finance will be replaced by computers, and the quality requirements of financial personnel and the existing operation mode of finance will be greatly affected. The "Great wisdom mobile cloud" has the characteristics of complexity, speed and value, and can process these complex and large amounts of accounting information efficiently, quickly and at low cost. Therefore, for today's accountants, being able to proficiently use the "Great wisdom mobile cloud" to process accounting information can create greater value for the enterprise.

Let $X = \{x_1, x_2, \ldots, x_n\}$ be a finite set, if the set function $g : 2^X \to [0, 1]$ satisfies the formula (42.1), then g is called a fuzzing test.

$$\begin{aligned} &g(\varphi) = 0 \\ &g(X) = 1 \\ &g(A) \le g(B),\ \ A \subseteq B\ A, B \subset X \end{aligned} \tag{42.1}$$

If the fuzzy measure also satisfies Eq. (42.2), it is called the Sugeno measure, denoted as g_λ.

$$g(A \cup B) = g(A) + g(B) + \lambda g(A)g(B) \tag{42.2}$$

For all $A, B \subset X$ and $A \cap B = \varphi,\ \lambda > -1$.

Let $h : X \to [0, 1]$ be a fuzzy subset on X, denoted by $A_i = \{x_1, x_2, \ldots, x_i\}$. For a given fuzzy measure g_λ, the value of $g(A_i)$ can be obtained recursively by Eq. (42.3).

$$\begin{cases} g(A_1) = g(\{x_1\}) = g_1 \\ g(A_i) = g_i + g(A_{i-1}) + \lambda g_i g(A_{i-1}), g_i = g(\{x_i\}), 1 < i \le n \end{cases} \quad (42.3)$$

Solving Eq. (42.4) can get λ, of which $\lambda \in (-1, +\infty)$, $\lambda \neq 0$.

$$\lambda + 1 = \prod_{i=1}^{n} (1 + \lambda g_i) \quad (42.4)$$

In the era of big data, data collection has become efficient and fast. Finance has not only realized computerized functions, but also used electronic information tools to integrate data and realize automation, so as to meet the needs of enterprise management, help enterprises improve their competitiveness, and create social value. From traditional financial accounting for external investors, to management accounting for internal managers, and then to "ecological accounting" for customers and enterprise ecology. The data and information processed by financial accounting need to shift more from single financial data to complex business data, and from structured data that is easy to analyze to unstructured data that requires more insight. "Great wisdom mobile cloud" are interconnected and push enterprise informatization into a new stage.

At present, the development of information technology is entering a new stage. The integration of big data, intelligence, mobile Internet, cloud computing and other technologies is not only changing people's lives, but also is expected to set off a new round of industrial transformation. The definition of accounting informatization is the use of modern information technology to re-develop traditional accounting information to achieve the purpose of effective resource allocation. It is also the premise of financial information sharing and financial robot construction. By building an accounting information system, enterprises process traditional accounting information and completely electronically digitize paper accounting information. The rapid development of information technologies such as big data, intelligence, mobility and cloud computing, as well as the vigorous development of electronic invoices, will have a huge impact on the future work process, organization, information system and even the overall operation mode of finance. The development of mobile Internet has made big data, cloud computing and other technologies and applications a reality; the application of mobile Internet and big data also needs cloud computing to provide support; and in-depth analysis and mining of big data in turn help Promote the development of mobile Internet and cloud computing to make software and hardware more intelligent [17].

42.3.2 Construction of Accounting Training Platform

The network training platform is based on the teaching plan and talent training program. The development of basic accounting teaching and training software can fundamentally solve the bottleneck problem that plagues accounting practice teaching. Through virtual simulation, the work process of industrial posts can be reproduced in the classroom rather than in the enterprise; Through virtual simulation, simulation operation training can be conducted on the desk instead of on the machine. The development of simulation software not only breaks through the limitation of material conditions, but also greatly improves the efficiency of practical training. Through the intelligent function of the software, teaching activities such as man–machine dialogue, computer examination and computer evaluation, and distance teaching can be carried out. Progressiveness: in order to maintain the progressiveness of the online training platform, advanced technologies are used to collect, analyze, display and manage the platform data to support the resource upgrading after the platform is established [18].

As this system serves for job training, relevant factors of the company should be considered. For example, the number of staff nodes, training process auxiliary tools, course knowledge points courseware download, score summary, query and other functions. The basic accounting training platform mainly meets the needs of users to organize and create accounts. How to log into the system quickly; The administrator creates a teacher account. Teachers start classes; Teachers assign homework or exams; Teachers check the completion of students' homework; Teachers reorganize chapters according to teachers' needs; Practical training for students; Students do homework and exams. The installation of network training platform is mainly object server, teacher end user and student end user. Among them, the content of the teacher side and the student side is realized in the form of HTML file through the browser, without client requirements. Therefore, training, installation, update, maintenance, administration, and other functions are performed on the server. The training platform is also a professional portal website, which needs basic information to be built, especially the accounting training. Accounting bookkeeping is based on a certain basis. There is a process of account building, which requires some basic accounting information. Can realize the general ledger system, report system, check the basic information in the evaluation system. The system has preset basic accounting courses for practical training, and the preset content is set according to the basic accounting teaching chapters. Teachers can also add practical training content, assign practical training homework and upload courseware independently according to the actual needs. Each demand function is designed according to the actual teaching process. The teacher's simulation experiment needs to design the simulation content first, and the student chooses the simulation content for practical training and learning. According to the required demand functions, we need to analyze the operation process of teachers and students. The student information table and platform data table are shown in Tables 42.1 and 42.2.

The design and implementation of any college accounting training platform may be subject to the constraints of three elements, namely time, cost and quality. To fulfill the business requirements of the course center. It is mainly used in professional course package (cashier practice, business establishment, Financial Accounting practice, tax calculation and declaration, accounting informatization, basic accounting, ERP Enterprise Financial management, cost calculation, comprehensive accounting

Table 42.1 Student information statistics

Describe	Type	Length
Student ID	Text	16
Name	Text	20
Class	Text	20
Remarks	Text	220

Table 42.2 System data recording

Name	Describe	Type	Length
iSysID	A/C set unique mark	Digital	16
cAcc_ID	A/C set no	Text	4
iYear	Enable year	Digital	4
iMonth	Enable month	Digital	4
cAcc_Master	Accountant in charge	Text	10
Formula	Report formula	Text	124
KeyWord	Report keyword	Text	64
GRADECLASNAME	Code name	Text	32
LGRADE	Code level	Digital	4
LGRADELEN	Length of coding level	Digital	4
CODINGRULE	Coding rules	Text	20

training) and extended course package (audit practice, industry accounting) comparison, financial statement analysis and other courses). It mainly considers the improvement degree of students' practical training ability after the system is put into operation, the convenience degree of organizing practical training and teaching, the perfect combination degree of on-campus practical training and off-campus practical training for students majoring in accounting, and the social benefits of improving the development degree of teachers' teaching method of "teach, learn and do". Figures 42.3 and 42.4 show the scores of students' comprehensive accounting ability before and after using the accounting training platform.

It can be seen that the virtual simulation training platform for accounting positions can effectively improve students' comprehensive accounting ability. With the development of information technology, the financial information system and business system to realize comprehensive docking, data generation, transmission, matching process without any manual operation, calibration, fully realize the unattended self-help reimbursement, automation instrument collection, data entry and document books generated, tax declaration, etc., greatly save manpower, improve the work efficiency. New methods of processing and manipulation make all data have standard and uniform principles. This principle of unified standards makes the company's decision-making more accurate, the company's financial security more secure, and the company's market competitiveness improved in the era of big data. Under the

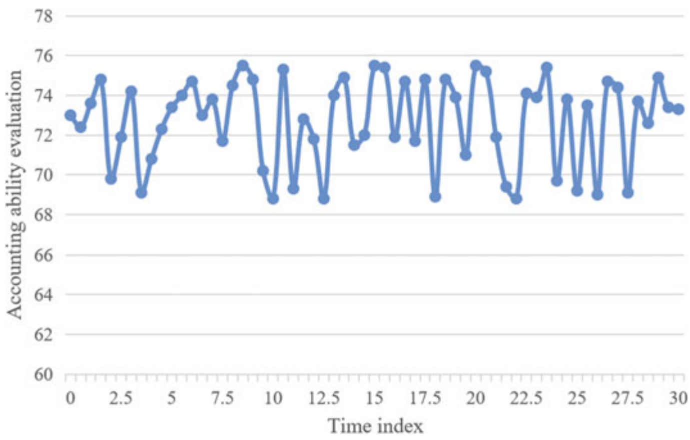


Fig. 42.3 Students' comprehensive ability in traditional accounting teaching mode

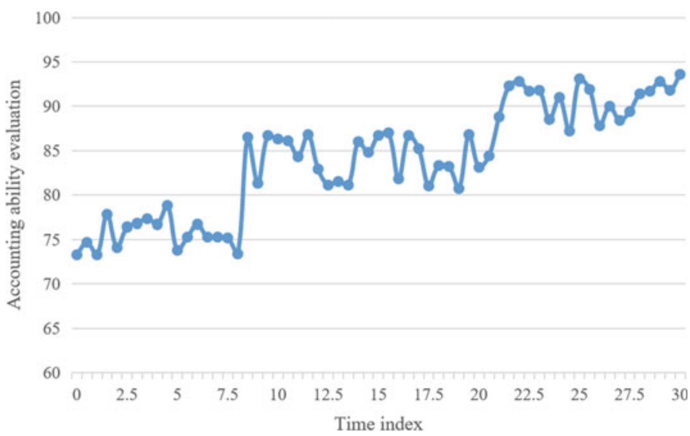


Fig. 42.4 Comprehensive ability of students in the teaching mode of virtual simulation training platform for posts

background of "Great Wisdom Propelling Clouds", the use of modern technology to process data provides a guarantee for the data security of enterprises.

42.4 Conclusions

With the development and application of new technologies, while certain changes are made to the business model, a new smart financial model has also been gradually formed. In the context of the continuous development of smart finance, the existing financial processes have been comprehensively improved, so that the financial personnel who used to be information producers began to gradually change to information providers and processors. For business managers, smart financial management is both an opportunity and a challenge. In the Internet environment, the phenomenon of the digital divide will be greatly improved, and the operation mode of enterprises and the production and distribution of value will be changed accordingly. Financial management and social environment will be more closely integrated, information flow, capital flow and enterprise integration process will be accelerated, and the situation of enterprise information asymmetry will be greatly improved. Enterprises need to design a smart financial management system based on their own reality and the characteristics of smart financial management, advocate financial personnel to improve their abilities, apply smart financial management in their work, give full play to the advantages of smart financial management, and help enterprises solve problems. The problems existing in financial management promote the stable and long-term development of enterprises.

Discussion

With the application of virtual simulation technology in the field of practical teaching, it further changes the teaching mode of traditional accounting comprehensive practical training courses and provides simulation. Comprehensive working situation of accounting, cultivating comprehensive professional quality of accounting talents. Therefore, accounting virtual simulation training platform is to improve the practical teaching efficiency of accounting major. It is the most intuitive, the most real and the most effective way to create a virtual simulation training platform and design simulation training teaching content, which is rich and flexible. Teaching methods, creating a "double-qualified" teacher team, widening the diversity of teaching evaluation, fully mobilize the enthusiasm of students to learn, promote students to learn from knowledge. Ability transformation, quickly integrate into the society, become a real compound accounting talent.

Acknowledgements This work was supported by Research on platform construction and Application of accounting post oriented virtual simulation training (No.Higher education teaching project of Jilin Provincial Department of education in 2020 (key project).

References

1. R. Evans, M.A. Ferreira, M.P. Prado, Fund performance and equity lending: why lend what you can sell? Rev. Financ. **21**(3), 1093–1121 (2017)
2. J. Pi, S. Li, Managerial delegation and wage inequality. Ann. Econ. Financ. **2022**(1), 23 (2022)
3. M.K. Linnenluecke, X. Chen, X. Ling, Research in finance: A review of influential publications and a research agenda. Pac. Basin Financ. J. **43**(7), 188–199 (2017)
4. G. Elliehausen, S.M. Hannon, The credit card act and consumer finance company lending. J. Financ. Intermediation **34**(4), 109–119 (2018)

5. J. Begenau, M. Farboodi, L. Veldkamp, Big data in finance and the growth of large firms. J. Monet. Econ. **97**(8), 71–87 (2018)
6. P.K. Narayan, D. Phan, A survey of Islamic banking and finance literature: issues, challenges and future directions. Pac. Basin Financ. J. **53**(2), 484–496 (2017)
7. H. He, Z. Yu, Product quality, incomplete contract and the product cycle. Int. Rev. Econ. Financ. **53**(1), 160–167 (2018)
8. P. Guasoni, M. Weber, Dynamic trading volume. Math. Financ. **27**(2), 313–349 (2017)
9. M. Larrain, S. Stumpner, Capital account liberalization and aggregate productivity: the role of firm capital allocation. J. Financ. **72**(2012), 506 (2017)
10. M.H. Basse, Innovative efficiency and stock returns: Should we care about nonlinearity? Financ. Res. Lett. **2018**(2), 24 (2018)
11. S. Parida, T. Teo, The impact of more frequent portfolio disclosure on mutual fund performance. J. Bank. Financ. **87**(2), 427–445 (2018)
12. M. Faccio, H.C. Hsu, Politically connected private equity and employment. J. Financ. **2017**(4), 72 (2017)
13. E. Pikulina, L. Renneboog, P.N. Tobler, Overconfidence and investment: An experimental approach. J. Corp. Finan. **2017**(2), 43 (2017)
14. P. Xia, Reform of network security technology practice teaching system based on virtual simulation training platform, in *International Wireless Communications and Mobile Computing Conference* (2020)
15. Z. Ran, Exploration on the key issues of practical teaching reform of computer network. Energy Procedia **17**(1), 1914–1919 (2012)
16. L. Leng, L. Wang, Study of practical teaching based on "Network Protocol Simulation System." Appl. Mech. Mater. **380–384**, 2741–2744 (2013)
17. G. Lugaresi, A. Matta, V.V. Alba, An internet of things architecture for lab-scale prototypes of real-time simulation, in *International Conference on Automation Science and Engineering* (2020)
18. R. Acceptance et al., *Programming Systems Lab*. Columbia University Department of Computer Science, CUCS-023–95e (1995)

Chapter 43
Research on the Design of Supply Chain Finance System Based on Genetic Algorithm

Minglei Han, Linyang Xie, Linzhu Xie, and Yilin Chen

Abstract In the background of the era of big data, the financial field in the study and design of supply chain finance system, proposed to use artificial intelligence algorithm for optimization processing, which can not only optimize the system performance, but also show the application value of various algorithms. Supply chain management, as the main content of current research scholars, has a lot of application theory and practical results. Although there are still a lot of unsolved problems, with the continuous improvement of social economy and technological level, the design of supply chain finance system with genetic algorithm as the core has been paid more attention. On the basis of understanding the development status of supply chain finance system with block chain technology as the core, this paper compares and analyzes the main structures of traditional supply chain finance system and new supply chain finance system, defines the basic concepts of adaptive system and genetic algorithm, and proposes to use genetic algorithm to realize supply self-adaptive adjustment. The final experimental results prove that the supply chain finance system with genetic algorithm as the core has practical research value.

Keywords Genetic algorithm · Supply chain · Finance · Blockchain technology · Self adaptive system

43.1 Introduction

With the steady development of social economy and science and technology, the comprehensive management level of enterprises continues to improve and the internal management function becomes more and more perfect. Although this can obtain more benefits for the innovation and development of enterprises, more opportunities come from the coordination and cooperation with suppliers and sellers. Especially

M. Han (✉) · L. Xie · L. Xie · Y. Chen
Harbin University of Commerce, Harbin, China
e-mail: 2728028355@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_43

after entering the era of big data, the close cooperation among suppliers, manufacturers and sellers has become particularly critical. While studying internal production management, enterprises of all kinds should also regard the supply chain and financial system constituted by the cooperation among the three as the main content of future technological innovation [1–3]. Nowadays, enterprises are facing increasing pressure of market competition. The supply chain finance system composed of various enterprises must have the consciousness ability of rapid adaptation, which is also the main factor to evaluate the performance of supply chain. According to the accumulated experience of practical construction research, there are many factors leading to the change of system demand. In different supply chain finance systems, the entities constituting the supply chain have great differences in quantity, cooperation mode, basic nature and other aspects. Under the condition of a clear technical structure, changes in products and markets will lead to changes in internal processes and operational strategies, while the development of information technology will change the software and hardware environment in which the system runs. Nowadays, when scientists study the response ability of supply chain finance system, they mainly start from the aspects of system structure, model method and management strategy, among which the application of multi-agent system is the most critical research content. The results have been excellent, and they are specific and focused. There is no one category that covers all areas. Hollander of Santa Fe Research Center in the United States proposed in the study that the dynamic adjustment process of supply chain finance system is regarded as an adaptive reaction process, thus getting the basic concept of complex adaptive system. Meanwhile, the interaction relationship in the system is extracted from the evolution of life, and the intelligent algorithm is used to describe this relationship. As one of them, genetic algorithm plays an important role in financial resource scheduling [4–6].

According to the definition and analysis of eight departments including the People's Bank of China, supply chain finance refers to a functional network chain structure model that takes the supply chain industry chain as the core, integrates information flow, capital flow, logistics and other information with the application of fintech technology to provide systematic financial solutions for all enterprises and facilitate the establishment of a virtuous circle of industrial ecology. From 1999, when Shenzhen Development Bank first entered the field of supply chain finance with bill discount business in southeast China, to 2017, the term supply chain finance appeared repeatedly in national policies, and local governments put forward a number of preferential policies to support the development of supply chain finance. From the perspective of overall development, the supply chain finance in our country has experienced three stages. Firstly, commercial banks as the dominant, core enterprises as credit carriers and artificial credit granting as the main form; Secondly, core enterprises take the lead, multi-subject participation and online operation; Finally, supply chain finance in our country has gradually developed to create a trans-region, cross-department and cross-chain supply chain ecological circle. Especially in the comprehensive popularization of cloud computing, big data and other technologies, the platform of supply chain finance system can use blockchain, cloud computing, big data and other fintech to obtain more information, cross-verification of information, and further improve the risk control ability of service subjects. In the new era of development, supply chain finance system pays more attention to the construction and management of a virtuous circle within the industrial ecosystem. From the introduction of Bitcoin to the attention of the world, the price of this new digital cryptocurrency has been higher and higher, reaching a high of $19,000 in 2018. Since 2014, blockchain technology has been used as the underlying platform of the initial cryptocurrency, and researchers have started to conduct in-depth studies based on practical cases. Up to now, blockchain technology has developed from the underlying support technology to an emerging technology that improves life efficiency and social production level in multiple dimensions, and its application has also expanded from the financial industry to other industries such as logistics and notarization. Fully meet the work needs under different conditions. Although the domestic blockchain was not fully developed until 2016, after the release of the White Paper on the Development of China's Blockchain Technology and Application, the domestic blockchain industry received support at the policy level for the first time. At the same time, the 13th Five-Year National Informatization Plan also laid out the layout of cutting-edge technologies such as blockchain. Now it has surpassed Europe and the United States and become the most mature region for the application of blockchain technology. Therefore, on the basis of studying the design structure of supply chain finance system with genetic algorithm as the core, this paper focuses on discussing related principles and main components, so as to provide effective basis for the operation of supply chain finance system in the new era [7–9].

43.2 Methods

43.2.1 Supply Chain Finance System

On the basis of understanding the application situation of traditional supply chain finance system commonly used in the market at present, it can be seen from the analysis of the structure diagram of traditional supply chain finance system shown in Fig. 43.1 below that there are the following problems: First of all, all participants in the system can only verify the authenticity and perfection of the business through the contracts and bills provided by enterprises. Even if trade information can be recorded in the supply chain financial system, the system is centralized, so it is difficult to ensure the privacy and authenticity of the information, and cannot solve the problem of trust between enterprises, leading to information asymmetry in the supply chain. The overall system operation efficiency is getting lower and lower; Second, it is difficult to guarantee the authenticity of information in the traditional supply chain finance system. Financial institutions need to invest a lot of time and manpower costs to accurately check the transaction information in the supply chain after taking money and lending, which leads to longer and longer execution time

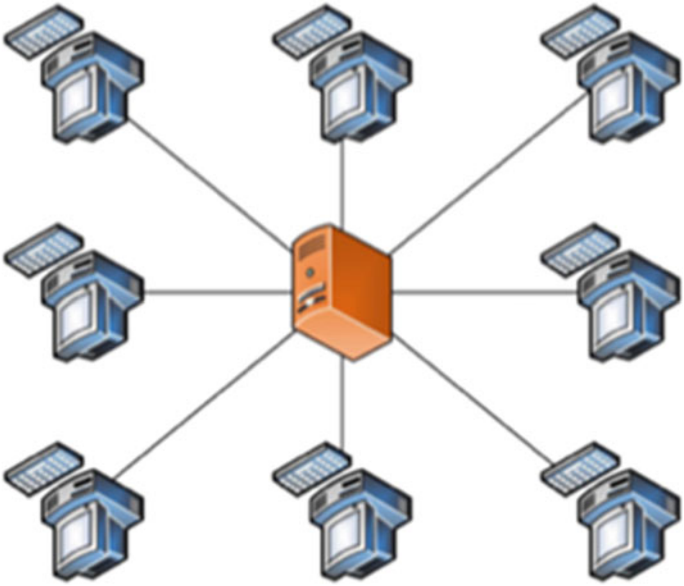


Fig. 43.1 Structure diagram of traditional supply chain finance system

of the lending business and less and less income. Finally, all participants are afraid of their private information and core business being leaked, and are reluctant to share core information with others, which leads to the obstruction of information flow in the supply chain and directly limits the further development of the supply chain finance system. The supply chain finance system with block chain technology as the core will build a financial transaction system for banks, core enterprises and suppliers with transaction business. The suppliers and core enterprises will record the trade information in the system, the suppliers will submit the application for pledge financing in the system, and the core enterprises will confirm the receivables through the system. Banks can review pledges in the system and authorize lending. The actual system design is shown in Fig. 43.2 below [10–12].

43.2.2 Principle of Adaptive Supply Chain Based on Genetic Algorithm

As a common technical term in control theory, adaptive system is suitable to be applied to the objects with a wide range of dynamic characteristics. In the case of incomplete system working condition information, when the dynamic characteristics of the object change greatly and unpredictably, the parameters or structure can be changed actively, so as to ensure the optimal state of the system in a certain sense. The specific structure is shown in Fig. 43.3 below [13–15].

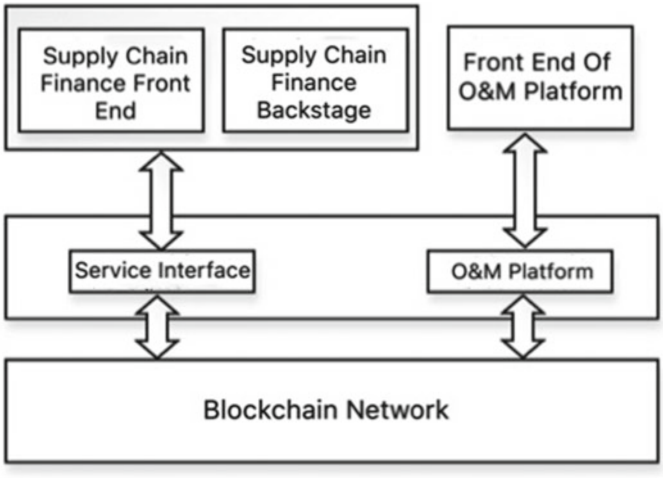
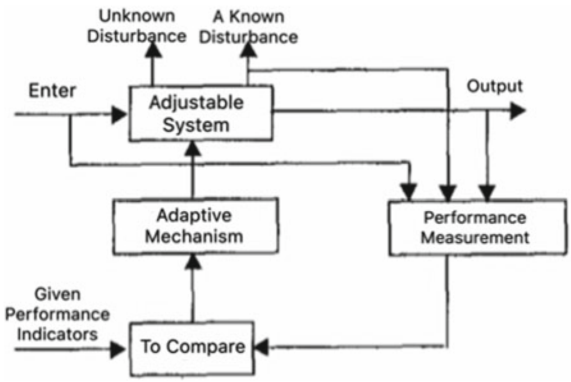


Fig. 43.2 Structure diagram of supply chain finance system with block chain technology as the core

Fig. 43.3 Structure diagram of the adaptive system



Genetic algorithm is based on genetic theory and natural selection and uses the evolutionary criteria of survival of the fittest and survival of the fittest to search for the satisfactory solution of the problem space. When the American scholar J. Holland put forward this concept, he would use some coding technology to act on the binary number string, and the basic idea is to simulate the evolution process of the group formed by these strings. According to the analysis of the algorithm flow chart shown in Fig. 43.4 below, the specific operation steps involve the following points:

First, code. It is necessary to encode the state variables of the problem space so as to realize effective genetic manipulation.

Second, create groups. A population composed of multiple individuals is randomly generated, which represents the set of possible solutions to the optimization problem. Abide by the basic principle of survival of the fittest, finally select

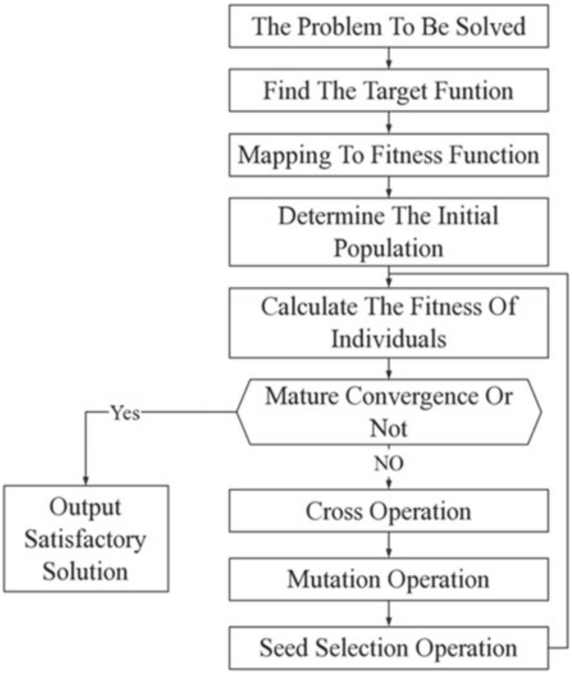


Fig. 43.4 Flow chart of genetic algorithm

excellent groups and individuals, fully meet the optimization requirements of the objective function;

Third, evaluation. After the completion of each iteration, the fitness value of the individual or sister is accurately calculated, which is used as the individual evaluation;

Fourth, choice. According to a certain law, multiple individuals are selected as parents in the group for reproduction, and new individuals are generated to join the next group;

Fifth, cross. After selecting the individual tons for reproduction, the same position is randomly selected and the parents are effectively exchanged in this position.

Sixth, compile. According to a certain probability, a number of individuals are randomly selected in the population, and in the selected individuals, a random selection of a take and reverse operation, mutation simulates the phenomenon of genetic mutation in biological evolution;

Seventh, the newly generated population is evaluated, selected, crossed and mutated again in the third step. In the continuous cycle, when the fitness value of the optimal individual reaches the limited value, iterative convergence is needed to end the algorithm.

43.2.3 Structure of Adaptive Supply Chain Finance System with Genetic Algorithm as the Core

With the supply chain financial information infrastructure as the core and the use of e-commerce, standard protocols, Internet and other information technologies, the architecture as shown in Fig. 43.5 can be built, which includes three core modules: process definition, process operation analysis and process adaptive. From the perspective of practical application, process adaptive will determine a new supply chain finance strategy according to the changes of genetic algorithm and adaptive rules.

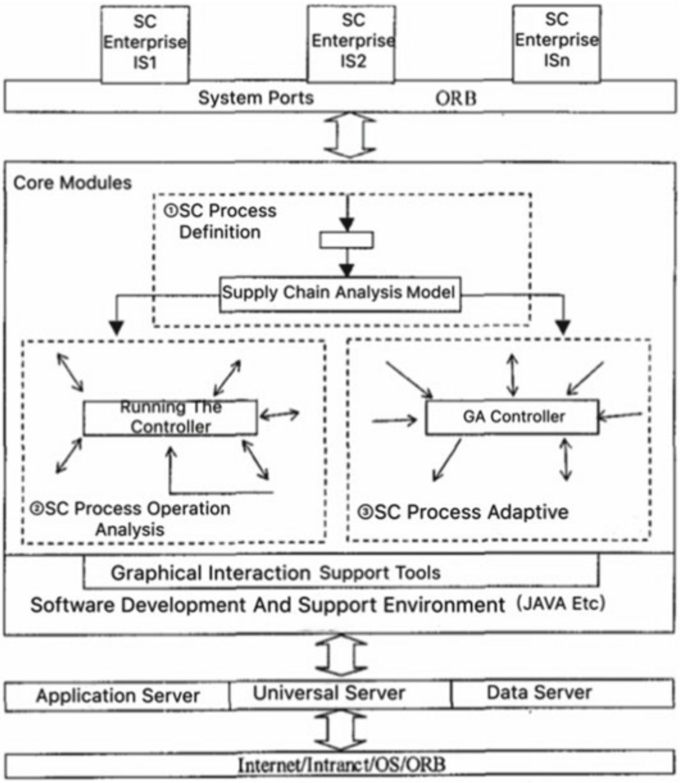


Fig. 43.5 Structure diagram of adaptive supply chain finance system with genetic algorithm as the core

Table 43.1 Scheduling results of genetic algorithm

Order no.	3	2	3	1	1	2	2
The number of	42	12.7	703.5	27	189.3	97	86.5
Time of start	0	1.2	1.5	5.2	7.4	9.5	11.2

43.3 Result Analysis

As an effective bridge for communication between product users and providers, supply chain finance system will span multiple functional departments such as raw material supply, production and production, and product sales. Therefore, the management efficiency of practice system directly affects the efficiency and quality of enterprise operation activities. Taking an enterprise as an example, this paper mainly considers the production capacity allocated by manufacturer i from various perspectives. In order to better highlight the basic idea of the algorithm, the relevant problems are simplified in the empirical study, and only the penalty of late delivery and the reduction of delivery time are analyzed. Suppose the enterprise has three orders, the first order $O1 = \{300, 16, 0.1\}$, the second order $O1 = \{450,12,0.3\}$, the third order $O1 = \{100, 3, 0.5\}$, using the genetic algorithm to get the scheduling results as shown in Table 43.1 below, the final experimental results prove that, Genetic algorithm plays an important role in the design and application of supply chain finance system [15].

43.4 Conclusion

To sum up, this study regards supply chain finance system as a complex adaptive system. On this basis, the introduction of genetic algorithm solution can further optimize the basic structure and main function of the system, so it is the main issue discussed by modern scientific researchers.

References

1. X. Han, Research on supplier selection under multiple constraints based on Genetic algorithm. Value Eng. **39**(14), 2 (2020)
2. B. Zhang, Z. Liang, Q. Mo et al., Research on supply chain ordering problem based on genetic algorithm. Mod. Inf. Technol. **5**(14), 4 (2021)
3. T. Jiang, Y. Yang, R. Wang, Study on the dynamic effect of reverse factoring on the efficiency of supply chain finance system: an empirical analysis based on system dynamics. West. Financ. **3**, 9 (2022)
4. J. Wang, H. Shao, S. Li et al., Path optimization method of electricity meter supply chain based on worker ant colony algorithm. Electron. Des. Eng. **020**, 028 (2020)
5. Y. Ye, W. Fan, X. Wang, Research on optimization of bevel gear transmission parameters based on genetic algorithm. J. Anhui Univ. Sci. Technol. (Natural Science Edition) **003**, 042 (2022)

6. H. Xu, Research on cooling load prediction of office building central air conditioning engineering system based on Genetic algorithm. Refrig. Air Cond. (Sichuan) **34**(4), 6 (2020)
7. H. Liu, X. He, L. Sun, Optimization method of spread spectrum matrix based on genetic algorithm in upstream no-scheduling NOMA system. Signal Process. **38**(3), 554–561 (2022)
8. D.-B. Jiang, J. Zhang, W.-Q. Ouyang et al., Research on supplier selection decision support system based on supply chain risk management. China Manag. Informatiz. **23**(6), 3 (2020)
9. G. He, B. Li, D. Wang, Research on vehicle routing problem based on improved dual-population hybrid genetic algorithm. Supply Chain Manag. **1**(7), 11 (2020)
10. H. Wu, H. Tan, F. Deng, Research on parametric design method of renewable energy utilization potential of low-density residential buildings based on genetic algorithm. Resid.Ial Sci. Technol. **41**(7), 8 (2021)
11. X. Cao, Y. Sun, C. Wang, Research on freight path planning system based on genetic algorithm. Electron. Technol. Softw. Eng. **16**, 2 (2021)
12. Z. Sun, X. Xu, Research on financial risk assessment of agricultural supply chain—based on GA-BP Neural network model. Res. Tech. Econ. Manag. (008), 78–82 (2021)
13. J. Li, L. Lin, W. Zhang et al., Research on unbalance current protection leveling method based on genetic algorithm. Power Capacit. React. Power Compens. **43**(5), 6 (2022)
14. B. Zhao, H. Ning, R. Zhang, Research and implementation of intelligent paper grouping system based on Genetic algorithm. Appl. Sci. Technol. **48**(2), 4 (2021)
15. Y. Zou, H. Huang, X. Xia et al., Design optimization of curved curtain wall based on Genetic algorithm under cost orientation. J. Zhejiang Univ.: Eng. Sci. **56**(10), 8 (2022)

Chapter 44
Research on the Impact of Digital Trade Development on Regional Income Gap: Empirical Analysis Based on Pan-Pearl River Delta Data

Nanyi Li and Bo Sun

Abstract With the opening up of our economy, the economic development of the pan-Pearl River Delta region has made remarkable achievements. However, the problem of unbalanced economic development between regions has become increasingly prominent. Taking 9 provinces in Pan-Pearl River Delta region from 2013 to 2021 as the research object, we measured the digital trade development level from six dimensions: information network infrastructure, logistics environment, digital technology level, industrial digital trade scale, digital industrialization trade scale, and trade potential. The result shows that the digital trade development level is on the rise year by year, but the development level of each province is different. By empirical analysis, we found that developing digital trade could help narrow the income gap among the Pan-Pearl River Delta region.

Keywords Digital trade · Income gap · Pan-pearl river delta region

44.1 Introduction

As a new mode of trade, digital trade is an important part of China's sustainable economic development and an effective way to cope with complex international situations. In the digital economy era, with the support of various favorable policies to promote the development of digital economy, the development level of digital trade is greatly increased. According to data released by the Ministry of Commerce, China's digital trade reached 42.89 trillion yuan in 2021, accounting for 80.95% of the country's total trade in services, up 9.5% from 2020.

N. Li (✉) · B. Sun
School of Economics and Trade, Guangdong University of Foreign Studies, Guangzhou, China
e-mail: lny99811@126.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_44

The concept of the Pan-Pearl River Delta region was formally put forward in 2003. The Pan-Pearl River Delta Region mainly refers to the regional economic cooperation established by nine provinces along the Pearl River Basin, including Guangdong, Fujian, Hainan, Jiangxi, Hunan, Guangxi, Sichuan, Yunnan and Guizhou. Since its establishment, the economic situation in the region has been improving. Paradoxically, the economic development among the provinces in the region is imbalance. Especially the income gap. In 2021, theper capita disposable income of Guangdong Province is 44993 yuan while that of Guizhou Province is 23996 yuan, only about half of the income of Guangdong Province. Therefore, we should pay great attention to the impact of digital trade development on the income gap in the Pan-Pearl River Delta region.

44.2 Measurement and Analysis of the Digital Trade Development Level in Pan-Pearl River Delta Region

44.2.1 Construction of Index System

By studying relevant literature, based on [2] definition of digital trade and [3] practice, we set the index system following the scientific and rational construction of evaluation index system. To construct the comprehensive index system of digital trade development level, we selected indicators from six dimensions: information network infrastructure, logistics environment, digital technology level, industrial digital trade scale, digital industrialization trade scale, and trade potential. The above six first-level indicators are subdivided into 16 s-level indicators. Considering the integrity and availability of the data, we selected data of nine provinces in the Pan-Pearl River Delta region from 2013 to 2021. Table 44.1 shows the specific indicator selection.

44.2.2 Measurement of the Development Level of Digital Trade

44.2.2.1 Data Standardization Processing

Each index we selected in this paper has different properties, that is, the dimension and magnitude are different. In order to effectively ensure the reliability and accuracy of measurement results, we adopt the linear dimensionless method to standardize the original data. The calculation formula is as follows:

$$y_i = \frac{x_i - \min x_i}{\max x_i - \min x_i} \tag{44.1}$$

Table 44.1 Comprehensive indicators of digital trade development level

First-level indicators	Second-level indicators	Symbol
Information network infrastructure	Internet broadband access ports (10,000 units)	X1
	Number of domain names (10,000 units)	X2
	Broadband subscribers of internet (10,000 subscribers)	X3
	Popularization rate of mobile telephone (subscribers/100 persons)	X4
Logistics environment	Express delivery volume (10,000 pieces)	X5
	Express business revenue (10,000 yuan)	X6
Digital technology level	Number of employed persons in information transmission, software and information technology services (10,000 persons)	X7
	Internal expenditure on R&D of industrial enterprises above designated size (100 million yuan)	X8
	Number of patent applicated accepted (unit)	X9
Industrial digital trade scale	E-commerce sales (10,000 yuan)	X10
	Number of enterprises with E-commerce Transactions (unit)	X11
Digital industrialization trade scale	Business volume of telecommunication services(100 million yuan)	X12
	Software revenue(100 million yuan)	X13
Trade potential	Per Capita GDP (yuan)	X14
	Market openness (%)	X15
	Total retail sales of consumer goods (100 million yuan)	X16

Data Sources National Bureau of Statistics, Provincial Statistical Yearbook

After standardization processing, the values of all secondary indicators are intermediate between 0 and 1, and the higher the value, the higher the level of indicators.

44.2.2.2 Weight Establishment

We use Stata 15.1 to make the principal component analysis, so as to calculate the weight of all levels of indicators.

In order to verify whether principal component analysis is applicable to the original data, we make KMO and Bartlett tests first. The value range of KMO system measurement is usually between 0 and 1, which is mainly used to determine whether there is phase correlation between two variables. The stronger the phase correlation is, the more suitable for principal component analysis. The closer the value is to 1

Table 44.2 KMO, Bartlett test results

Kaiser–Meyer–Olkin measure of sampling adequacy		0.895
Bartlett test of sphericity	Chi-square	3314.782
	Degrees of freedom	120
	P-value	0.000

Table 44.3 Principal component analysis results

Component	Eigen value	Proportion	Cumulative
Comp 1	12.6126	0.7883	0.7883
Comp 2	1.13589	0.0710	0.8593

means that there is a strong correlation between the two variables. The test results are shown in Table 44.2.

The test results show that the index system is very suitable for principal component analysis. After principal component analysis, we selected the eigenvalue greater than 1 from all the extracted principal components. Analysis results are as follows (Table 44.3).

From the cumulative, we can know that 85.93% of the 16 s-level index information can be extracted from the first two principal components. Therefore, the first two principal components can completely replace the original index, and it will be reasonable to measure them after giving them weight. The second-level index coefficients of each principal component are shown in Table 44.4.

According to the content in the above table, multiply the coefficient of the second-level index contained in each principal component by the corresponding variance contribution proportion. Then divide them by the cumulative, sum them up. Finally, we get the comprehensive evaluation model of the digital trade development level, and the corresponding expression is as follows:

$$\begin{aligned} \mathrm{Comp} = {} & 0.2319\mathrm{X}1 + 0.233\mathrm{X}2 + 0.2342\mathrm{X}3 \\ & + 0.2216\mathrm{X}4 + 0.2181\mathrm{X}5 + 0.2274\mathrm{X}6 \\ & + 0.2322\mathrm{X}7 + 0.2464\mathrm{X}8 + 0.2375\mathrm{X}9 \\ & + 0.2352\mathrm{X}10 + 0.2497\mathrm{X}11 + 0.1673\mathrm{X}12 \\ & + 0.2446\mathrm{X}13 + 0.2282\mathrm{X}14 + 0.2158\mathrm{X}15 \\ & + 0.2488\mathrm{X}16 \end{aligned} \tag{44.2}$$

Finally, we made normalization processing to the coefficients. The treatment method is to divide the system of each second-level index by the sum of all second-level index coefficients, so as to obtain the weight of each second-level index. On this basis, the weight of each first-level indicator is the the sum of weight of all the second-level indicators. The specific formula of normalization processing is as follows:

Table 44.4 The weight of each principal component's second-levelindex

Variable	Comp 1	Comp 2
X1	0.2585	−0.0629
X2	0.2126	0.4592
X3	0.2544	0.0105
X4	0.1981	0.482
X5	0.2586	−0.2318
X6	0.2667	−0.2095
X7	0.271	−0.1989
X8	0.2747	−0.0679
X9	0.2741	−0.1684
X10	0.2723	−0.1764
X11	0.276	−0.042
X12	0.1908	−0.0934
X13	0.2756	−0.099
X14	0.2017	0.5219
X15	0.2134	0.2423
X16	0.2703	0.0102

$$z_i = \frac{x_i}{\sum_{i=1}^{16} x_i} \tag{44.3}$$

According to the above formula, the weights of six first-level indicators can be further obtained as follows: 0.2507, 0.1213, 0.1950, 0.1321, 0.1122 and 0.1887. The comprehensive evaluation index system of the development level of digital economy (DTL) can be expressed as:

$$\begin{aligned} \text{DTL} = {} & 0.0632\text{X1} + 0.0634\text{X2} + 0.0638\text{X3} \\ & + 0.0603\text{X4} + 0.0594\text{X5} + 0.0619\text{X6} \\ & + 0.0632\text{X7} + 0.0671\text{X8} + 0.0647\text{X9} \\ & + 0.0641\text{X10} + 0.0680\text{X11} + 0.0456\text{X12} \\ & + 0.0666\text{X13} + 0.0621\text{X14} + 0.0588\text{X15} \\ & + 0.0678\text{X16} \end{aligned} \tag{44.4}$$

44.2.2.3 Measure Result Analysis

According to the comprehensive evaluation index system, the corresponding standardized values can be substituted in to calculate the measurement results of the

Table 44.5 Measure result of digital trade development level index

Province	2013	2014	2015	2016	2017	2018	2019	2020	2021	Avg.
Guangdong	0.4124	0.4430	0.4867	0.5481	0.6080	0.7142	0.7912	0.8299	0.8826	0.6351
Fujian	0.1574	0.1707	0.1956	0.2315	0.2829	0.3061	0.3250	0.3048	0.3292	0.2559
Sichuan	0.1074	0.1267	0.1525	0.1798	0.2122	0.2554	0.2885	0.3126	0.3142	0.2166
Hunan	0.0748	0.0879	0.1007	0.1219	0.1425	0.1718	0.2086	0.2274	0.2286	0.1516
Jiangxi	0.0438	0.0542	0.0729	0.0848	0.1007	0.1285	0.1377	0.1655	0.1730	0.1068
Guangxi	0.0420	0.0582	0.0687	0.0797	0.0979	0.1228	0.1446	0.1605	0.1606	0.1039
Yunnan	0.0426	0.0531	0.0618	0.0708	0.0848	0.1089	0.1307	0.1452	0.1403	0.0931
Guizhou	0.0269	0.0372	0.0480	0.0569	0.0759	0.0986	0.1182	0.1234	0.1328	0.0798
Hainan	0.0473	0.0534	0.0538	0.0573	0.0663	0.0785	0.0893	0.0854	0.0954	0.0696

digital trade development level in Pan-Pearl River Delta region. The index and ranking of the digital trade development level in each province are as follows.

From Table 44.5, we can see that the digital trade development level of all provinces shows an increasing trend year by year. This shows that the development of digital trade in the Pan-Pearl River Delta region is getting better year by year. What's more, the development of digital trade has great regional differences. As the most developed economy province in China, Guangdong's digital trade development level index is much higher than other provinces'. Although the digital trade development level of the several western less-developed provinces is relatively low, it has been growing rapidly in recent years.

44.3 Empirical Analysis

44.3.1 Variables

To consider the availability of data, this paper takes the data of the nine provinces in Pan-pearl River Delta Region from 2013 to 2021 as our sample. The data were obtained from China Statistical Yearbook and local statistical yearbooks.

44.3.1.1 Dependent Variable

Income gap (GAP):per capita disposable income is used as the income target for each province. Firstly, we calculate the ratio of provincial income (x) to the regional average ($\overline{x}$). The closer the ratio is to 1, the closer the income level of the province is to the regional average, and thus the smaller the income gap [2]. As shown in Table 44.6, incomes of three provinces—Guangdong, Fujian and Guangxi—are higher than the

Table 44.6 Income gap

Province	2013	2014	2015	2016	2017	2018	2019	2020	2021
Guangdong	1.4694	1.4603	1.4492	1.4447	1.4400	1.4336	1.4287	1.4218	1.4249
Fujian	1.3312	1.3265	1.3215	1.3165	1.3110	1.3068	1.3043	1.2892	1.2877
Jiangxi	0.9474	0.9514	0.9591	0.9590	0.9612	0.9640	0.9617	0.9709	0.9694
Guangxi	0.8835	0.8845	0.8777	0.8729	0.8685	0.8601	0.8543	0.8512	0.8464
Hainan	0.9871	0.9936	0.9873	0.9849	0.9840	0.9840	0.9770	0.9670	0.9646
Hunan	1.0041	1.0019	1.0049	1.0069	1.0080	1.0105	1.0137	1.0182	1.0132
Sichuan	0.8928	0.8954	0.8958	0.8969	0.8979	0.8992	0.9046	0.9191	0.9210
Yunnan	0.7891	0.7830	0.7919	0.7973	0.8005	0.8040	0.8087	0.8073	0.8128
Guizhou	0.6953	0.7034	0.7125	0.7211	0.7288	0.7378	0.7470	0.7553	0.7600

regional average, incomes of other provinces are all under the average level. There exists large income gap among provinces in Pan-pearl River Delta Region.

To measure the income gap intuitively, we take the absolute value of the D-value between this ratio and 1 to measure the income gap, the greater the value, the greater the income gap among these provinces. The calculation formula is as follows:

$$\mathrm{GAP} = \left|\frac{\mathrm{X}}{\overline{\mathrm{X}}} - 1\right| \tag{44.5}$$

44.3.1.2 Explanatory Variable

Digital trade development level (DTL): we take the index calculated in Table 44.5.

44.3.1.3 Control Variables

Urbanization rate (UR): take the proportion of urban population in total population.

Industrial structure (IS): take the ratio of the sum of the added value of the secondary and tertiary industries to the provincial GDP (Gross Domestic Product).

Fiscal expenditure (PAY): take the proportion of local budget expenditure in GDP.

Level of education (EDU): take the number of college students in school. To facilitate regression, take the logarithm of the actual value, denote as lnEDU.

Table 44.7 presents the summary statistics for the main variables.

Table 44.7 Summary statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
GAP	81	0.1691054	0.1416318	0.0019015	0.4694147
DTL	81	0.1902674	0.1843852	0.0269288	0.8825902
UR	81	0.5537367	0.0877766	0.3788546	0.7462946
IS	81	0.8807422	0.0507291	0.7677718	0.961616
PAY	81	0.2454946	0.0732093	0.1067586	0.3866326
lnEDU	81	4.460947	0.6561937	2.845491	5.537255

Table 44.8 Hausman test result

Test: H_0: difference in coefficients not systematic
chi2(5) = 9.82
Prob > chi2 = 0.0806

44.3.2 Model Specification

In this paper, we use correctedHausman test to determine the type of the panel data model, and the test results show that the random effect model is rejected. Therefore, we use the fixed effect model in the follow-up empirical analysis. The Hausman test result is shown in Table 44.8 [3–5].

The empirical analysis model is as follows. The subscripts i and t represent province and year respectively.

$$GAP_{it} = \alpha_i + \beta_1 DTL_{it} + \beta_2 UR_{it} + \beta_3 IS_{it} + \beta_4 PAY_{it} + \beta_5 lnEDU_{it} + \mu_{it} \quad (44.6)$$

44.3.3 Co-Integration Test

In order to determine the co-integration relationship between variables, we make Pedroni test. Result in Table 44.9 shows that there is a long-term stable co-integration relationship between variables [6–10].

Table 44.9 Pedroni test result

	Statistic	Conclusion
Modified Phillips-Perron	5.2626^{***}	Co-integration
Phillips-Perron	-12.1387^{***}	Co-integration
Augmented Dickey-Fuller	-11.9155^{***}	Co-integration

*, **, ***denote statistical significance at 10, 5, and 1%, respectively

Table 44.10 Regression result

Explanatory variables	1	2	3	4	5
DTL	−0.0923157***	−0.067832***	−0.0671487***	−0.0825887***	−0.0903525***
	(−5.28)	(−2.67)	(−2.83)	(−3.56)	(−4.09)
UR		−0.0645837	−0.1362359***	−0.0375548	−0.2465255***
		(−1.32)	(−2.69)	(−0.64)	(−2.77)
IS			0.5372961***	0.3617988**	0.437937***
			(−3.29)	(−2.17)	(−2.75)
PAY				0.2486326***	0.3335994***
				(−2.91)	(−3.9)
lnEDU					0.0557102***
					(−3.01)
C	0.1866701***	0.217774***	−0.2158989	−0.1740746	−0.3933199***
	(−52.45)	(−9.17)	(−1.62)	(−1.36)	(−2.79)

*, **, ***denote statistical significance at 10, 5, and1%, respectively

44.3.4 *Regression Analysis*

In this part we use step-wise regression analysis to explore the impact of import trade on overall national employment. From Table 44.10 we can find that digital trade development is negatively correlated with income gapwith or without adding the control variables. This shows that digital trade development can help narrow the regional income gap. Meanwhile, the development of urbanization could also help narrow the income gap. On the contract, industrial structure, fiscal expenditure and level of education all shows positive correlation with the income gap. This phenomenent suggests that the upgrading of industrial structure, the increase of government investment and the improvement of education level would widen the income gap.

44.4 Conclusions and Recommendations

By principal component analysis, we found that the digital trade development level is improving year by year, and the development prospect is promising. While the digital trade development of each province among the region is different. The more developed the province, the higher the digital trade development level. Through the regression analysis of panel data, we come to a conclusion that digital trade development as well as the urbanization can help narrow the income gap.

While vigorously developing digital trade, we should also pay attention to the coordinated development among regions. At the same time, we should give full play to the role of digital trade in driving the economy and national income. Less developed areas should vigorously develop digital trade in order to improve the income level of residents and narrow the income gap with the residents in developed areas. Specific measures include: Establish a cross-regional digital trade development linkage mechanism, so that the developed areas can help the less developed areas through cross-regional and provincial “pairing” in economy, technology and industry;increase investment in research and development of digital trade on all fronts, and train talents for scientific and technological innovation vigorously; focus on coordinated development between urban and rural areas; formulate relevant regulation policies to promote the flow of financial and educational resources from developed to less developed areas.

References

1. Y. Na, Research on the development level measurement and innovative development strategyof china’s digital trade. J. Tech. Econ. Manag. (11):56–61 (2022)
2. M. Shuzhong, F. Chao, L. Yinfeng, Digital trade: definition, practical significance and research prospects. J. Int. Trade (10), 16–30 (2018)
3. Z. Diping, Z. Xiaoyu, Measurement of digital trade development level and analysis of its influencing factors—a case study of Zhejiang Province. J. Zhejiang Univ. Sci. Technol. **32**(04), 249–256+271 (2020)
4. L. Yuxin, G. Yinghui, A research of the level of facilitation of frontier trade of Xinjiang, China and the surrounding countries. Int Bus Res **35**(01), 24–33 (2014)
5. H. Yanhui, Research on the impact of inclusive finance development on regional income gap—an empirical analysis based on panel data of guangdong province. J. Reg. Financ. Res. (05), 46–50 (2019)
6. T. Zhang, Research on the influence of transportation infrastructure on urban development gap in Yangtze river delta based on the difference-in-difference model, in *2021 2nd International Conference on Urban Engineering and Management Science (ICUEMS)* (2021)
7. L. Wang, Research on the impact of energy price fluctuations on regional economic development based on panel data model. Resour. Policy **75**, 102484 (2022)
8. F. Wu, Y. Chen, X. Yang, Research on the impact of financial agglomeration on the coordinated development of urban ecological green: based on the empirical comparison of four metropolitan areas in the Yangtze River Delta of China. Environ. Sci. Pollut. Res. Int. (2022)
9. L. Luo, X. Ma, Research on the impact of income gap on environmental pollution based on balanced panel data of 48 countries. IOP Conf. Ser.: Earth Environ. Sci. **781**(3), 032003 (6pp) (2021)
10. Y. Men, Research on the impact of corruption on a country’s trade flows—based on the extended trade gravity model. Mod. Econ. Manag. Forum **3**(2), 75–80 (2022)

Chapter 45
Pricing and Wage Strategies for Ride-Hailing Platform with Riders' Heterogeneous Waiting Costs

Xinhang Xu and Huihui Wang

Abstract This paper focuses on the ability of the platform's pricing and wage strategies to regulate both supply and demand in the market, especially when consumer demand is surging, and we find that the optimal pricing and wage strategies increase with the market size. In addition, we also take into account the heterogeneity of consumer waiting costs in the general model, and consider the service strategies of the ride-hailing platform based on the heterogeneity of consumer waiting costs. Similarly, we also find that the optimal pricing and wage strategies increase with market size in the general model. Last but not least, we find that despite the fact that consumers suffer from some waiting costs, the pricing model chosen by the platform is well suited to meet consumer demand, maximizing the profitability of the platform, and give drivers as much profit as possible, thus achieving a win-win-win outcome.

Keywords Pricing strategy · Ride hailing · Heterogeneity

45.1 Introduction

The advent of sharing economy has become the one of the most important marketplace innovations in the years, defined by online platforms assisting service providers to match with individual customers. Several platforms, such as Airbnb and TaskRabbit, serve as online marketplaces, giving the customers free access to selecting their favorite service providers. Other platforms, especially for riding-hailing platforms like Uber or Lyft, completely controls the whole matching processes, deciding which service provider serves which individual customer and how much each rider should pay and each driver could earn. In terms platform's strategy, pricing is the primary lever to manage demand and supply, also the most effective one.

X. Xu (✉) · H. Wang
SILC Business School, Shanghai University, Shanghai, China
e-mail: xxh9874@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_45

The dynamic pricing strategy determines the dynamic supply and demand equilibrium of the ride-hailing platform. In reality, the platform uses pricing strategy to control the demand of riders and the wage strategy to control the supply of drivers. However, this strategy has caused a lot of controversies. For example, some drivers believe that dynamic pricing strategies are unpredictable and exist for a short period [1, 2]. Some riders are also dissatisfied with the platform's high price strategy [3]. However, Uber claims that surge pricing can bring better service quality to consumers [4]. Despite the controversy, Uber and Bolt continue to use dynamic pricing to serve riders in reality.

In the domain of ride-hailing market, there are plenty of literatures focusing on pricing strategy and wage strategy. Taylor works on impact of delay sensitivity on the optimal prices and wages, and find that delay sensitivity increases the optimal prices and lower the optimal wages [5]. Bai et al. focus on serval factors (demand, service rate, the volume of service providers and waiting time sensitivity), and find the relationship between these factors and the optimal prices and wages. They demonstrate that optimal prices and wages increase with higher demand rate [6]. Cochon et al. claim that consumers can be benefit by flexible prices and wages, while be worse off by fixed wages and flexible prices [7]. In the special pricing strategy like surge pricing, Yang et al. claim that limited surge pricing could not work on demand and supply equilibrium, while the subsidy with surge pricing could make all stakeholders better off [8]. Guda and Subramianian analyze surge pricing strategically where they could predict high demand [9]. Moreover, Hall et al. describe that surge pricing can well improve service quality by shortening waiting time [10]. In all, we can find that existed researches have not considered the case when riders have heterogenous waiting costs, and never consider the condition of supply and demand.

In this paper, from the consumer's perspective, we focus more on the consumer's valuation of riding and their own waiting costs. Based on these two factors, the utility model is built to present the size of overall consumer demand. From the driver's perspective, we build the model about the driver's income, and then present the size of the driver's supply. The platform makes pricing and wage decisions based on the principle of profit maximization, thus dynamically regulating the supply and demand equilibrium. In contrast to previous literatures [11], we concentrate on the consumer's waiting cost and consider both homogeneous and heterogeneous cases of waiting cost. Compared with work of Hu et al. [12], we focus on the driver's revenue model based on wage rate, thuswe integrate the revenue model of three parties: platform, rider and driver. Finally, our model compensates the shortcomings of the current papers and is innovative.

45.2 Model

45.2.1 Basic Model

For this problem, we develop a dynamic game model in which the ride-hailing platform uses price rate (price per kilometer) and wage rate (driver's revenue per kilometer) to integrate riders and drivers respectively. The consumer travel model is chosen to maximize consumer utility, as opposed to work of Yu et al., where we assume that consumers need to wait to get a taxi. In real life, passengers are likely to experience waiting time for riding, such as the time taken by the platform to call for riding, the travel time for the driver to arrive at the requesting place, the time for the consumer to arrive at the requesting place.

45.2.1.1 Riders' Perspective

In order to better capture the heterogeneity of consumers' willingness to pay for riding, we develop a rider utility model, which is widely used in the literature on operations management and transportation. On this basis, we assume that the passenger's utility of taking a ride is:

$$U = v - p - \gamma t^2 \tag{45.1}$$

Here, we define the consumer's valuation of a ride as v, where $v \sim U[0, 1]$ [0, 1]. p denotes the price rate set by the platform, where the condition $0 < p < 1$; γ denotes the sensitivity of the consumer's waiting time, and it also meets the condition $0 < \gamma < 1$. We also set t to be the average time that all consumers have to wait, consistent with $0 < t < 1$. On this basis, we set γt^2 to be the cost of waiting for riders. In the base model, we assume that the waiting cost of all riders is homogeneous. In the subsequent general model, we relax this assumption and set heterogeneous waiting costs. We choose to set the consumer's valuation of a ride to be uniformly distributed, and we can conclude that the consumer's demand for riding is a linear function that varies according to the price. This linear demand model allows for a good analysis of the subsequent dynamic supply and demand relationship.

Based on the basic model, rider will choose to request a ride when Eq. (45.1) is greater than zero, i.e., only when riders whose valuations are consistent with $v \geq p + \gamma t^2$, he or she will choose to take a ride, as shown in Fig. 45.1.

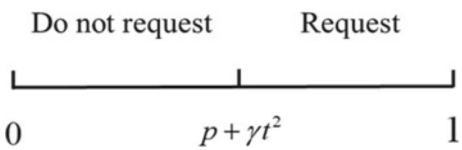


Fig. 45.1 Riders' requesting decisions based on their valuations

And if we assume that the market size is λ, we can get the market demand D as:

$$D = \lambda(1 - p - \gamma t^2) \tag{45.2}$$

45.2.1.2 Drivers' Perspective

If we assume that the number of drivers involved in the service is n, and the overall number of drivers that can be dispatched is N, then we can get the number of service transactions on the online taxi platform as $Q = \min\{D, n\}$, where the expression for demand is Eq. (45.2). In this case, we can get the utilization efficiency of each driver involved in the service as $Q/n = \min\{D, n\}/n$, and we can calculate $Q/n = (\min\{D, n\}/n) \leq 1$. Combining the wage rate set by the platform and the average service speed of the driver μ (the number of passengers served per unit of time), we can express the benefits received by the driver as follows:

$$E = w\mu(Q/n) \tag{45.3}$$

If we assume that there is a reservation rate R for drivers, which is consistent with the distribution $G(\cdot)$ and has a density function $g(\cdot)$. If the driver wants to serve the consumer, he needs to get more than the reservation rate, i.e., $E \geq R$. We can get the proportionality of the number of drivers: $n/N = G(w\mu(Q/n))$. Based on the above conditions, we can obtain the following equation:

$$n = NG(w\mu(Q/n)) \tag{45.4}$$

And under this equation, we can directly see that the number of drivers providing service increases with the wage rate.

45.2.1.3 Platform's Perspective

Based on the overall number of transactions we obtained $Q = \min\{D, n\}$, where D and n are represented as completed in Eqs. (45.2) and (45.3), respectively. In what follows, we need to decide the optimal pricing strategy set by the ride-hailing platform as well as the wage strategy (p^*, w^*), and the profit that the platform can obtain for every single order served is $(p - w)$. Based on this, we can express the profit maximization problem of the online taxi platform as follows:

$$\begin{aligned}
&\max\ \pi = (p - w)Q \\
&s.t.\ Q = \min\{D, n\} \\
&D = \lambda(1 - p - \gamma t^2) \\
&n = NG(w\mu(Q/n)) \\
&0 < w < p < 1 - \gamma t^2
\end{aligned} \tag{45.5}$$

On this basis, for ease of calculation, we assume that $R \sim U[0, 1]$, therefore $G(x) = x$.

Proposition 45.1

There exists the optimal solution for problem (45.5). *This optimal solution can well balance the quantities of supply and demand, i.e.,* $D = n$.

(a) *If when the demand is less than the supply, that is,* $D \leq n$, *the profit function is:*

$$\begin{aligned}
&\max\ \pi = (p - w)D \\
&s.t.\ n = Nw\mu(D/n) \\
&D \leq n \\
&0 < w < p < 1 - \gamma t^2
\end{aligned} \tag{45.6}$$

Based on problem (45.6), *by deriving, we can get* $\partial\pi/\partial w < 0$, *which means that the only way to maximize the profit of the platform is to obtain the smallest* w. *According to problem* (45.6), $n = \sqrt{Nw\mu D}$. *Based on the above analysis, we can easily prove that the case (1) is optimal when* $D = n$.

(b) *If when the demand is higher than the supply, that is,* $D \geq n$, *the profit function is:*

$$\begin{aligned}
&\max\ \pi = (p - w)n \\
&s.t.\ n = Nw\mu \\
&D \geq n \\
&0 < w < p < 1 - \gamma t^2
\end{aligned} \tag{45.7}$$

Based on problem (45.7), *by deriving, we can obtain* $\partial\pi/\partial p > 0$, *which means that the platform has to maximize the profit by obtaining the largest* p. *Based on Eq.* (45.2), D *is decreasing as* p. *To obtain the maximized* p, *it will be necessary to obtain the minimized* D. *On this basis, we have the optimal case (2) when* $D = n$.

Proposition 45.1 sufficiently shows that when consumers' waiting costs are homogeneous, the platform can always use the pricing strategy as well as the wage strategy to make the service available to riders who request rides, regardless of the volume of the market size. Based on the proof of Proposition 45.1, we can obtain the condition that $D = n$ in optimal solution, and thus problem (45.5) can be simplified to the following form:

$$\begin{aligned} &\max \pi = (p - (D/N\mu))D \\ &s.t.\, D = \lambda(1 - p - \gamma t^2) \\ &0 < w < p < 1 - \gamma t^2 \end{aligned} \tag{45.8}$$

By analyzing the derivative for problem (45.8), it allows us to obtain the optimal pricing strategy as well as the wage strategy, which will be shown in Proposition 45.2.

Proposition 45.2

When consumers' waiting costs are homogeneous, we can obtain the optimal pricing strategy for the platform as well as the optimal wage strategy, $p^*=\left(1-\gamma t^2\right)(2\lambda+N\mu)/2(\lambda+N\mu)$, $w^*=\left(1-\gamma t^2\right)\lambda/2(\lambda+N\mu)$. *And we find the relevant properties:* (i) $\partial p/\partial\lambda > 0$; (ii) $\partial w/\partial\lambda > 0$.

According to Proposition 45.2, we can see that as the market size increases, the optimal pricing strategy and wage strategy both increase, which strongly safeguards the supply and demand balance during the demand surge period and guarantees the stable operation of the ride-hailing platform. The pricing strategy implemented by the platform, as defined by Bernstein et al. [13], increases with the market size, which can be called surge pricing. Wage strategy for drivers also increases with the market size, which is also in line with the basic market economic principles (Fig. 45.2).

The gap between optimal pricing and optimal wages can be expressed in the following form: $p^* - w^*=\left(1-\gamma t^2\right)/2$, and it can be seen that the gap between optimal pricing and optimal wages remains fixed as the market size increases. This effectively shows that the platform does not want to charge extra benefits as the market size increases, and surge pricing strategy subsidizes the price increase into the driver's rising wage strategy, which is in line with the reality. For example, when the Spring Festival peaks, many ride hailing platforms offer to collect additional consumer Spring Festival bonus and fully subsidize the drivers, while the platform does not charge any difference in price.

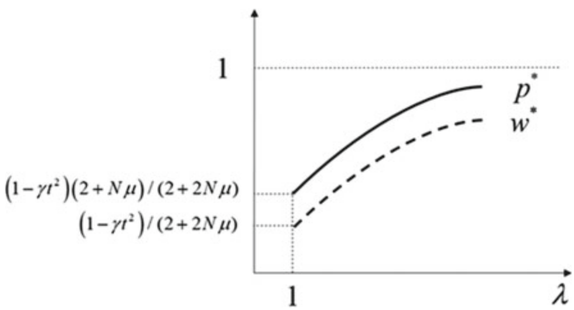


Fig. 45.2 The optimal pricing strategy and wage strategy

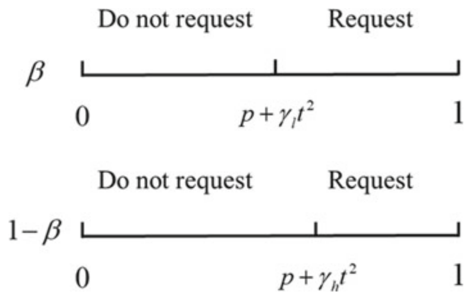


Fig. 45.3 Riders' requesting decisions based on their valuations

45.2.1.4 General Model

In the general model, we expand more on the original base model. We classify a proportion β of consumers as low waiting cost consumers, with their wait time sensitivity set to γ_l, and the rest of $(1-\beta)$ consumers with high wait cost consumers, with their wait time sensitivity set to γ_h, and both types of consumers have the same wait time t. Based on the above analysis, then the utility of high and low waiting cost consumers is shown below:

$$U_l = v - p - \gamma_l t^2 \tag{45.9}$$

$$U_h = v - p - \gamma_h t^2 \tag{45.10}$$

Similar to the base model, the riding behavior is chosen when the utility of the two types of consumers is greater than 0. The expressed hoteling line segment is shown in the following Fig. 45.3

It is important to note that, in general, platforms choose to satisfy consumers' needs as much as possible, regardless of the cost of waiting. Therefore, in this article, we assume that the platform will choose to serve both high and low waiting cost consumers. By assuming that the market size of the platform is λ, we can obtain the demand for the platform as:

$$D_e = \lambda(\beta(1 - p - \gamma_l t^2) + (1 - \beta)(1 - p - \gamma_h t^2)) \tag{45.11}$$

In such case, we can formulate the profit problem as follows:

$$\begin{aligned} &\max\ \pi = (p - (D_e/N\mu))D_e \\ &s.t.\ D_2 = \lambda(\beta(1 - p - \gamma_l t^2) + (1 - \beta)(1 - p - \gamma_h t^2)) \\ &0 < w < p < 1 - \gamma_h t^2 \end{aligned} \tag{45.12}$$

By computing the optimal result of problem (45.12), we can obtain Proposition 45.3.

Proposition 45.3
The platform can obtain the optimal pricing strategy and wage strategy (p^*, w^*), *but if the platform wants to serve consumers with high and low waiting costs together, it needs to satisfy the following conditions:*

(i) *When consumer waiting cost heterogeneity is large, i.e.,*$2\gamma_h t^2 - \gamma_l t^2 > 1$, *and there are fewer consumers with low waiting costs, i.e.,*$0 < \beta < (1 - \gamma_h t^2)/(\gamma_h t^2 - \gamma_l t^2)$, *more registered drivers are needed, i.e.,* $N > 2\beta\lambda(\gamma_h - \gamma_l)t^2/(\mu(1 - t^2((1 + \beta)\gamma_h - \beta\gamma_l)))$.

(ii) *Otherwise, as long as registered drivers exist, the platform will serve both high and low waiting cost consumers.*

By obtaining the FOC conditions of problem (45.12), *we can obtain the optimal pricing strategy for the platform as well as the wage strategy, respectively.*

$$\begin{aligned} p^* &= (2\lambda + N\mu)\big(1 - t^2((1 - \beta)\gamma_h + \beta\gamma_l)\big)/(2\lambda + 2N\mu) \\ w^* &= \big(1 - ((1 - \beta)\gamma_h + \beta\gamma_l)t^2\big)\lambda/(2\lambda + 2N\mu) \end{aligned} \tag{45.13}$$

According to case (1), we can find that if the heterogeneity of consumers' waiting cost is large, the consumer classification is more obvious, and there are fewer consumers with low waiting cost, the platform will conditionally choose to serve both types of consumers when the number of registrable drivers is sufficient. Compared to consumers with high waiting costs, consumers with low waiting costs tend to give more benefits to the platform and are able to accept price increases. Therefore, when there are fewer drivers available for the platform to dispatch and fewer low-waiting-cost consumers, the platform will choose to serve the low-waiting-cost consumers first rather than both high-waiting-cost and low-waiting-cost consumers (i.e., $p^* > 1 - \gamma_h t^2$). In all other cases, the platform can choose to serve both high and low waiting cost consumers, as long as there are registered drivers at that stage ($N > 0$).

For the properties of the pricing strategy and the wage strategy, it also increases with the market size, i.e., $\partial p^*/\partial\lambda > 0$,$\partial w^*/\partial\lambda > 0$. And, for the difference between the optimal price and the optimal wage, by calculation, we find that there is also a constant value relationship, i.e., $p^* - w^* = \big(1 - ((1 - \beta)\gamma_h + \beta\gamma_l)t^2\big)/2$, which is also explained in Proposition 45.2.

Proposition 45.4

Whether consumers have homogeneous or heterogeneous waiting costs, profit increases with the size of the market.

When riders have homogenous waiting costs, the profit expression is:

$$\pi^* = (\big(1 - \gamma t^2\big)/2)D \tag{45.14}$$

And, we can get $\partial D/\partial\lambda = n^2\left(1 - t^2\gamma\right)\mu^2/(2(\lambda + n\mu)^2) > 0$. *And we can get* $\partial\pi^*/\partial\lambda > 0$. *When the consumer waiting cost is heterogeneous, the proof process is similar to the proof above.*

For this proposition, it is an intuitive proposition. It can be clearly expressed that even if consumers need to pay a certain waiting cost, the demand and supply equilibrium can also be reached through the pricing strategy and wage strategy used by the platform, which achieves the goal of maximizing the profit.

45.3 Conclusion

This article focuses on the ride-hailing platform's riding problem under the surge of riders' demand. When demand surges, the supply and demand in the market are unevenly matched, and the platform can use pricing and wage strategies to dynamically adjust to achieve the balanced supply and demand in the market and to satisfy the requirement of profit maximization. In our study, we find that the optimal pricing and wage strategies increase with the market size regardless of whether the consumer waiting cost is homogeneous or heterogeneous, which is consistent with the surge pricing model defined by Bernstein.

When we classify consumers according to their waiting costs, we find that the platform's service strategy changes depending on the degree of consumer heterogeneity. For example, when consumer waiting cost heterogeneity is large and the proportion of low-waiting-cost consumers is small, the platform serves both types of consumers provided that the number of registered drivers is sufficient; otherwise, the platform will refuse serving both types of consumers. Finally, we find that although consumers are impacted by waiting cost, the platform can well meet the market demand by regulating consumers as well as drivers through pricing and wage strategy to achieve the supply–demand equilibrium and ensure the profit increases with the market size. The shortcoming for this article is whether the single-stage model can be expanded to N periods to be more realistic and whether the two types of consumers can be expanded to multiple types of consumers.

References

1. D. Kerr, Detest Uber's surge pricing? Some drivers don't like it either. C| NET (2015)
2. A. Rosenblat, When your boss is an algorithm. New York Times **12** (2018)
3. A. Lowrey, Is Uber's surge-pricing an example of high-tech gouging. The New York Times **1** (2014)
4. Uber, How surge pricing works (2018). [2022–12–25]. www.uber.com/drive/partner-app/how-surge-works/
5. T.A. Taylor, On-demand service platforms. Manuf. Serv. Oper. Manag. **20**(4), 704–720 (2018)
6. J. Bai, K.C. So, C.S. Tang et al., Coordinating supply and demand on an on-demand service platform with impatient customers. Manuf. Serv. Oper. Manag. **21**(3), 556–570 (2019)

7. G.P. Cachon, K.M. Daniels, R. Lobel, The role of surge pricing on a service platform with self-scheduling capacity. Manuf. Serv. Oper. Manag. **19**(3), 368–384 (2017)
8. H. Yang, C. Shao, H. Wang et al., Integrated reward scheme and surge pricing in a ridesourcing market. Transp. Res. Part B: Methodol. **134**, 126–142 (2020)
9. H. Guda, U. Subramanian, Your uber is arriving: Managing on-demand workers through surge pricing, forecast communication, and worker incentives. Manag. Sci. **65**(5), 1995–2014 (2019)
10. J. Hall, C. Kendrick, C. Nosko, *The effects of Uber's Surge Pricing: A Case Study*. The University of Chicago Booth School of Business (2015)
11. J.J. Yu, C.S. Tang, Z.J. Max Shen et al., A balancing act of regulating on-demand ride services. Manage. Sci. **66**(7), 2975–2992 (2020)
12. B. Hu, M. Hu, H. Zhu, Surge pricing and two-sided temporal responses in ride hailing. Manuf. Serv. Oper. Manag. **24**(1), 91–109 (2022)
13. F. Bernstein, G.A. DeCroix, N.B. Keskin, Competition between two-sided platforms under demand and supply congestion effects. Manuf. Serv. Oper. Manag. **23**(5), 1043–1061 (2021)

Chapter 46
Enterprise Value Evaluation of the BYD Company Based on FCFF Model

Xiaoyan Zheng, Mengsi Hu, Lixia Lai, and Jiahao Li

Abstract Objectively assessing the value of an enterprise is especially important for enterprises. It can not only help the external investors and creditors to make a correct judgment, but also play a key role in the development of the enterprise itself. This thesis will focuses on the automobile manufacturing industry, and selects The BYD Company as the research object, adopts the FCFF model of the enterprise value evaluation model to evaluate it, and obtains the appropriate evaluation value.

Keywords Enterprise value evaluation · FCFF model · Free cash flow · The BYD Company · WACC

46.1 Introduction

In recent years, the new energy automobile industry has become the focus of investors increasingly, and the key for the enterprise investment is to discover the ability of enterprises to create value in the future. The development of The BYD Company in China has been placed high expectations, investors and the public attention is very high, so it has the practical significance to evaluate the BYD Company.

X. Zheng (✉) · M. Hu · L. Lai · J. Li
College of Finance and Economics, Guangdong University of Science and Technology, Dongguan 523000, Guangdong, China
e-mail: 50383248@qq.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_46

46.2 Enterprise Value Evaluation System Based and FCFF Model

Enterprise value evaluation is to evaluate the overall value of the enterprise as a whole under the specific evaluation purpose of the base date of evaluation. At present, the methods of enterprise value evaluation mainly include: cost method, market method and income method.

The income method is to estimate the objective and reasonable price or value of the appraisal object by predicting the normal net income of the appraisal object in the future, and then selecting the appropriate rate of return or capitalization rate and the income multiplier to discount it to the time point of appraisal. It predicts the future earnings of the valuation object, and then uses the rate of return or capitalization rate, earnings multiplier to convert it into value to obtain the value of the valuation object [1].

The use of income method to evaluate the value of enterprises, mainly using free cash flow method, discounted cash flow method, economic value added method and so on.

FCFF model is often used in free cash flow method for specific evaluation.

FCFF model, whose full name is Free cash flow for the firm, was proposed by American scholar Rabaport in the 1980s. It refers to the use of company free cash flow to evaluate the whole company instead of equity. Alfred Rappaport, an American scholar, put forward the concept of free cash flow in the 1980s: the cash generated by an enterprise and remaining after meeting the reinvestment needs, which is available for distribution by capital suppliers/various interest claiors (shareholders and creditors) under the premise that it does not affect the sustainable development of the enterprise.

Considering that BYD is a large company with stable earnings, FCFF model is adopted in this paper to evaluate its enterprise value. At the same time, the specific application of the evaluation model in the automobile industry also broadens the connotation of the FCFF model.

46.3 The Profile of the Company

The BYD Co., Ltd. is mainly engaged in automobile business including new energy automobile and traditional fuel automobile, mobile phone components and assembly business, rechargeable battery and photovoltaic business, and actively expand the urban rail transit business field. The main products of the company are rechargeable batteries and photovoltaic, mobile phone components and assembly, automobile and related products. BYD is a global industry leader in the field of new energy automobile [2]. In 2019, BYD's new energy automobile product structure was further improved, and its sales volume still ranked among the top in the world.

China holds 28% of global automobile sales and more than 50% of global new-energy automobile sales [3]. At the same time, China has also built a relatively complete automobile industry chain. With the conversion of traditional automobile to electric automobile, supported by the huge domestic market of new energy automobile and the complete supply chain, China will emerge world-class outstanding automobile companies in the future. BYD is the most competitive electric automobile company in China, so it is expected to become a world-class automobile company with global competitiveness [4]. After Tesla builds a factory in China, foreign-invested/joint-venture high-end products will enrich the supply of new energy automobile, improve consumer awareness of new energy automobile, and further drive the penetration rate of new energy automobile.

BYD started with nickel-cadmium batteries business and later has branched out into lithium-ion and power batteries. In 2003, the company acquired Qinchuan Automobile Factory and formally into the automotive field. At present, the company is mainly engaged in automobile business (covering traditional fuel automobile and new energy automobile), mobile phone components and assembly business, rechargeable batteries and photovoltaic business [5]. The automobile business and mobile phone business account for more than 90% of the company's revenue, is the company's most important source of performance.

① Automobile business. The company has independently developed and mastered traditional powertrain technologies such as fuel engine and dual-clutch transmission, as well as core technologies of "Three Electric" new-energy automobile and intelligent networking technologies. The company's new energy automobile products fully cover passenger cars, buses and trucks [6].

② Mobile phone business. Its mobile phone business is dominated by BYD Electronics, which is listed on the Hong Kong stock exchange. BYD Electronics is one of the few suppliers in the world can provide both components and assembly business, with major customers including Huawei, Samsung, Apple and other global leading manufacturers [7]. In 2019, BYD sold 461,000 cars, including 231,000 fuel cars and 230,000 new energy cars. The global market share of BYD's new energy cars was 10.4% (No.2 in the world), and the domestic market share was 20% (No.1 in China) [8].

46.4 The Enterprise Value Evaluation of the BYD Company Based on FCFF Model

The most important step of the FCFF model is to determine the following three parameters: Discount Period, FCFF and Discount Rate.

46.4.1 Discount Period

The discount period is the time of profit attributable to the appraised asset. When the appraisal asset is an enterprise, the profit time is the time when the enterprise creates value. The value of an enterprise consists of the following two parts:

Enterprise value = present value of enterprise free cash flow in forecasting period + present value of enterprise free cash flow in perpetual period.

Based on the above references, this thesis takes 2022 to 2026 as the next five-years forecast period, and 2027 and subsequent years as the sustainable period of stable growth [9].

46.4.2 FCFF

FCFF is the free cash flow of a business, which is the cash flow attributable to its owners after tax. Owners include creditors and shareholders. FCFF can be calculated in the following ways:

Corporate free cash flow (FCFF) = operating income − operating costs − administrative expenses − selling expenses − taxes and surcharges − corporate income tax + depreciation and amortization − capital expenditure − working capital increase.

46.4.2.1 Operating Income

This study uses the historical average operating revenue growth rate to predict the future operating revenue, as shown in Table 46.1.

According to the previous historical income situation, the average income growth rate in the past five years is 16.79%. Based on this growth rate, the income in the next five years is predicted, as shown in Table 46.2.

Table 46.1 Historical operating income analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Growth rate	2.32%	22.85%	−1.84%	22.63%	37.99%
Average growth rate	16.79%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.2 Operating income forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Average growth rate	16.79%				
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59

Data source Own processing

Table 46.3 Historical operating cost analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Operating costs	857.80	1087.00	1069.00	1263.00	1880.00
%Revenue	81.00%	83.55%	83.71%	80.65%	87.00%
Average %revenue	83.18%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.4 Operating expense forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	83.18%				
Operating costs	2099.39	2451.89	2863.57	3344.37	3905.90

Data source Own processing

46.4.2.2 Operating Expense

Since the cost and expenses and other items maintain a certain proportion with the income, the relevant items in this study all adopt the average percentage of sales revenue method to predict the future cost and expense items, as shown in Table 46.3.

According to the analysis of the proportion of expenses in income in the past five years, it can be seen that the average proportion of expenses in income in the past five years is 83.18%. Based on the average proportion, the expenses in the next five years are predicted, as shown in Table 46.4.

46.4.2.3 Administrative Expenses

By analyzing the ratio of BYD's management expenses, it can be seen that the average ratio of management expenses in the past 5 years is 2.94%. This is the norm for car manufacturers, as shown in Table 46.5.

Based on the expense analysis in the past 5 years, the average expense ratio is used to predict the possible management expenses of BYD in the next 5 years, as shown in Table 46.6.

Table 46.5 Historical administrative expenses analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Administrative expenses	30.47	41.41	41.41	43.21	57.10
%Revenue	2.88%	3.18%	3.24%	2.76%	2.64%
Average %revenue	2.94%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.6 Administrative expenses forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	2.94%				
Administrative expenses	74.22	86.69	101.24	118.24	138.09

Data source Own processing

46.4.2.4 Selling Expenses

Sales cost is an important index of self-owned brand production enterprises. By analyzing the proportion of sales expenses and operating income of BYD in the past 5 years, it can be seen that the average proportion is 3.58%, as shown in Table 46.7.

According to the ratio of selling expenses to operating income in the past 5 years, the average value-3.58% is used to predict the possible selling expenses in the next 5 years, as shown in Table 46.8.

Table 46.7 Historical selling expenses analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Selling expenses	49.25	49.25	43.46	50.56	60.82
%Revenue	4.65%	3.79%	3.40%	3.23%	2.81%
Average %revenue	3.58%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.8 Selling expenses forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	3.58%				
Selling expenses	90.27	105.42	123.12	143.79	167.94

Data source Own processing

Table 46.9 Historical taxes and surcharges analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Taxes and surcharges	13.29	21.46	15.61	21.54	30.35
%Revenue	1.25%	1.65%	1.22%	1.38%	1.40%
Average %revenue	1.38%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.10 Taxes and surcharges forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	1.38%				
Taxes and surcharges	34.86	40.72	47.55	55.54	64.86

Data source Own processing

46.4.2.5 Taxes and Surcharges

According to the correlation between tax and income, the analysis of the proportion of tax paid to income in the past five years shows that the average value of this ratio is 1.38%, as shown in Table 46.9.

Based on the average ratio of tax to income—1.38% and the predicted business income, the tax for the next 5 years is predicted, as shown in Table 46.10.

46.4.2.6 Corporate Tax Rate

Enterprise income tax is also an important indicator of enterprise valuation. Based on the analysis of corporate income tax and sales revenue paid in the past 5 years, it can be seen that the average income tax accounted for 0.47% of business revenue, as shown in Table 46.11.

The corporate income tax rate of 0.47% is relatively low for an enterprise, but considering that many BYD products are new energy vehicles and the government

Table 46.11 Historical corporate tax rate analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Corporate tax	7.04	8.29	3.12	8.69	5.51
%Revenue	0.66%	0.64%	0.24%	0.55%	0.25%
Average %revenue	0.47%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.12 Corporate tax rate forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	0.47%				
Corporate tax	11.89	13.89	16.22	18.95	22.13

Data source Own processing

Table 46.13 Historical depreciation and amortization analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Depreciation	57.51	75.89	81.04	92.42	108.80
Amortization	13.33	18.09	14.77	30.73	29.28
Amortization of long-term deferred expenses	0.85	0.26	0.43	0.31	0.27
D and A	71.69	94.24	96.24	123.46	138.35
%Revenue	6.77%	7.24%	7.54%	7.88%	6.40%
Average %revenue	7.17%				

Data source 2017–2021 annual financial report of the BYD Company

supports them greatly, the future corporate income tax rate of 0.47% is still valid, as shown in Table 46.12.

46.4.2.7 Depreciation and Amortization

The items of depreciation and amortization include two parts: depreciation and amortization. However, since both of them maintain a certain proportion relationship with sales revenue, they are respectively predicted by the percentage of sales revenue method, and then summed up.

Depreciation and amortization = depreciation of fixed assets + amortization of intangible assets + amortization of long-term deferred expenses.

Plug the specific numbers into the formula, as shown in Table 46.13.

Based on the analysis of the ratio of past depreciation and amortization to operating income, the average value of 7.17% is used to predict the future depreciation and amortization expense, as shown in Table 46.14.

46.4.2.8 Capital Expenditures

We look at the difference between operating long-term assets and operating long-term liabilities in the statement of cash flows as follows:

Table 46.14 Depreciation and amortization forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	7.17%				
D and A	180.88	211.25	246.72	288.15	336.53

Data source Own processing

Table 46.15 Historical capital expenditures analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Long-term asset	147.77	178.42	206.27	117.74	373.44
Long-term liability	2.14	39.36	4.13	2.59	8.26
Capital expenditures	145.63	139.06	202.14	115.15	365.18
%Revenue	13.75%	10.69%	15.83%	7.35%	16.90%
Average %revenue	12.90%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.16 Capital expenditures forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	12.90%				
Capital expenditures	325.68	380.37	444.23	518.82	605.93

Data source Own processing

Capital expenditure = operating long-term assets (non-current assets) − Operating long-term liabilities (non-current liabilities).

Plug the specific numbers into the formula, as shown in Table 46.15.

According to the relationship between the past capital expenditure and the operating revenue, the average ratio of 12.9% is used to predict the future capital expenditure amount, as shown in Table 46.16.

46.4.2.9 Net Working Capital

Working capital focuses on the consumption of short-term assets and liabilities, so the difference between them is the working capital.

Operating working capital = operating current assets − operating current liabilities.

Net Working capital = Working capital of the current year − working capital of the last year.

Table 46.17 Historical working capital analysis (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Operating income	1059.00	1301.00	1277.00	1566.00	2161.00
Current asset	1026.84	1152.11	1069.67	1116.05	1661.10
%Revenue	96.96%	88.56%	83.76%	71.27%	76.87%
Average %revenue	83.48%				
Current liability	1049.97	1165.69	1080.29	1064.31	1713.04
%Revenue	99.15%	89.60%	84.60%	67.96%	79.27%
Average %revenue	84.12%				

Data source 2017–2021 annual financial report of the BYD Company

Table 46.18 Net working capital changes forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
Average %revenue	83.48%				
Current asset	2106.99	2460.76	2873.94	3356.48	3920.05
Average %revenue	84.12%				
Current liability	2122.94	2479.39	2895.69	3381.88	3949.72
Working capital	−15.95	−18.62	−21.75	−25.40	−29.67
Net working capital	35.99	−2.68	−3.13	−3.65	−4.27

Data source Own processing

Plug the specific numbers into the formula, as shown in Table 46.17.

The relationship between working capital and operating income is also closely related. Based on the proportion of previous working capital to operating income, the working capital forecast for the next 5 years is shown in Table 46.18.

46.4.2.10 FCFF

Corporate free cash flow (FCFF) = operating income − operating costs − administrative expenses − selling expenses − taxes and surcharges − corporate income tax + depreciation and amortization − capital expenditure − working capital increase.

According to the formula, the following results can be obtained, as shown in Table 46.19.

Table 46.19 FCFF forecast (unit: 100 million yuan)

Time	2022	2023	2024	2025	2026
+: Operating income	2523.84	2947.60	3442.52	4020.53	4695.59
−: Operating expense	2099.39	2451.89	2863.57	3344.37	3905.90
−: Administrative expenses	74.22	86.69	101.24	118.24	138.09
−: Selling expenses	90.27	105.42	123.12	143.79	167.94
−: Taxes and surcharges	34.86	40.72	47.55	55.54	64.86
(EBIT)	225.10	262.89	307.03	358.58	418.79
−: Corporate tax rate	11.89	13.89	16.22	18.95	22.13
+: Depreciation and amortization	180.88	211.25	246.72	288.15	336.53
(OCF)	394.09	460.26	537.53	627.79	733.20
−: Capital expenditures	325.68	380.37	444.23	518.82	605.93
−: Net working capital	35.99	−2.68	−3.13	−3.65	−4.27
(FCFF)	32.41	82.57	96.43	112.62	131.53

Data source Own processing

46.4.3 Discount Rate

Since it is the discount rate of enterprise value, we can calculate it according to the following formula:

Weighted Average Cost of Capital = Cost of Equity × Weight in Equity + Cost of Debt × Weight in Debt.

46.4.3.1 Re

The composition of Re is:

$$\text{Re} = \text{Rf} + \beta \times (\text{Rm} - \text{Rf})$$

(1) Rf

Until Dec. 31, 2021, the 5-years Treasury yield is 2.66%, which is used as the risk-free yield for this assessment.

(2) Rm

Until December 31, 2021, according to the wind database, the average market return rate of the 300×× industry in Shanghai and Shenzhen is 9.85%, which is taken as the Rm in this evaluation.

(3) β

Table 46.20 Beta coefficient

Rf	Rm	β	Re
2.66%	9.85%	1.50	13.45%

Data source Wind database

Until December 31, 2021, according to the wind database query, the beta coefficient of the enterprise is 1.5, as shown in Table 46.20.

46.4.3.2 Rd

Based on the actual situation of ×× enterprise, this assessment will take the 3–5-years loan interest rate of the People's Bank of China at the end of 2021 at 4.75% as its debt capital cost.

46.4.3.3 T

Although The BYD company is a new energy enterprise, it also has other non-new energy industries. Therefore, this assessment adopts the 25% corporate income tax rate published on the official website.

46.4.3.4 Capital Structure

Capital structure is an important index that affects the cost of capital. The capital structure of the enterprise in the past 5 years is analyzed according to its financial report, as shown in Table 46.21.

Table 46.21 Capital structure analyse (unit: 100 million yuan)

Time	2017	2018	2019	2020	2021
Capital	1780.99	1945.71	1956.41	2010.17	2957.80
Equity	599.57	606.94	626.01	644.54	1042.44
Equity%	33.66%	31.19%	32.00%	32.06%	35.24%
Debt	1181.42	1338.77	1330.40	1365.63	1915.36
Debt%	66.34%	68.81%	68.00%	67.94%	64.76%

Data source 2017–2021 annual financial report of the BYD Company

Table 46.22 WACC

Time	2017	2018	2019	2020	2021
Re	13.45%				
We	33.66%	31.19%	32.00%	32.06%	35.24%
Rd	4.75%				
Wd	66.34%	68.81%	68.00%	67.94%	64.76%
T	25%				
WACC	6.89%	6.65%	6.72%	6.73%	7.05%
Average WACC	6.81%				

Data source Own processing

46.4.3.5 WACC

According to the analysis of relevant parameters affecting WACC in the past five years, the average value of WACC index is 6.81%, as shown in Table 46.22.

This value can be used for the future valuation analysis of BYD.

46.4.4 Calculation of Evaluation Value

Two-stage evaluation model:

Enterprise value = present value of enterprise cash flow in forecasting period V1 + present value of enterprise cash flow in perpetual period V2.

$$V = \sum_{i=1}^{n} \frac{FCFF_i}{1 + WACC^i} + \frac{FCFF_{n+1}}{WACC - g \times 1 + WACC^n}$$

The revenue growth rate of FCFF in 2027 and beyond is relatively stable. We use the average of GDP growth rate of previous years by 4.5%.

46.4.4.1 Present Value of Earnings at Forecast Period

$$V_1 = \sum_{i=1}^{n} \frac{FCFF_i}{1 + WACC^i}$$

$$= \frac{32.41}{1 + 6.81\%} + \frac{82.57}{1 + 6.81\%^{\ 2}} \frac{96.43}{1 + 6.81\%^{\ 3}} \frac{112.62}{1 + 6.81\%^{\ 4}} \frac{131.53}{1 + 6.81\%^{\ 5}}$$

46.4.4.2 Present Value of Perpetual Income

$$V_2 = \frac{FCFF_{n+1}}{WACC - g \times 1 + WACC^{n}} = \frac{131.53 \times 1 + 4.5\%}{6.81\% \text{ - } 4.5\% \times 1 + 6.81\%^{\ 5}}$$

46.4.4.3 After Calculation, the Overall Enterprise Value of the BYD Company is

$$\text{V} = \text{V1} + \text{V2} = 36.303 + 428.60 = 464.903 \text{ (billion RMB)}$$

46.5 Conclusion

Through the above evaluation, it can be seen that the BYD Company's enterprise valuation is 464.903 billion RMB, which is equivalent to the market value, which verifies the rationality of FCFF model [10]. In the specific evaluation process, we found that the BYD Company had excellent operating performance in the past, which led to a more optimistic value estimate in the future. However, due to the decrease of fertility rate after the epidemic in China, whether they will affect the future enterprise value is not reflected in FCFF, which is also the deficiency of this model. Further research should be conducted in the future.

In terms of corporate investment, BYD is known to be the leader of new energy automobile in China. Power batteries account for up to 40% of the cost of new energy automobile, which have become a key component of automobile manufacturers. BYD is a rare new-energy automobile company that can supply its own power batteries. In the past, CATL focused on three-way lithium batteries, and BYD is focused on lithium iron phosphate batteries [11]. With the new energy subsidies to high mileage (high energy density battery) and the market demand for high energy density battery, terre lithium battery has gradually become the preferred choice for passenger cars, and BYD has quickly completed the switch from lithium iron phosphate to terre lithium battery. In addition to profound accumulation in the field of power batteries, BYD also has unique advantages in design, plug-in hybrid technology, E platform and so on. The company's future performance growth lies in: new energy automobile market growth, power battery external supply, IGBT domestic replacement, mobile phone business development. The development of the enterprise also greatly responds to China's basic national policy of reaching carbon peak by 2030 and carbon neutrality by 2060. To sum up, BYD is a potential stock worthy of long-term investment.

By using FCFF model to evaluate BYD's enterprise value, the application connotation of FCFF model is broadened. However, due to limited space, it fails to take into account the impact of non-financial indicators on enterprise value. Follow-up research should enrich these deficiencies.

References

1. H. Tan, Enterprise value evaluation based on free cash flow discount model. Intern. Audit. China **02**, 96–101 (2016)
2. Takács, Ulbert, Fodor, Have investors learned from the crisis? An analysis of post-crisis pricing errors and market corrections in US stock markets based on the reverse DCF model. Appl. Econ. **52**(20) (2020)
3. M. Kopacz, J. Kulpa, D. Galica, P. Olczak, The influence of variability models for selected geological parameters on the resource base and economic efficiency measures—example of coking coal deposit. Resour. Policy **68** (2020)
4. T. Quill, Valuation techniques under construction—about the dissemination of the CAPM in German judicial valuation. Schmalenbach Bus. Rev. **72**(3) (2020)
5. E.-M. Nichita, Intangible assets—insights from a literature review. J. Account. Manag. Inf. Syst. **18**(2) (2019)
6. D. Xue, S. Tao, Thought on contemporary architectural regionalism from the perspective of construction. World Sci. Res. J. **7**(8) (2021)
7. Y. Shen, Evaluation of enterprise investment value based on principal component analysis: information transmission, software and information technology services in China. Acad. J. Eng. Technol. Sci. **3**(7) (2020)
8. Y. Gong, Performance evaluation of commercial banks based on EVA—take ICBC for example. J. Financ. Res. **4**(1) (2020)
9. K. Sylwia, Impact of capital structure on corporate value—review of literature. J. Risk Financ. Manag. **14**(4) (2021)
10. M.N. Kaloshina, Business valuation based on RAS and IFRS. J. Phys.: Conf. Ser. **1515**(3) (2020)
11. Y. Lei, H. Wang, Y. Guan, Research on the comprehensive budget management system based on EVA model. J. Innov. Soc. Sci. Res. **7**(7) (2020)

Chapter 47
DWT-CNN-TRANS: High Frequency Stock Prediction Model Based on Improved Transformer

Guangwei Yang, Xianghui Yuan, and Zongze Li

Abstract In recent years, many researchers and investors have used the latest machine learning and deep learning techniques for financial time series prediction and classification problems. How to avoid overfitting and improve the prediction performance of deep learning algorithms is a hot issue of concern for many researchers. In this paper, a LOB-based high-frequency prediction model DWT-CNN-TRANS is proposed based on the features of high-frequency order books. The DWT-CNN-TRANS first inputs the time-series data into a transformer based on the convolutional self-attentive mechanism for feature extraction, then performs a DWT transform on the time-series data to obtain low-frequency features, uses multi-layer multi-scale convolution for feature extraction, and finally inputs the extracted features into MLP for modelling. Using high-frequency data of six Chinese stocks with multiple deep learning models such as the base transformer on different prediction cycles respectively, the experimental results show that the algorithm proposed in this paper can significantly improve the prediction performance.

Keywords Transformer · Wavelet transform · Convolutional network · High-frequency forecasting · Multilayer perceptron

47.1 Introduction

With the continuous development of the financial sector, researchers and investors are currently showing great interest in the patterns of financial product price movements [1]. The ability to accurately predict the price of a financial product plays a very important role in whether or not an investor achieves a significant return. However,

G. Yang (✉)
School of Software, Xi'an Jiaotong University, Xi'an 710001, Shaanxi, China
e-mail: 2406077734@qq.com

X. Yuan · Z. Li
School of Economics and Finance, Xi'an Jiaotong University, Xi'an 710001, Shaanxi, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_47

there are many factors that affect the price of financial products, in addition to many common technical and deterministic indicators, there are also many non-smooth and highly stochastic indicators, which makes the problem of financial product price forecasting a hot issue that is attracting more and more attention from researchers and investors [2]. As quantitative investment technology is developing faster and faster, machine learning and deep learning techniques are frequently used to predict the change of prices, which has achieved more and more widespread applications. Zhang et al. [3] used a support vector machine (SVM) to predict the future trend of listed company stocks and found that the prediction accuracy of the model was higher than that of traditional neural network classification methods. Akita et al. [4] compared a long-short-term memory (LSTM) network with a traditional neural network and found that the LSTM had good fitting performance for stock series data. Peng et al. [5] performed wavelet noise reduction during data pre-processing based on LSTM network, the prediction effect was improved. Kim and Han [6] combined genetic algorithm (GA) and ANN to perform data mining on the input feature matrix and used the model in the field of stock prediction. Alberg and Lipton [7] used manually extracted earnings data of US companies by features to predict a company's fundamental data five years out. They used a variety of deep neural networks to build the model and developed corresponding investment strategies based on the prediction results, where the proposed model based on multilayer perceptron (MLP) outperformed the benchmark model by 2.7%. Zhang et al. [8] and Hu and Qi [9] replaced the memory units in the LSTM with a state frequency matrix, giving the model the ability to mine the features of different frequencies, and the LSTM with the replacement of memory cells has higher performance in predicting the US stock market compared to the traditional LSTM model.

Transformer is a deep learning model proposed by Google on arxiv in June 2017 which aims to solve the problem of sequence to sequence. Instead of LSTM, transformer used a full-Attention structure, which abandoned the previous traditional encoder-decoder model, and it's not necessary for transformer to combine RNN or CNN. By using the self-attention mechanism, Transformer completely eliminates the horizontal propagation of the traditional RNN and only propagates in the vertical direction, simply by overlaying the self-attention layers. By this means, on top of the accelerated GPU, each layer can be computed in parallel. Transformer is able to achieve better performance without using of sequence-aligned recurrent architectures, simply by using self-attention and Feed Forward Neural Network. Transformer was initially applied mainly in natural language processing (NLP), but was later gradually applied to various fields, such as intelligent robotics, computer vision, time series prediction and engine recommendation, and achieved better results.

Although Transformer has achieved good performance in many areas, in particular its ability to model sequences makes it naturally more suitable for data structures such as time series, which are also sequence types. However, time series have many characteristics that differ from text series, such as autocorrelation and periodicity, and time series prediction often involves very long-period sequence prediction tasks. These present new challenges for the application of Transformer in time series prediction scenarios, and thus a group of researchers has emerged to adapt Transformer for time series tasks. Wu et al. [10] proposed decomposing time series into trend and seasonal terms, and used the autocorrelation coefficient of the time series to find the most correlated segments of the time series. Liu et al. [11] proposed a tree-structured Transformer to solve the long-period time series forecasting problem. Zhou et al. [12] proposed calculating attention score scoring distribution and uniformly distributed KL scatter for each query, forming a structure of sparse attention, which can significantly enhance computational efficiency. Lim et al. [13] used the LSTM + Transformer approach, where the time series is first input into the LSTM, and then the sequential modeling capability of the LSTM replaces the original LSTM's sequential modeling capability during the approach.

In order to overcome the problems of transformer in time series prediction and improve the performance of the transformer in high frequency stock prediction, this paper proposes an improved algorithm based on the convolutional self-attention mechanism and wavelet transform. First, transformer is optimised using the convolutional self-attention mechanism, which generates Q and K at the self-attention layer through convolution. Matching Q and K in the perceived local context can help the model achieve lower training loss and thus improve prediction accuracy. On the other hand, in order to better learn the global trend characteristics of the stock data, this paper applies the Discrete Wavelet Transform (DWT) into the model. The DWT is used to decompose the signal into low-pass and high-pass coefficients, and then the low-pass coefficients are used to reconstruct the signal so as to remove the high-frequency noise and obtain the low-frequency signal, and then the multi-layer and multi-scale convolution is used to extract features for the low-frequency signal, finally the two parts of features are combined to predict the future trend. In this paper, the performance of the proposed algorithm is verified on high-frequency data from six stocks by comparing it with the traditional transformer algorithm and other algorithms, and the experimental results show that the proposed algorithm outperforms the compared algorithms.

The rest of the paper is structured as follows. Section 47.2 briefly describes the basic transformer algorithm. Section 47.3 describes the proposed algorithm DWT-CNN-TRANS in detail. Section 47.4 reports and analyses the comparison results with the transformer algorithm as well as with other algorithms. Section 47.5 summarises the findings of the paper and suggests future research directions.

47.2 Basic Transformer Algorithm

The basic transformer discards the CNN and RNN, and the entire network structure consists entirely of the attention mechanism, which achieves the prediction of time series through the encoder-decoder structure. The network structure is shown in Fig. 47.1.

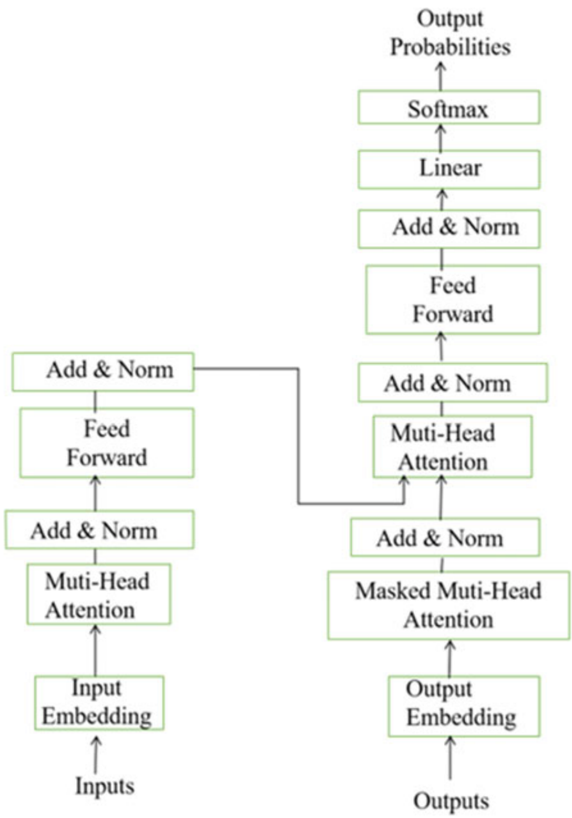


Fig. 47.1 Structure of the transformer

47.2.1 Network Structure

The basic transformer model consists of two main parts: the encoder and the decoder.

Encoder: There are two sub-layers in Encoder, one is the multi-head attention layer, which is used to learn the relationships within the source series using self-attention. The other one is the feed forward layer, it is a simple fully connected network, and it performs the same operation on each position vector, including two linear transformations and a ReLU activation function, and then produces the encoder output to be passed to the decoder. The encoding process is computed in parallel, which is a significant improvement in efficiency compared to the original encoder-decoder model. The structure is shown in Fig. 47.2.

Decoder: There are three sub-layers in the decoder, two of which are multi-head attention layers. The attention layer uses self-attention to learn the relationships within the target series, after which the output of this layer is fed to the upper attention layer. For this Attention, query represents the output of the previous step of decoder, and key and value are the output from encoder. It is worth mentioning here that the decoding process is generated step by step like an RNN, since the output of the

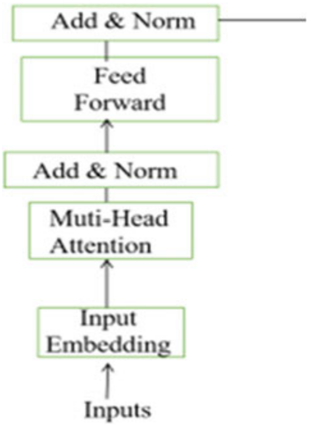


Fig. 47.2 Structure of the encoder

previous position is used as the query for this position's attention. Finally a feed forward layer, similar to the encoding part, is passed through to obtain the output of the decoder. The network structure is shown in Fig. 47.3.

47.2.2 Main Operations

Multi-head self-attention: the attention mechanism used by the transformer is formulated as follows, Q, K, V are the matrices of query, key, value respectively, divided by $\sqrt{d_k}$ is for better numerical operations.

$$\mathrm{Attention}(\mathrm{Q}, \mathrm{K}, \mathrm{V}) = \mathrm{softmax}\left(\frac{\mathrm{QK}^{\mathrm{T}}}{\sqrt{\mathrm{d_k}}}\right)\mathrm{V} \tag{47.1}$$

The multi-head attention mechanism is equivalent to having multiple sets of such attention mechanisms, extracting different relationships between Q, K, V and finally stitching the results together. Transformer also adds a different linear transformation layer for each set of attention mechanisms to handle Q, K, V. There is a scaled dot-product attention module, where scale refers to the division by $\sqrt{d_k}$, and the purpose of the scale operation is to make the softmax results more obvious.

The operation of multi-headed attention mechanism firstly performs an expand operation: uses a linear transformation that generates three vectors of Q, K and V; then a split operation that divides the original 512 dimensions of each position into eight heads, each with 64 dimensions; after that, a self-attention is performed; finally, the results of the self-attention of all the heads are stitched together.

Mask: Certain values are masked by Mask. In this case, when the parameters are updated, these values do not have an effect. Two types of mask are involved in transformer, the padding mask and the sequence mask. Padding mask operation

Fig. 47.3 Structure of the decoder

usually adds a very large negative number (negative infinity) to the value of these positions. And the probability of these positions will be close to 0 after softmax and will not affect the attention result. The sequence mask is the first multi-head attention layer in the decoder, we need to add a mask module into it. This is to make the future information invisible to the decoder.

47.3 Improved Algorithm

47.3.1 Network Architecture

In the beginning the data is pre-processed and relevant features are calculated. During training, the data is fed into the model, firstly, the time-series data is input into transformer based on the convolutional self-attentive mechanism for feature extraction, and the output of the feature map is obtained; then the feature map is mean-pooled to obtain feature 1, The DWT transform is applied to the time-series data to obtain

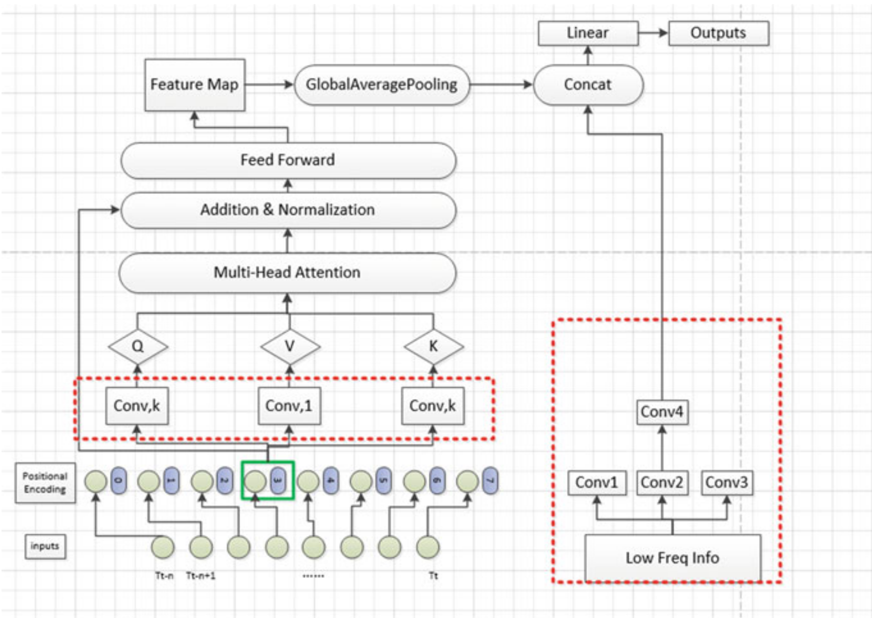


Fig. 47.4 Structure of improved algorithm

low-frequency features, followed by feature extraction using multi-layer multi-scale convolution to obtain feature 2. Combined with features 1 and 2, the combined feature is fed into the MLP network to make predictions on future data. During testing, the output of the network is compared with the real stock values and the network performance is evaluated by different metrics. The network architecture is illustrated below as Fig. 47.4.

47.3.2 Convolutional Transformer Module

In financial markets, the phenomenon of price increases and decreases in financial time series may evolve significantly over time due to various political, economic, cultural and social contingencies. In the self-attention layer of the basic transformer, the similarity between queries and keys is calculated based on their point-by-point values without making full use of contextual information, which results in poor training performance of the self-attention module and posing potential optimisation problems.

The convolutional transformer network is a network that uses convolutional multi-headed attention mechanism instead of attention mechanism used in the basic transformer. The main structure of the convolutional transformer consists of several modules including dilated causal convolution, convolutional multi-headed attention mechanism, feed-forward neural network, residual connectivity and layer normalisation. It is shown in the Fig. 47.5. The algorithm learns financial time series contextual information by incorporating a convolutional self-attentive mechanism, while using a layer normalisation network and a residual connectivity network to enhance network convergence and mitigate problems such as gradient disappearance due to increasing network depth.

The network structure starts with positional encoding of the input high frequency financial time series. The positional encoding is given by sine and cosine functions of different frequencies.

$$\mathrm{PE}_{(\mathrm{pos},2\mathrm{i})} = \sin(\mathrm{pos}/10000^{2\mathrm{i}/\mathrm{d}_{\mathrm{model}}}) \tag{47.2}$$

$$\mathrm{PE}_{(\mathrm{pos},2\mathrm{i}+1)} = \cos(\mathrm{pos}/10000^{2\mathrm{i}/\mathrm{d}_{\mathrm{model}}}) \tag{47.3}$$

In the above equation, d denotes the dimension of the output embedding space, pos denotes the data position in the input sequence, where $0 \leq \mathrm{pos} \leq \mathrm{L}/2$, i is used to map to column indices, where $0 \leq \mathrm{i} < \mathrm{d}/2$, and individual values of i are also mapped to the sine and cosine functions. The sine function is used for even positions and the cosine function for odd positions.

In this paper, we use the inflated convolutional self-attentive mechanism to learn node sequence information around financial time series. Inflated causal convolution can be seen as a combination of two types of convolution, causal and inflated convolution. The core of causal convolution is that events occurring before moment t can have an effect on events after moment t, and vice versa. In signal processing, to ensure that future information is never accessible at the current location, a filter is designed so that the output passing through it is related only to past and present inputs. Let the input sequence $\mathrm{X} = (\mathrm{x}_1, \mathrm{x}_2, \ldots, \mathrm{x}_\mathrm{t})$, and the filter $\mathrm{A} = (\mathrm{a}_1, \mathrm{a}_2, \ldots, \mathrm{a}_\mathrm{t})$, then the causal convolution at moment t is shown in equation:

$$(A * T)_t = \sum_{n=1}^{N} a_k x_{t-N+n} \tag{47.4}$$

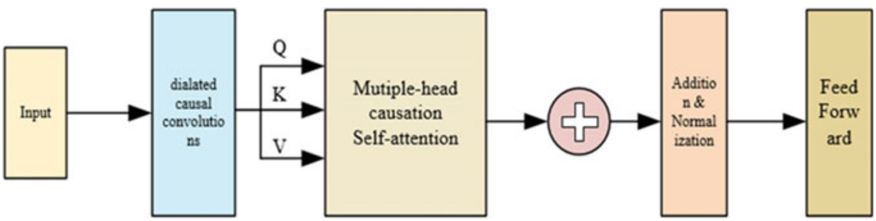


Fig. 47.5 Structure of convolutional transformer module

In basic CNN, the problem of information loss by pooling to expand the receptive field often arises and is overcome in the paper using dilation convolution. Dilated convolution uses an expansion factor d, to determine the size of the kernel spacing during convolution, which is the distance between every two convolved kernels in the receptive field. In the absence of a pooling layer, more information is obtained by increasing the kernel spacing to expand the receptive field. For a sequence X, the expanded convolution at moment t is shown in equation, where m is the expansion factor, and when m = 1, it is the standard CNN.

$$(A * T)_t = \sum_{n=1}^{N} a_k x_{t-m(N-n)} \tag{47.5}$$

Combining the causal convolution with the inflated convolution gives us the inflated causal convolution. Instead of using a kernel size 1 with step size 1 (matrix multiplication), we use an inflated causal convolution of kernel size k with step size 1 to transform the input with appropriate padding into queries and keys using the inflated convolution self-attentive mechanism to learn node sequence information. To prevent the appearance of future functions, this inflated causal convolution is to ensure that the current position can never access future information. By using inflated causal convolution, the generated queries and keywords can be more aware of the series, and their similarity can be computed from information around the sequence rather than point-by-point values, which helps in accurate prediction. When k = 1, the convolutional self-attentive mechanism degenerates to a general self-attentive mechanism. The convolutional multi-headed attention mechanism is shown as Fig. 47.6.

In order to normalise the values after a certain number of layers picking up the normalisation layer, so that the feature values are within a reasonable range. In this paper, layer normalisation is used, and the formula for layer normalisation is shown as below.

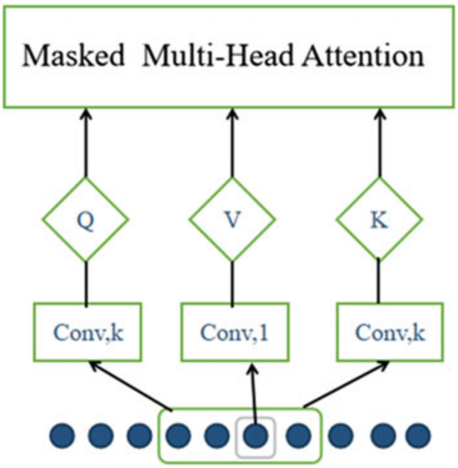


Fig. 47.6 Convolutional multi-headed attention mechanism

$$y = \frac{x - E[x]}{\sqrt{Var[x] + \epsilon}} * \gamma + \beta \tag{47.6}$$

where x denotes the original value, E[x] denotes the mean of the original value, Var[x] denotes the standard deviation of the original value, ϵ is a very small quantity and usually defaults to 10^{-5}, β, γ are parameters and defaults to $\gamma = 1$ and $\beta = 0$.

In this paper, a residual block X is added to the data obtained by the convolutional attention mechanism. The purpose of adding the residual block X is to prevent degradation problems during the training of the deep neural network, whose network structure is shown in Fig. 47.7.

It can be seen that X is the input to this layer of the residual block, also known as F(X) for the residual, X is the input value, and F(X) is the output after the first layer has been linearly changed and activated. The figure indicates that in the residual network, F(X) is added to this layer of the input value X before the second layer is activated after the linear change, and then the output is activated. The path where X is added before the second layer output value is activated is called a shortcut connection. The formula for this is shown as below:

$$X^{(l)} = F(X^{(l-1)}) + X^{(l-1)} \tag{47.7}$$

In order to extract features more deeply, the network structure proposed in this paper uses a feed-forward neural network, whose input is the data obtained after the output of the convolutional self-attention has been layer-normalised and residual-connected, and then feed-forward does two linear transformations in order to extract

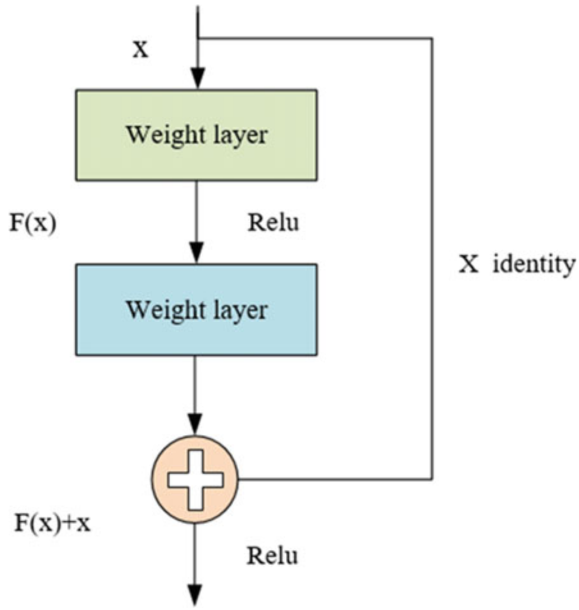


Fig. 47.7 Structure of residual block

features more deeply. A non-linear activation function Relu, is introduced in each linear transformation. In the convolutional multi-headed attention mechanism, matrix multiplication is mainly performed, which means they are all linear transformations, feed-forward is calculated as follows:

$$\mathrm{FFN(x)} = \max(0, \mathrm{xW_1} + \mathrm{b_1})\mathrm{W_2} + \mathrm{b_2} \tag{47.8}$$

In the formula, max is equivalent to the Relu function. Feed-forward maps the data to the high latitude space and then to the low latitude space through a linear transformation in this process, which eventually extracts the deeper features. The final output is fed into the feature map and global_average_pooling to finalise the feature extraction.

47.3.3 Wavelet Transform Module

In order to better learn the trend features in high frequency financial time series, this paper designs a wavelet feature extraction module for the data characteristics of LOB. The module mainly consists of wavelet decomposition and reconstruction and well-designed multi-scale convolution layers.

The wavelet transform is a time–frequency analysis method for signals and is well suited to analysing non-stationary signals and extracting local features of the signal. Common forms of wavelet transform are continuous wavelet transform (CWT), discrete wavelet transform (DWT), etc. In this paper, the discrete wavelet transform is used to process high frequency financial data and obtain low frequency information features.

The Discrete Wavelet Transform (DWT) is the term used in relation to the Continuous Wavelet Transform (CWT), where the scale parameter a and the time shift parameter b are discretized, i.e. a and b are discretized, but t is still continuous.

The continuous wavelet transform is expressed as follows:

$$\varphi \mathrm{f(a,b)} = \int_{-\infty}^{+\infty} \mathrm{f(t)}\overline{\varphi}_{\mathrm{a,b}}(t)dt \tag{47.9}$$

In this module, the wavelet decomposition of the original sequence is first performed to obtain the wavelet coefficients for each layer.

As shown in the Fig. 47.8, a signal x of length N is decomposed at the first level into a high-frequency part D1 and a low-frequency part A1, both of length N/2; the second level decomposes A1 into a high-frequency part D2 and a low-frequency part A2, both of length N/4,and so on. The sum of the lengths of all the results obtained by the decomposition remains N. For example, one level of decomposition gives D1 and A1 (two sequences of length N/2), and two levels of decomposition give D1, D2 and A2 (N/2 + N/4 + N/4).

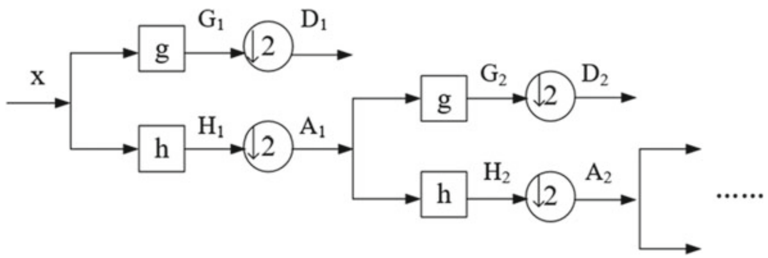


Fig. 47.8 Process of wavelet decomposition

The information is then subjected to wavelet reconstruction. The wavelet reconstruction process is the opposite of the wavelet decomposition process. The one-dimensional reconstruction function is the opposite of the one-dimensional decomposition function, first up-sampling the low-frequency coefficients and filling in the missing zeros in the sampling process, then doing a low-pass convolution with the wavelet reconstruction and finding the high-frequency coefficients first from the reconstructed results. The high-frequency coefficients are then sampled and a high-pass convolution is done. In the same way as the decomposition, the new signal should be equal to the high-frequency plus the low-frequency coefficients, and then the new signal is reconstructed at the next level to finally obtain the low-frequency information.

The obtained low-frequency information is first extracted by three convolutional kernels for multi-scale feature extraction, and the features extracted by the three convolutions are converged, and then a convolutional conv4 is used for the final feature extraction.

47.3.4 The MLP Layer

The DWT-CNN-TRANS model uses features extracted with improved transformer and wavelet transform, which are fed into a multi-layer perceptron MLP. The MLP is an artificial neural network which is forward-structured. It maps a set of input vectors to a set of output vectors. The MLP consists of multiple node layers, each fully connected to the next, and it can be seen as a directed graph. Each node is a neuron with a non-linear activation function besides the input nodes. Compared to the single-layer perceptron, MLP overcomes the weakness of the single-layer perceptron in its inability to recognise linearly indistinguishable data. As a result, the model has better performance for time-series data, and it can take into account both the continuity of the data series and the data itself, so it has better capture of the extracted features.

Table 47.1 Stock high frequency dataset information

Stock	002371.SZ	300059.SZ	000858.SZ	300760.SZ	300750.SZ	600436.SH
Tick quantity	1,051,298	1,151,412	1,147,845	1,032,408	1,133,909	1,012,037
Lowest price	133.53	26.44	357.00	502.00	691.5	491.88
Highest price	452.56	40.56	192.50	276.36	280.1	240.15

47.4 Experiment

47.4.1 Datasets

The experimental data set for this section is Shanghai Stock Exchange and Shenzhen Stock Exchange level-2 quotes, each tick interval of 3 s, order book depth of 5 steps, and exclude the data of the early pool bidding (9:15–9:25) and the late pool bidding (14:57–15:00). In this paper, six stocks are selected: 002371.SZ, 300059.SZ, 000858.SZ, 300760.SZ, 300750.SZ and 600436.SZ, the data of all trading days from 1 January 2021 to 31 December 2021 are selected. The specific quantities are shown in Table 47.1.

47.4.2 Feature Engineering

In this paper, the basic share price data are selected, such as bid price p_b, ask price p_a, volume of pending orders from buyers v_a and pending orders from sellers v_b. In addition, the following features are also been selected:

Volume Order Imbalance (VOI): was proposed by Shen [14] and defined t as the moment when an order arrived or an order was filled, with the bid price and buy volume denoted by $p_t^B(s)$ and $v_t^B(s)$ respectively, and similarly the ask price and sell volume denoted by $p_t^A(s)$ and $v_t^A(s)$ respectively, between two consecutive order books, from the order state at moment $t-1$ to the order state at moment t. The indicators of each moment was defined as below:

$$\delta V_t^A(s) = \begin{cases} V_t^A(s) P_t^A(s) < P_{t-1}^A(s) \\ V_t^A(s) - V_{t-1}^A(s) P_t^A(s) = P_{t-1}^A(s) \\ 0 P_t^A(s) > P_{t-1}^A(s) \end{cases} \tag{47.10}$$

$$\delta V_t^B(s) = \begin{cases} 0 P_t^B(s) < P_{t-1}^B(s) \\ V_t^B(s) - V_{t-1}^B(s) P_t^B(s) = P_{t-1}^B(s) \\ V_t^B(s) P_t^B(s) > P_{t-1}^B(s) \end{cases} \tag{47.11}$$

$$OI_t(s) = \delta V_t^B(s) - \delta V_t^A(\mathrm{s}) \tag{47.12}$$

V_t^B (s) and V_t^A(s) are the bid and ask volumes for s-level at time t respectively, P_t^B and P_t^A are the bid and ask quotes for s-level at time t respectively. δV_t^B denotes the incremental volume of orders to buy.

Depth imbalance (DR): Introduced by Cao et al. [15], the indicator is a measure of the current price capacity to withstand shocks and is based on the formula shown as below:

$$DR_t(s) = \frac{V_t^B(s) - V_t^A(s)}{V_t^B(s) + V_t^A(s)}, \mathrm{s} = 1, 2, \ldots, 5 \tag{47.13}$$

Height Imbalance (HR): This indicator was also proposed by Cao et al. in 2009 and its formula is shown as below:

$$HR_t(s) = \frac{(P_t^B(s) - P_{t-1}^B(s)) - (P_t^A(s) - P_{t-1}^A(s))}{(P_t^B(s) - P_{t-1}^B(s)) + (P_t^A(s) - P_{t-1}^A(s))}, \mathrm{s} = 2, 3, 4, 5 \tag{47.14}$$

Pressure: according to the distance between the pending order price and the middle price to give different weights to different gears of the commission order, so as to weight the volume and build pressure indicators, define the weight of the s-level pending orders as:

$$w_s = \frac{M_s/(p_S - M_s)}{\sum M_s/(p_S - M_s)} \tag{47.15}$$

where M is the mid-quote, and combined with the commissioned volume for each level, this gives bid and offer side pressures for each stock as:

$$press_{buy} = \sum vol_s^B \frac{M_s/(p_s^B - M_s)}{\sum M_s/(p_s^B - M_s)} \tag{47.16}$$

$$press_{sell} = \sum vol_s^A \frac{M/(p_s^A - M)}{\sum M/(p_s^A - M)} \tag{47.17}$$

Use the log difference between buying and selling pressure as an indicator of buying and selling pressure:

$$P = log(press_{buy}) - log(press_{sell}) \tag{47.18}$$

In the experiment, the number of features L at each moment is 35, $\mathrm{x_t} = \left[\mathrm{p_a^{(s)}}, \mathrm{p_b^{(s)}}, \mathrm{v_a^{(s)}}, \mathrm{v_b^{(s)}}, \mathrm{voi^{(s)}}, \mathrm{dr^{(s)}}, h\mathrm{r^{(s)}}, \mathrm{pressure}\right]$, where s = 1,2,3,4,5.

Table 47.2 Server configuration

Type	Configuration
CPU	Intel(R) Xeon(R) Silver 4214 CPU @ 2.20 GHz *2
Memory	128 GB
Graphics cards	RTX 3080Ti(12 GB) *4
OS	Ubuntu 20.04.4
Software	Python3.8 + Tensorflow2.6.0 + CUDA10.0

47.4.3 Experimental Design

The experiment was programmed in python and implemented based on tensorflow. The training of the model was done on a server with the relevant configurations shown in Table 47.2.

In the experiment, the time window for each sample was taken as T = 100, it was used to predict the change in the next k = [20, 60, 100] ticks, which means the change in the next 1, 3 and 5 min. The training batch size was set to 128, the number of epochs was set to 100, and the initial learning rate was set to 5e−3, decreasing as the number of iterations increased, with the learning rate for the last 20 epochs set to 1e−5. Adam's algorithm was used for training.

In the experiment, in order to better analyse the model, three indicators are set to evaluate the model effect, namely MSE (Mean Square Error), MAE (Mean Absolute Error) and R^2. They are calculated as follows:

$$\mathrm{MSE} = \frac{1}{\mathrm{n}}\sum_{\mathrm{t}=1}^{\mathrm{n}}\left(\hat{y}_{t+k} - \mathrm{y}_{\mathrm{t+k}}\right)^2 \tag{47.19}$$

$$\mathrm{MAE} = \frac{1}{\mathrm{n}}\sum_{\mathrm{t}=1}^{\mathrm{n}}\left|\hat{y}_{t+k} - \mathrm{y}_{\mathrm{t+k}}\right| \tag{47.20}$$

$$R^2 = 1 - \frac{\sum_{\mathrm{t}=1}^{\mathrm{n}}\left(\hat{y}_{t+k} - \mathrm{y}_{\mathrm{t+k}}\right)^2}{\sum_{\mathrm{t}=1}^{\mathrm{n}}\left(\overline{y}_{t+k} - \mathrm{y}_{\mathrm{t+k}}\right)^2} \tag{47.21}$$

where MSE is the mean variance and MAE the mean absolute difference. R^2 indicates the degree to which the model results explain the true results, higher values of R^2 show better results.

47.4.4 Experimental Results and Analysis

This section will illustrate the effectiveness of each module in the network on the stock dataset and the different parameters on the performance of the overall algorithm.

Impact of adding convolutional self-attention. In order to verify the effect of the improved convolutional transformer in the DWT-CNN-TRANS model on the overall performance of the model, the following experiment was designed. The wavelet transform module in the DWT-CNN-TRANS model was removed and the features were directly learned using the improved convolutional transformer and then input into the MLP, which was named as CNN-TRANS. In this experiment, the above six stocks are still selected as the dataset and used as evaluation indicators. From Table 47.3, we can see that the R^2 of the CNN-TRANS model is higher than that of the TRANS model, which means the CNN-TRANS model fits the data better, and the MSE and MAE of the CNN-TRANS model are smaller than those of the TRANS model, indicates that its prediction error is reduced and its prediction accuracy is higher, which proves that the performance of the model has been improved after adding the convolutional self attention has improved the performance of the model.

Impact of wavelet transform module. This section focuses on verifying the impact of the addition of the wavelet module to the DWT-CNN-TRANS model on the overall performance of the model. In this experiment, the above six stocks are still selected as the dataset and used as evaluation indexes to compare the CNN-TRANS model with the DWT-CNN-TRANS model to analyse the impact on the model after the introduction of the wavelet module. From Table 47.4, it can be seen that the R^2 of the DWT-CNN-TRANS model is higher than that of the CNN-TRANS model, which means that the CNN-TRANS model fits the data better, and the MSE and MAE of the DWT-CNN-TRANS model are smaller than those of the CNN-TRANS model, which indicates that its prediction error is reduced and the accuracy of the prediction is higher. The prediction accuracy is higher, proving that the performance of the model has been improved by adding the wavelet transform.

High-frequency stock price prediction graph. Based on the prediction results, this section plots the effect of using the past 100 ticks to predict the future stock price for 20, 60 and 100 ticks respectively and the true stock price in the original model, CNN-TRANS, and DWT-CNN-TRANS, using 002371.SZ and 300760.SZ as examples. It can be seen from Figs. 47.9, 47.10, 47.11, 47.12, 47.13, and 47.14 that DWT-CNN-TRANS has the smallest difference from the true value and get the best prediction performance.

47.5 Conclusion

In this paper, a high frequency stock prediction algorithm with improved transformer is proposed. Firstly, the time-series data is input to the transformer based on the convolutional self-attention mechanism for feature extraction, then the wavelet transform is applied to the time-series data to obtain low frequency features, and the multi-layer multi-scale convolution is used for feature extraction, and finally the extracted features are input to the MLP for modelling. The prediction capability of the algorithm is compared with the comparison algorithm at 20, 60 and 100 tick cycles respectively on tick-level data of 6 stocks, and the results show that compared

Table 47.3 Results from TRANS and CNN-TRANS

Stock	Model	K = 20			K = 60			K = 100		
		MSE	MAE	R^2	MSE	MAE	R^2	MSE	MAE	R^2
002371.sz	TRANS	5.609	2.083	0.985	17.516	3.814	0.955	62.541	7.546	0.843
	CNN-TRANS	3.995	1.598	0.989	15.031	3.483	0.961	30.712	4.781	0.921
300059.sz	TRANS	0.159	0.384	0.906	0.033	0.163	0.981	0.342	0.857	0.952
	CNN-TRANS	0.009	0.078	0.994	0.013	0.091	0.992	0.042	0.174	0.975
000858.sz	TRANS	0.416	0.494	0.992	0.779	0.677	0.986	0.664	0.596	0.988
	CNN-TRANS	0.678	0.712	0.988	0.601	0.600	0.989	0.629	0.575	0.989
300760.sz	TRANS	3.496	1.781	0.967	5.870	2.265	0.944	5.167	2.007	0.951
	CNN-TRANS	0.596	0.606	0.994	2.498	1.308	0.976	2.503	1.261	0.976
300750.sz	TRANS	89.928	9.133	0.927	131.098	10.957	0.893	227.168	14.648	0.815
	CNN-TRANS	94.743	9.502	0.923	77.616	8.386	0.937	209.009	14.043	0.830
600436.sh	TRANS	23.181	4.567	0.907	15.551	3.653	0.938	114.731	10.527	0.540
	CNN-TRANS	56.095	7.305	0.775	49.238	3.463	0.802	16.623	3.521	0.933

Table 47.4 Results from CNN-TRANS and DWT-CNN-TRANS

Stock	Model	K = 20			K = 60			K = 100		
		MSE	MAE	R^2	MSE	MAE	R^2	MSE	MAE	R^2
002371.sz	CNN-TRANS	3.995	1.598	0.989	15.031	3.483	0.961	30.712	4.781	0.921
	DWT-CNN-TRANS	1.381	1.0461	0.996	1.102	0.762	0.997	2.425	1.2025	0.994
300059.sz	CNN-TRANS	0.009	0.078	0.994	0.013	0.091	0.992	0.042	0.174	0.975
	DWT-CNN-TRANS	0.002	0.032	0.998	0.009	0.076	0.995	0.011	0.071	0.993
000858.sz	CNN-TRANS	0.678	0.712	0.988	0.601	0.600	0.989	0.629	0.575	0.989
	DWT-CNN-TRANS	0.230	0.417	0.996	0.244	0.306	0.996	0.445	0.449	0.992
300760.sz	CNN-TRANS	0.596	0.606	0.994	2.498	1.308	0.976	2.503	1.261	0.976
	DWT-CNN-TRANS	0.322	0.402	0.996	1.361	0.937	0.987	1.793	1.034	0.983
300750.sz	CNN-TRANS	94.743	9.502	0.923	77.616	8.386	0.937	209.009	14.043	0.830
	DWT-CNN-TRANS	3.283	1.591	0.997	3.453	1.335	0.997	5.491	1.653	0.996
600436.sh	CNN-TRANS	56.095	7.305	0.775	49.238	3.463	0.802	16.623	3.521	0.933
	DWT-CNN-TRANS	0.929	0.745	0.996	2.836	1.294	0.989	4.261	1.496	0.983

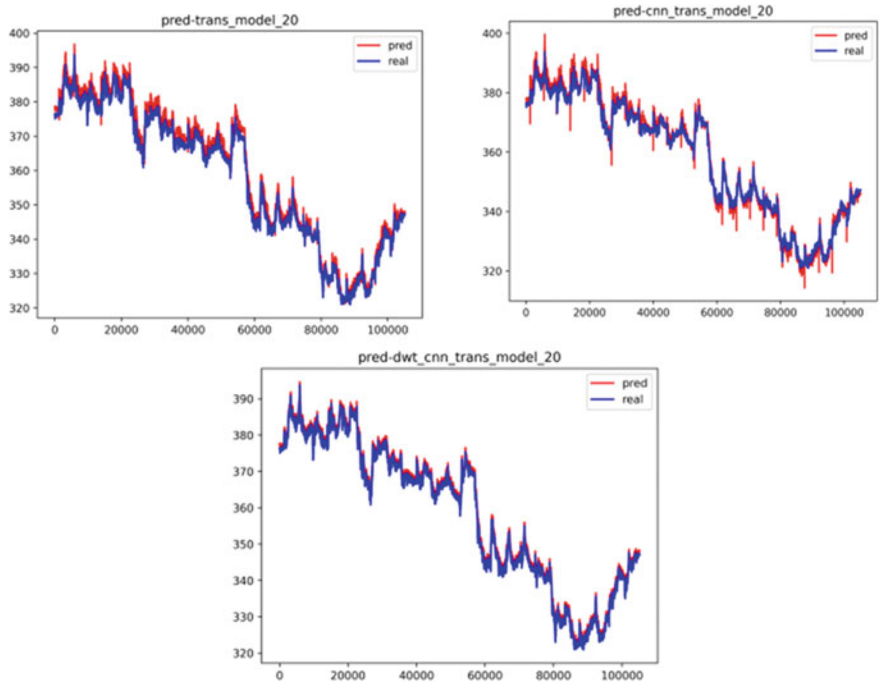


Fig. 47.9 Stock price forecast comparison (002371.sz K = 20)

with the comparison algorithm, the algorithm proposed in this paper has smaller prediction error, higher prediction accuracy and significantly improved prediction performance, which has certain engineering value. It is proved that the model can extract the characteristic information of high-frequency order book better, reduce the noise, obtain the trend information, and greatly improve the ability of high-frequency order book stock price prediction.

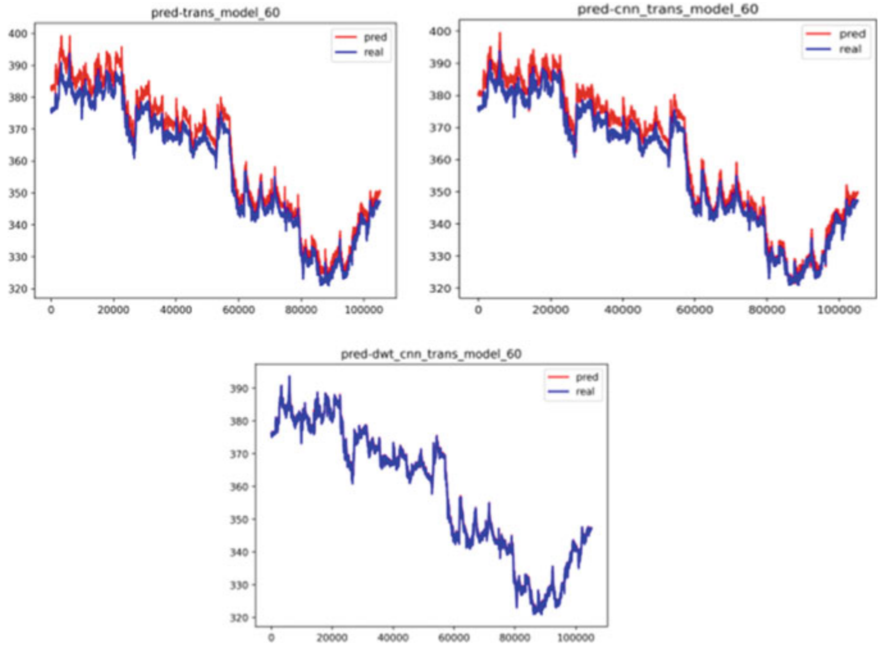


Fig. 47.10 Stock price forecast comparison (002371.sz K = 60)

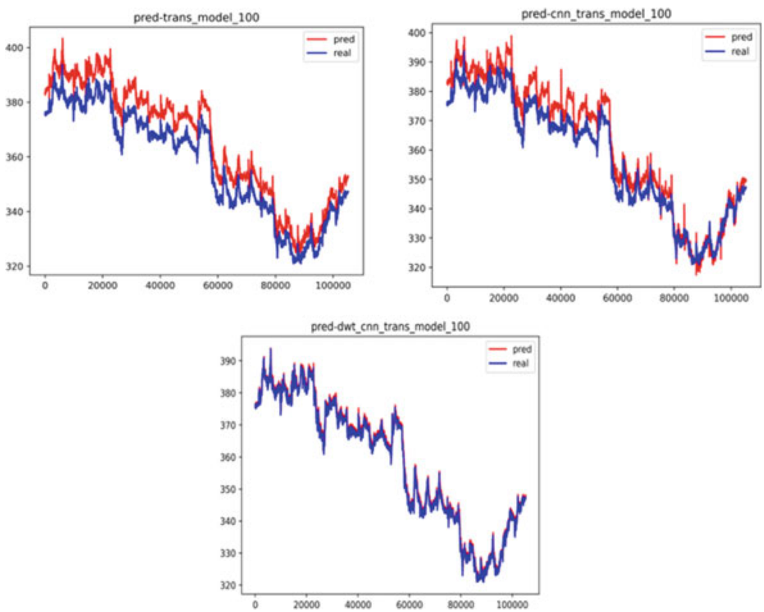


Fig. 47.11 Stock price forecast comparison (002371.sz K = 100)

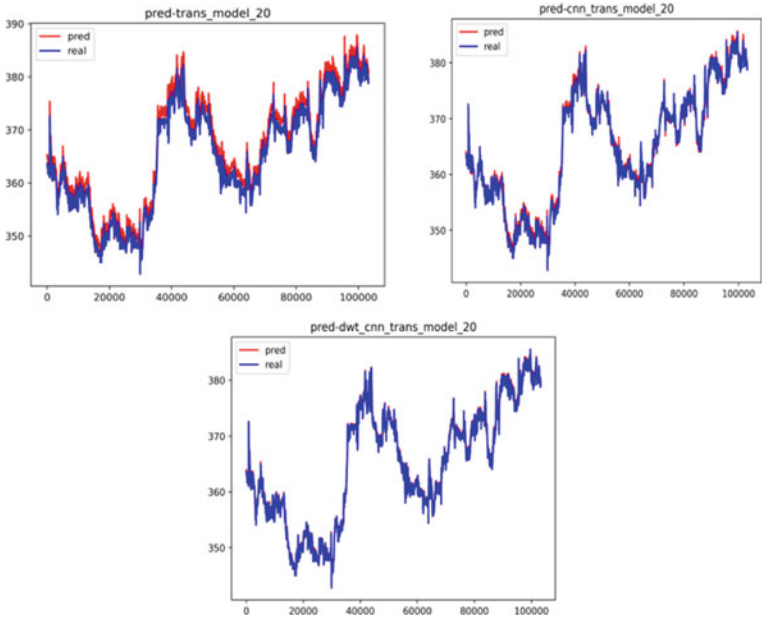


Fig. 47.12 Stock price forecast comparison (300760.sz K = 20)

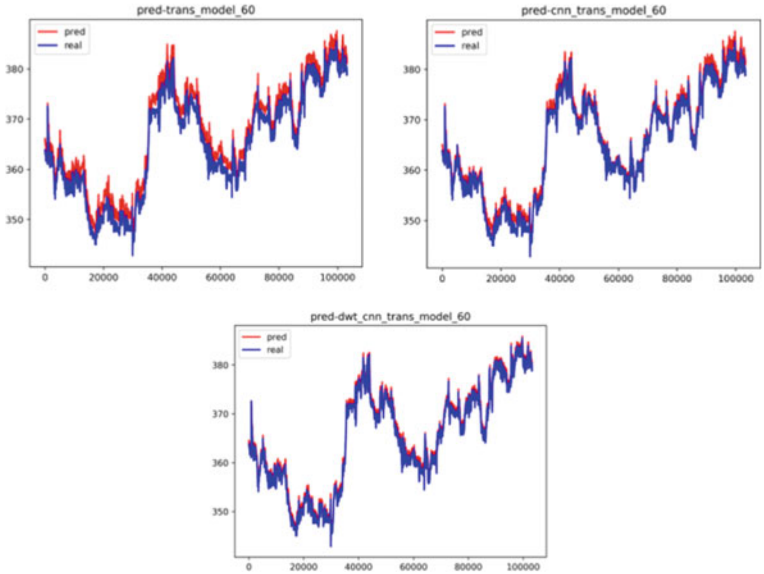


Fig. 47.13 Stock price forecast comparison (300760.sz K = 60)

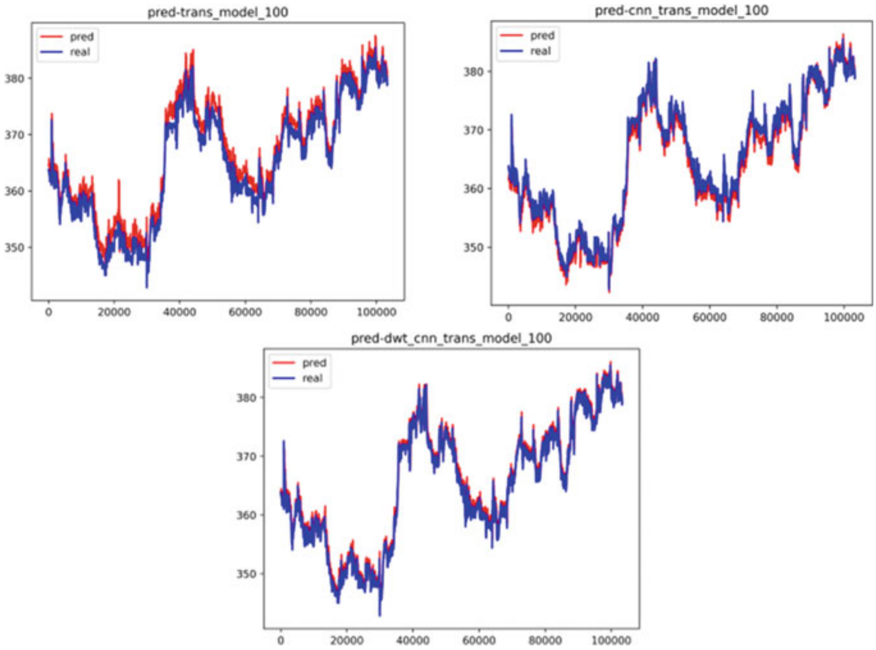


Fig. 47.14 Stock price forecast comparison (300760.sz K = 100)

References

1. A. Ntakaris, M. Magris, J. Kanniainen et al., Benchmark dataset for mid-price forecasting of limit order book data with machine learning methods. J. Forecast. **37**(8), 852–866 (2018)
2. Y. Xu, S.B. Cohen, Stock movement prediction from tweets and historical prices, in *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics*, vol. 1: Long Papers (2018), pp. 1970–1979
3. C. Zhang, Y. Zhang, Y. Zhang, Stock forecasting based on support vector machine. Comput. Technol. Dev. (6), 35 (2006)
4. R. Akita, A. Yoshihara, T. Matsubara et al., Deep learning for stock prediction using numerical and textual information [EB/OL] (2016-07-26), https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7550882. Accessed 23 Mar 2021
5. Y. Peng, Y. Liu, R. Zhang, LSTM-based stock price prediction modelling and analysis. Comput. Eng. Appl. **55**(11), 209 (2019)
6. K. Kim, I. Han, Genetic algorithms approach to feature discretization in artificial neural networks for the prediction of stock price index. Expert Syst. Appl. **19**(2), 125–132 (2000)
7. J. Alberg, Z.C. Lipton Improving factor-based quantitative investing by forecasting company fundamentals. arXiv preprint arXiv:1711.04837 (2017)
8. L. Zhang, C. Aggarwal, G.J. Qi, Stock price prediction via discovering multi-frequency trading patterns, in *Proceedings of the 23rd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (2017), pp. 2141–2149
9. H. Hu, G.J. Qi, State-frequency memory recurrent neural networks, in *International Conference on Machine Learning* (PMLR, 2017), pp. 1568–1577

10. H. Wu, J. Xu, J. Wang, M. Long, Autoformer: decomposition transformers with auto-correlation for long-term series forecasting, in *International Conference on Machine Learning* (PMLR, 2017), pp. 1568–1577
11. S. Liu, H. Yu, C. Liao, J. Li, Pyraformer: low-complexity pyramidal attention for long-range time series modeling and forecasting, in *International Conference on Machine Learning* (PMLR, 2017), pp. 1568–1577
12. H. Zhou, S. Zhang, J. Peng, S. Zhang, Informer: beyond efficient transformer for long sequence time-series forecasting, in *International Conference on Machine Learning* (PMLR, 2017), pp. 1568–1577
13. B. Lim, S. Arık, N. Loeff, T. Pfister, Temporal fusion transformers for interpretable multi-horizon time series forecasting, in *International Conference on Machine Learning* (PMLR, 2017), pp. 1568–1577
14. D. Shen, Order imbalance based strategy in high frequency trading (2015)
15. C. Cao, O. Hansch, X. Wang, The information content of an open limit-order book. J. Futur. Mark. **29**(1), 16–41 (2009)

Chapter 48
Selection of Export Models of Cross-Border E-commerce Platforms Based on the Improved AHP Algorithm

Xiudan Huang and Yecheng Yu

Abstract In recent years, with the rapid development of Internet technology and network technology, Chinese traditional trading companies and domestic trading companies are vigorously developing their own cross-border e-commerce (EC). In order to meet the needs of small, high-frequency and fast cross-border EC transactions, most cross-border EC companies outsource their export business. Therefore, it is very necessary to choose a suitable export method rationally. Based on the existing theories, this paper conducts an empirical analysis of Enterprise A, and analyzed export methods such as special regional exports, general exports, cross-border EC B2B direct exports, and cross-border EC exports to overseas warehouses; when establishing a export service supply evaluation index system, priority is given to export service supply; therefore, in the selection of export methods, the matrix method is first used to analyze it and combine it with service accessibility and AHP. The experimental results show that the highest overseas warehousing score is 78.705, which is the most suitable export model for the current development of Enterprise A. Therefore, it is particularly important to use the improved AHP algorithm to study the selection of Cross-border EC export models for cross-border EC platforms.

Keywords Cross-border EC · Export model · Improving AHP algorithm · Model evaluation · Overseas warehousing

X. Huang (✉)
Liaoning Vocational and Technical College of Economics, Shenyang, China
e-mail: 459286694@qq.com

Y. Yu
Shenyang Sport University, Shenyang, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_48

48.1 Introduction

With the acceleration of the process of global economic integration, the process of China's accession to the WTO has also entered a period of transition, and China's development will become more complicated [1]. The current situation of China's foreign trade is grim, and the call for deepening internal reforms is getting higher and higher. The traditional trade model has become more and more difficult to adapt to the diversified needs of consumers [2, 3]. In cross-border EC, foreign trade enterprises must choose appropriate export methods when conducting trade business. At the same time, reasonable export methods can also improve export costs, export service responsiveness, customer experience, and customer satisfaction [4]. The upgrading of China's industrial structure and economic transformation are already an important development direction. With the rapid development of network technology, cross-border EC has become more and more widely used in international trade [5]. Cross-border EC is a new type of international trade form. It has many advantages that traditional trade models do not have. It has important practical significance for traditional foreign trade enterprises to upgrade, improve the level of foreign trade, and reduce trade barriers.

At present, because cross-border EC involves the import and export of commodities, it is affected by many policies and regulations, which has led to some special requirements for the recommendation system, which makes the traditional collaborative filtering recommendation algorithm for cross-border EC recommendation is aimed at this problem. On this basis, Xiang D combined fuzzy association rules and composite preferences to establish a simple and efficient personalized recommendation algorithm for cross-border and cross-border EC. Under the constraints of fuzzy association rules, using the user's complex preference characteristics, a hybrid recommendation model is established, which is used to mine the user's preferences, so as to realize personalized product recommendations [6]. Gregory G D's research is based on the perspective of resources (RBV) and analyzes how cross-border EC affects our country's export performance. He designed and tested a relationship structure used to determine the resource/capability-market effectiveness-performance of cross-border EC. There is evidence that professional cross-border EC marketing capabilities can directly improve the sales and communication efficiency of enterprises, and therefore improve the performance of export risk markets [7]. EliaS explored the business opportunities created by digital output to promote companies to use digital technology in the B2C digital market. The study used a unique set of data to cover 102 companies of different sizes in Italy to study how their resources can be globalized digitally. Because compared with traditional export managers, companies that hire cross-border EC managers are more willing to engage in the output of digital products, regardless of the size of the company [2]. However, the above studies only roughly introduce the export model of cross-border EC on the surface, and they are not in-depth and need to be improved.

In this paper, the research results of the last year are further analyzed and presented in Table 48.1.

Table 48.1 Literature review statistics

Author	Time	Method	Result
Jiang [12]	2022	DANP technique	When consumers choose cross-border import e-commerce platforms, products and experience are the most prominent factors, service and risk are effective factors, and risk has the greatest impact
Mu [13]	2022	Bayesian model	The research results can help enterprises intuitively identify risk reduction factors and develop effective risk control schemes, so as to reduce the risk of CBEC logistics
Li [14]	2022	Deep learning	An improved topic model is proposed to solve the feature extraction problem of recommendation system text

In the process of decision-making, enterprises are often affected by subjective factors, resulting in less objective and reasonable decision-making results. Therefore, a more scientific and effective method is needed to make decisions. The purpose of this paper is to apply the analytic Hierarchy process (AHP) to the actual decision-making process of enterprises, so as to provide quantitative indicators of enterprise decision-making, so as to effectively manage enterprises. By improving the influence of traditional single AHP method based on subjective evaluation on EC platform evaluation results, this method makes the whole evaluation process more objective and reasonable, and improves the scientific nature and accuracy of decision making.

48.2 Cross-Border EC Platform Export Method

48.2.1 Cross-Border EC Platform Export Model

Export from special areas. This model is based on the comprehensive free trade zone and other special customs supervision zones, and implements a preferential policy of "tax refund when entering the zone" for cross-border EC enterprises (except for the free trade zone), which improves the utilization rate of corporate funds and reduces logistics costs [8].

General export. After overseas customers place orders and pay, the relevant enterprises transmit electronic data such as electronic transactions, collection, logistics, etc. to the customs, which reviews the "Declaration List", releases it after inspection, and then transfers it to overseas consumers through international transportation, overseas distribution, etc. Enterprises implement the customs clearance procedures of "list approval and summary declaration"; in the comprehensive pilot zone of cross-border EC, the customs clearance of "list approval and summary statistics" is implemented for foreign trade import and export goods that meet the requirements; for goods that do not involve export tax refunds, export tax refunds and license management, and the single amount is less than 5,000 yuan, the declaration can be simplified according to the 4-digit tax number [9].

B2B direct export. After a domestic enterprise enters into a transaction with an overseas enterprise through a cross-border EC platform, it directly exports the goods to the overseas enterprise through cross-border logistics [10].

Export to overseas warehouses. Domestic companies first ship their products to overseas warehouses, then trade on cross-border EC platforms, and then deliver them to overseas buyers from overseas warehouses [11].

The B2B direct export and overseas warehouse model allows goods to be delivered directly to overseas companies or to overseas warehouses first, and then shipped after the actual transaction is completed, which greatly reduces logistics costs and the final price drops accordingly; it provides convenience for the accurate identification and statistics of B2B export models in various countries, and provides convenience for the formulation of relevant policies by business, finance, taxation, foreign exchange and other departments.

48.2.2 Improved AHP Algorithm

Establish a hierarchical model. Through in-depth understanding of specific problems, determine the scope of the problem and the inherent relationship of the problem elements, divide by the meaning of the tree in the data structure, and design a hierarchical model of the target problem. An Enterprise selects the export model as shown in Fig. 48.1.

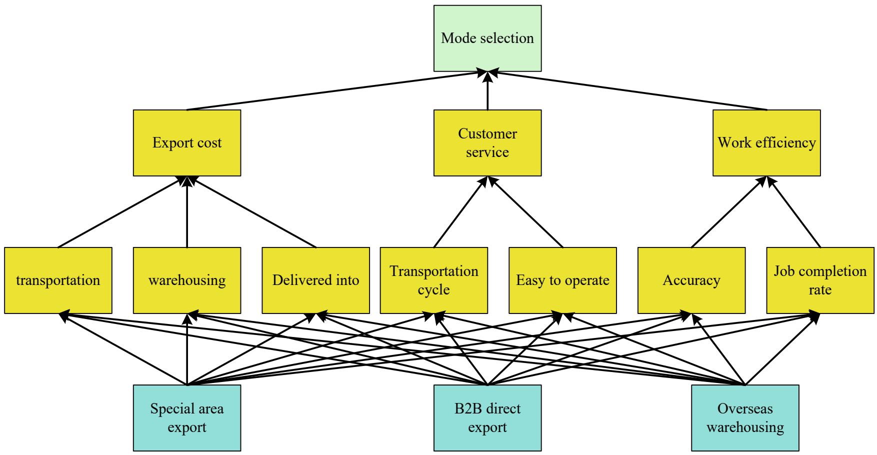


Fig. 48.1 A diagram of the export model selected by the enterprise

Construct a judgment matrix. In the hierarchical analysis method, the judgment matrix is constructed by comparing the importance of each criterion in each level pairwise. It is shown in Table 48.2.

Hierarchical single row and consistency inspection. Hierarchical sorting is to calculate the degree of importance of an element related to an element in the previous level based on the judgment matrix. The specific steps of the square root method used in this article are as follows:

Calculate the product a_i of each row:

$$a_i = \prod_{j=1}^{b} d_{ij}(i, j = 1, 2, ...,) \tag{48.1}$$

Calculate the root of b:

$$\overline{w_i} = \sqrt[b]{a_i} \tag{48.2}$$

Normalize the vector w:

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{b} \overline{w_i}} \tag{48.3}$$

Finally, the maximum characteristic root obtained is:

$$d_{\max} = \sum_{i=1}^{b} \frac{(BW)_i}{bW_i} \tag{48.4}$$

According to the knowledge of linear algebra, in order to check whether the structure of the judgment matrix is correct, a consistency test is required, that is, the consistency index CI and the random consistency ratio CR are calculated.

$$CI = \frac{d_{\max} - b}{b - 1} CR = \frac{CI}{RI} \tag{48.5}$$

Table 48.2 Judgment matrix

	D1	D2	…	Db
D1	d11	d12	…	d1b
D2	d21	d22	…	d2b
…	…	…	…	…
Db	db1	db2	…	dbb

When $CR \leq 0.1$, it is judged that the data in the matrix is reasonable and meets the consistency test.

Since the calculation of information entropy is based on objective data, the introduction of information entropy in the AHP model can effectively reduce the impact of human perception and experience. Entropy weighting method quantifies the information of evaluation indicators under objective circumstances. Using the entropy weighting method, the evaluation index is assigned to the evaluation matrix in order to obtain the weight of each index.

The entropy weight w_j^2 obtained by the information entropy method reflects the objective relationship between the evaluation attributes obtained from the statistical data on the basis of the effectiveness of the supplier, but it lacks the subjective intention of the decision maker. Therefore, organically combining the subjective weight of AHP with the objective weight of information entropy can make the evaluation results more objective and reasonable.

Finally, the comprehensive evaluation value of the program is calculated as follows:

$$s_i = \sum_{j=1}^{a} w_j p_{ij} (i = 1, 2, ...b) \tag{48.6}$$

Among them, si is the scoring value of the *i*-th export supplier, w_j is the comprehensive weight, and Pij is the specific score of the *i*-th supplier in the *j*-th scoring index.

48.3 Cross-Border EC Platform Model Data Collection

According to the model, an expert scoring table is made. In this article, the internal decision-making level of A company, industry experts and customer representatives are invited to score the questionnaire survey of this model.

First, the scoring form will be sent to all experts and customers by e-mail, and all of them will be recycled. The scoring principle is: compare the importance of these two indicators and score the corresponding scores, or the professionals will score based on their own experience (the scoring range is 2, 4, 6, 8).

Second, the recovered data is sorted out, and finally the scoring table is recovered, and each index is compared with EXCEL to obtain the corresponding average value to determine the weight of each evaluation matrix.

Third, the same method is used for the data processing of secondary indicators, that is, to organize the scores of each scoring table corresponding to the comparison of indicators to obtain the average value.

48.4 Cross-Border EC Export Results and Discussion

48.4.1 Cross-Border EC Export Strategy

Improved export customs clearance. Build a shared information platform for customs clearance and tax refunds for cross-border EC exports in China through information technology, so that cross-border EC enterprises, third-party cross-border EC platforms, and logistics enterprises can all share the customs clearance of goods exports on the same platform, reduce the customs clearance process, and reduce the time cost and logistics cost of cross-border EC enterprises' exports.

Establish a market supervision system. Accelerate the establishment of an international trade dispute mediation mechanism to provide foreign trade enterprises with a sound policy basis and regulations; it is necessary to adapt to the export form of Chinese foreign trade enterprises and continuously conduct market supervision over them so that they can meet the needs of China's foreign trade development, so as to form a set of advanced international trade supervision system in line with the current situation.

Optimize product categories. The first is to conduct a comprehensive analysis of the data of the cross-border EC platform, based on these data, to understand the positioning of the enterprise and the positioning of the platform, and to select the export product category by analyzing the sales types of the cross-border EC platform, the characteristics of the overseas customer base connected by the cross-border EC platform, etc.; The second is to conduct a comprehensive investigation of the current situation of the industry, collect relevant industry information, and analyze and select the types of exported commodities to make them richer; the third is to have a comprehensive understanding of the needs of customers and provide customized products for different consumers and importers. These products are difficult to buy overseas, and they are also Can provide customized products for overseas consumers and importers.

EC Export Model Selection. First of all, a total of 200 questionnaires were put into the internal and external of Enterprise A, 194 valid answers were recovered, and the scores of the 194 questionnaires corresponding to the transportation cycle indicators were added, and then divided by 194 to obtain the mean score of the transportation cycle indicators.

The second step is to multiply the corresponding weights of each factor by the corresponding scores of each Export mode, and sum the corresponding factors of each Export mode to obtain the corresponding scores of different Export modes as shown in Table 48.3.

Therefore, we have concluded that the highest score for overseas warehousing is 78.705, which is also the best Export model for the development of Enterprise A. Although the best solution has been obtained through mathematical models and quantitative methods, in practice, only one Export method cannot be considered.

Table 48.3 EC Export model selection scoring table

	Special area export	General export	B2B direct export	Export overseas warehouse	78.705
Transportation cost	0.062	60	65	85	5.27
Storage cost	0.094	60	65	80	7.52
Delivery cost	0.120	70	70	75	9
Transportation cycle	0.150	75	70	75	11.25
Easy to operate	0.085	75	65	70	5.95
Accuracy	0.119	70	75	85	10.115
Job completion rate	0.370	60	75	80	29.6

Because of the needs of the market, there will be many uncontrollable factors, such as goods transported abroad, such as delays in shipping, which will affect customer satisfaction.

48.5 Conclusions

This article comprehensively analyzes the main export models of major domestic cross-border EC companies. It is mainly divided into special regional exports, general exports, cross-border EC B2B direct exports, and cross-border EC exports to overseas warehouses. Among them, the growth trend of exports from special regions is particularly obvious. Through the combination of application-level analysis method and information entropy, this paper successfully evaluates, screens, and verifies online EC companies. However, the disadvantage of this article is that we can only select companies of a certain scale as cases, and it is impossible for a large number of multinational EC companies to appear as they are now. At the same time, due to various reasons, it is difficult for many family workshop-style cross-border EC companies to quantify and model all the data. In addition, as merchants, cross-border EC companies need to continuously adjust the optimal solutions according to customer needs in the actual operation process, so as to achieve the improvement of customer satisfaction. Future application directions could consider expanding the case scale to cover more multinational e-commerce companies, and explore how to quantify and model the data of cross-border e-commerce companies in the form of family workshops. At the same time, since cross-border e-commerce companies, as merchants, need to constantly adjust the optimal solution according to customer demand to improve customer satisfaction, future research can also consider how to better achieve this goal.

References

1. Q. Yuan, The construction mechanism and algorithm of cross border E-commerce export logistics mode from the perspective of value chain. J. Intell. Fuzzy Syst. **37**, 3393–3400 (2019)
2. S. Elia, M. Giuffrida, M.M. Mariani, S. Bresciani, Resources and digital export: an RBV perspective on the role of digital technologies and capabilities in cross-border e-commerce. J. Bus. Res. **132**, 158–169 (2021)
3. M. Mishra, S. Chatterjee, Application of analytical hierarchy process (AHP) algorithm to income insecurity susceptibility mapping—A study in the district of Purulia. India Soc.-Econ. Plan. Sci. **62**, 56–74 (2018)
4. C. Xinping, Influence factors of material parameters of police protection equipment based on AHP-fuzzy algorithm. Agro Food Ind. Hi Tech. **28**, 1982–1986 (2017)
5. S. Ahmed, R.F. Ibrahim, H.A. Hefny, Mobile-based routes network analysis for emergency response using an enhanced Dijkstra's algorithm and AHP. Int. J. Intell. Eng. Syst. **11**, 252–260 (2018)
6. D. Xiang, Z. Zhang, Cross-border EC personalized recommendation based on fuzzy association specifications combined with complex preference model. Math. Probl. Eng. **2020**(4), 1–9 (2020)
7. G.D. Gregory, L.V. Ngo, M. Karavdic, Developing e-commerce marketing capabilities and efficiencies for enhanced performance in business-to-business export ventures. Ind. Mark. Manag. **78**, 146–157 (2019)
8. Z. Yuan, J. Wang, L. Zhao, M. Gao, An MTRC-AHP compensation algorithm for Bi-ISAR imaging of space targets. IEEE Sens. J. **20**, 2356–2367 (2019)
9. L. Jiang, Y. Li, C. Jiang, Employment competitiveness of college students based on improved AHP. Eur. J. Math. Sci. Technol. Educ. **13**, 5225–5232 (2017)
10. Q. Zheng, X. Tian, M. Yang, H. Su, The email author identification system based on support vector machine (SVM) and analytic hierarchy process (AHP). IAENG Int. J. Comput. Sci. **46**, 178–191 (2019)
11. M. Li, G.H. Luo, C.L. Jiang, Y. Hao, Algorithm of networked ammunition attack decision-making based on AHP-TOPSIS. Beijing Ligong Daxue Xuebao/Trans. Beijing Inst. Technol. **37**, 1315–1320 (2017)
12. H. Jiang, Y. Lin, X. Luo, T. Shao, Understanding the selection of cross-border import e-commerce platforms through the DANP and TOPSIS techniques: a multi-study analysis. J. Glob. Inf. Technol. Manag. **25**, 26–53 (2022)
13. W. Mu, Analysis and warning model of logistics risks of cross-border e-commerce. Discret. Dyn. Nat. Soc. **2022**, 1–10 (2022)
14. L. Li, Cross-border e-commerce intelligent information recommendation system based on deep learning. Comput. Intell. Neurosci. **2022** (2022)

Chapter 49
Design of Pricing Decision Algorithm for Cross-Border E-business Import Supply Chain Based on Deep Learning

Xingzhi Li, Haolong Zhang, and Wei Zheng

Abstract Driven by big data, cross-border e-business is expanding its market scale and increasingly highlighting its position in international trade competition. The rapid development of cross-border electronic commerce has broken through the barriers between countries, made international trade move towards borderless trade, and caused great changes in world economy and trade. This paper studies the supply chain optimization of cross-border e-business import enterprises, and puts forward the pricing decision algorithm of cross-border e-business import supply chain based on deep learning, so as to help cross-border e-business make better use of its own advantages and make up for its own shortcomings based on the characteristics of supply chain platform. The simulation results show that this algorithm is more accurate in cross-border e-business import supply chain pricing decision-making, and the accuracy is improved by 23.07% and the recall is improved by 19.88% compared with the traditional decision tree algorithm (ID3 algorithm). Compared with the traditional data analysis and forecasting methods, the pricing decision model in this paper has higher decision-making accuracy and efficiency. By introducing rational expectation equilibrium analysis, retailers can guide customers at each stage to buy in advance when determining the optimal price path and initial inventory level, so as to maximize the overall profit.

Keywords Cross-border E-business · Supply chain · Pricing decision · Deep learning

X. Li (✉) · H. Zhang
Jining Polytechnic, Jining 272103, China
e-mail: lxz9528@163.com

W. Zheng
Zoucheng Weimin Service Center, Jining 273599, Shandong, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_49

49.1 Introduction

With the rapid growth of economy and the transformation of traditional international trade, transborder e-business has emerged as a new type of international trade activity. Among the development models of transborder e-business, imported transborder e-business is undoubtedly the most concerned one [1]. Driven by big data, transborder e-business has become the star growth point of market economy with its huge market space and great development potential. The growth rate of traditional international trade has slowed down. With the favorable national policies, economic and social environment and consumer base, the scale of import transborder e-business transactions in China has steadily expanded, showing an increasingly standardized and formalized development trend [2]. If there is too much inventory, there will be surplus inventory at the end of the sales period. The value of surplus inventory at the end of the sales period is usually small or even zero, which will bring losses to retailers. If the inventory quantity is small, it will not meet the normal demand in the sales period, which will lead to the loss of valuable sales opportunities, and may cause goodwill loss to retailers [3]. For short-life products, the inventory decision and pricing decision are usually interdependent. If the inventory quantity is too large, the selling price will decrease, while if the inventory quantity is too small, the selling price will increase. Rapid development has brought great benefits to transborder e-business and the market, but also exposed the drawbacks of its development model [4, 5].

In the business practice of import e-business, due to the limitation of the enterprise's own scale and the influence from other participants in the chain, all links from supply management to source organization, from cross-border transportation to reverse logistics, from cross-border payment to information sharing, etc., pose increasingly severe challenges to cross-border supply chain management [6]. Traditional foreign trade enterprises, domestic e-business, foreign shopping websites and foreign service enterprises have all entered the domestic import transborder e-business industry, resulting in intensified competition among enterprises [7]. The emergence of internet information technology has not eliminated the competition, and even intensified it to some extent. Although the intensification of competition is beneficial to the improvement of consumers' welfare, excessive competition also damages the innovative ability, service ability and sustainable development ability of producers, which is ultimately not conducive to the improvement of consumers' welfare [8]. In order to improve the chaos in cross-border electronic commerce and increase the profits of most transborder e-business companies and agents, we should help them establish scientific supply chain management strategies, realize the coordination of interests within the supply chain, and unify the maximization of individual profits with the maximization of the overall profits of the supply chain [9]. In this article, the supply chain optimization of transborder e-business import enterprises is studied, and the pricing decision algorithm of transborder e-business import supply chain based on deep learning is proposed.

49.2 Methodology

49.2.1 Cross-Border E-business Supply Chain

The internal components of the supply chain are target customers, upstream production suppliers, transborder e-business and logistics companies. The construction of the supply chain platform is mainly to analyze the big data generated by various transaction information generated by several different entities, and extract useful information from them through screening. In practice, due to the uncertainty of demand, retailers will adopt different prices at different stages of the sales period to attract more customers and increase sales profits. This dynamic pricing strategy has been proved to be more effective than the single pricing strategy in improving retailers' profits. Its theoretical basis lies in dynamically adjusting prices according to different estimated values of customers, thus affecting customers' purchasing behavior [10]. The upstream suppliers analyze and summarize the consumption habits of the target customers by using Internet information technology, divide the market reasonably according to the needs of different customers, and provide tailor-made services for different customers. Upgrade and transform products according to consumers' satisfaction, and actively take effective measures to deal with changes in market demand. Cross-border e-business should share resources with suppliers, try to make the market information of both sides more symmetrical, and timely reflect customers' needs to each other.

Researchers and practitioners of marketing and operation management have also begun to find that this dynamic price adjustment strategy of retailers has trained customers to be rational and strategic, that is, customers may consider waiting for the product price reduction before purchasing, thus delaying their purchase decision. When customers put forward the distribution requirements, they can assemble the raw materials in time according to the reserve, and give the consumers the products and services they need [11]. In modern commercial society, rapid response has been applied to various economic activities. After the members cooperate, they realize information sharing and complementary advantages, and replace the original push supply chain with demand-oriented pull supply chain. Due to inaccurate functions and positioning, many e-business platforms don't have a clear charging standard, and even adopt the policy of zero charging or subsidy in order to increase traffic, which not only leads to the confusion of enterprises on the platform, but also damages the overall image of the platform, and at the same time makes the platform's operation lack the necessary income coverage, so that its supposed functions can't be effectively exerted.

49.2.2 Pricing Decision Algorithm of Transborder E-business Import Supply Chain

In order to better promote the growth of transborder e-business, we must build a scientific and reasonable supply chain platform, make full use of big data information resources, coordinate with government policies, improve the management and service level of transborder e-business, better serve consumers, better serve the economic development, and better realize the healthy and long-term growth of e-business enterprises. In the bilateral transaction mode, transborder e-business companies negotiate the transaction price with foreign agents. Although the higher the result of agreement pricing, the higher the profits of transborder e-business companies from unit products, but foreign agents may reduce the purchase of products, which will lead to the reduction of total revenue [12]. The big data of the supply chain includes all kinds of information about the transactions between suppliers, consumers and transborder e-business. This information flow is the main basis for building the logistics, capital flow and commodity flow in the transborder e-business supply chain.

By analyzing the demand and consumption data of target customers, transborder e-business and suppliers can promote a virtuous circle of logistics and commodity flow, thus realizing the flow of funds. During the negotiation process, both parties to the agreement do not know each other's real trading bottom line, thus greatly improving the difficulty of realizing interest coordination. In this case, one party of the agreement can only update its judgment on the bottom line of the transaction according to the quotation of the other party, and on this basis, make its own possible minimum concession, thus gradually approaching the equilibrium price. The environment and steps of transborder e-business import supply chain data mining are shown in Fig. 49.1.

E-business companies can know the service quality of logistics companies through consumers' evaluation of logistics service orders. Cross-border e-business companies will use these evaluations as a basis to analyze the situation of purchasing, transportation and storage, and share the results and data of comprehensive analysis with logistics companies. This will help logistics companies find their own problems in time, and find corresponding optimization schemes for different problems, so as to improve their service quality, reduce the cost of warehousing and logistics, and create more economic benefits. Upstream suppliers use Internet information technology to collect, integrate, and analyze the consumption preferences and purchase information of target customers, and dig deep into customer needs, so as to segment the market and provide personalized services for customers. Continuously improve and update products and services according to consumers' feedback, timely respond to changes in market demand, and improve commodity homogenization.

The amount of commodity information is inversely proportional to the frequency of information, and the amount of information contained in different information can be accumulated. Set sample set:

$$S = \{s_1, s_2, \ldots, s_m\} \tag{49.1}$$

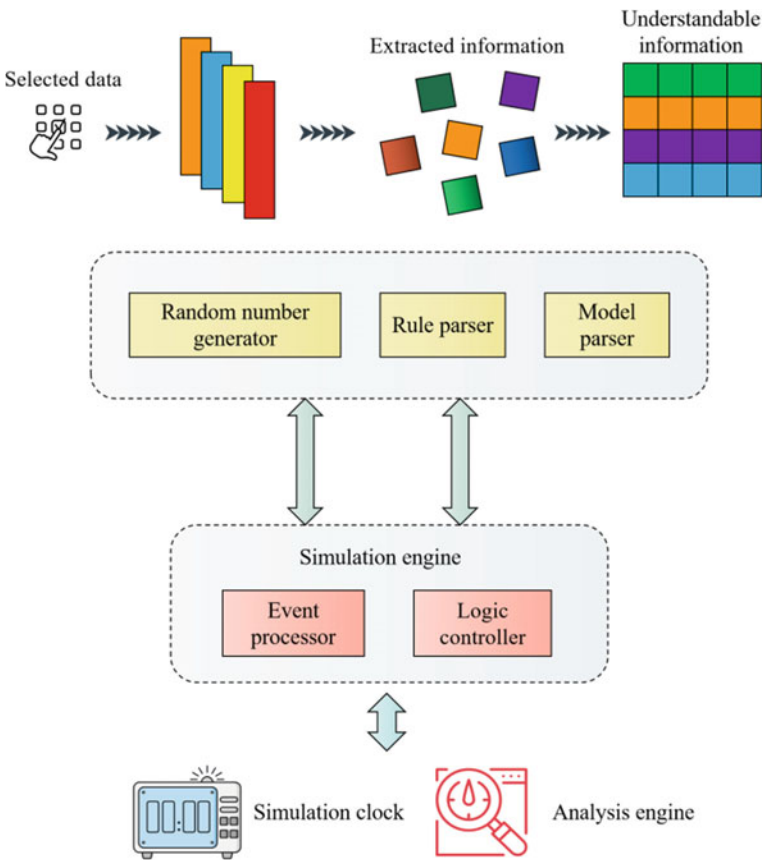


Fig. 49.1 Cross-border e-business import supply chain data mining

The sample categories are:

$$C = \{c_1, c_2, \ldots, c_k\} \tag{49.2}$$

The formula for calculating the information entropy of the commodity sample is as follows:

$$\begin{aligned} H(S) &= \sum_{j=1}^{k}\sum_{i=1}^{m} p(s_{ij}) \log \frac{1}{p(s_{ij})} \\ &= -\sum_{j=1}^{k}\sum_{i=1}^{m} p(s_{ij}) \log p(s_{ij}) \end{aligned} \tag{49.3}$$

where $p(s_{ij})$ represents the probability that the sample points in the commodity sample set belong to category c_j. Let the sample attribute set:

$$A = \{a_1, a_2, \ldots, a_t\}^T \tag{49.4}$$

Which has t different values. The sample set is divided into t sample subsets according to the attribute A, and the information entropy of the sample set is as follows:

$$H(S|A) = -\sum_{j=1}^{k}\sum_{i=1}^{t} p(a_{ij}) \log p(a_{ij}) \tag{49.5}$$

Among them, $p(a_{ij})$ represents the probability that the sample point belongs to the category c_i when the attribute A is a_i.

The government, transborder e-business and financial institutions should cooperate to build a transborder e-business credit system in China, establish norms and standards, improve the credit rating of enterprises, and enhance international credibility. Cross-border e-business can choose an appropriate third-party payment platform for cooperation according to its own actual situation and characteristics, so as to avoid the loss of funds and other risks. Cross-border e-business should increase the evaluation mechanism for suppliers, determine the feasibility of cooperation through comparison and scoring, strictly control the quality of goods, and put an end to goods with serious homogenization. In this way, the supply chain of commodities can be optimized, the quality and level of commodities managed by the enterprises can always be guaranteed, and the transborder e-business can improve the evaluation and reputation of consumers, thus improving the economic benefits of enterprises.

49.3 Result Analysis and Discussion

With the growth of supply chain globalization, the supply chain becomes more complex and less controllable, which makes it more vulnerable to the impact of financial crisis, natural disasters and political turmoil. After optimizing the supplier evaluation mechanism and selecting suppliers who can cooperate for a long time, it is also very important to strengthen the supplier relationship. When managing suppliers, transborder e-business import enterprises can divide suppliers into strategic suppliers, core suppliers providing bulk materials for enterprises and general suppliers providing other materials. In the 21st century digital era, in the field of e-business that relies on Internet platform to provide services and cross-border supply chain to realize value, imported transborder e-business needs to keep certain sensitivity to new digital technologies, and then build lean supply chain and realize refined services. After the model training, it needs to be tested. Use the test data set of purchase transaction to check the classified forecast results, as shown in Fig. 49.2.

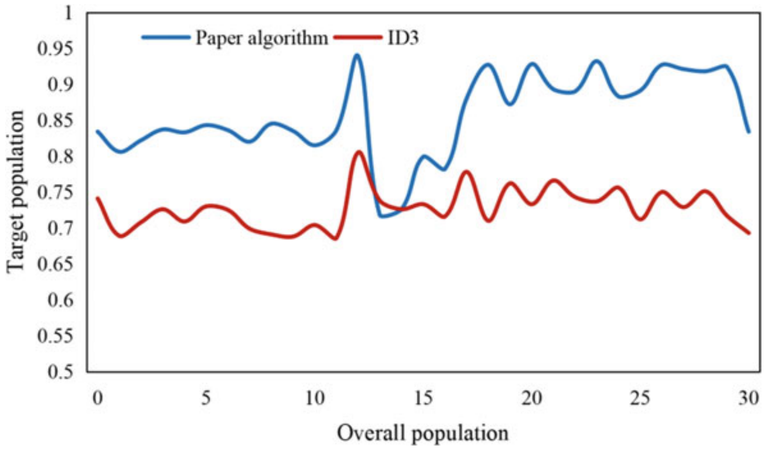


Fig. 49.2 Comparison of classification performance of pricing decision models

Artificial intelligence can improve the efficiency of transborder e-business platform. Through the combination of data and business logic, technologies such as artificial intelligence and operational optimization will effectively promote the optimization of import transborder e-business supply chain. The corresponding speed comparison of the algorithm is shown in Fig. 49.3.

Under the transborder e-business platform, buyers and sellers need to spend a lot of time to choose the most suitable products from many optional collections.

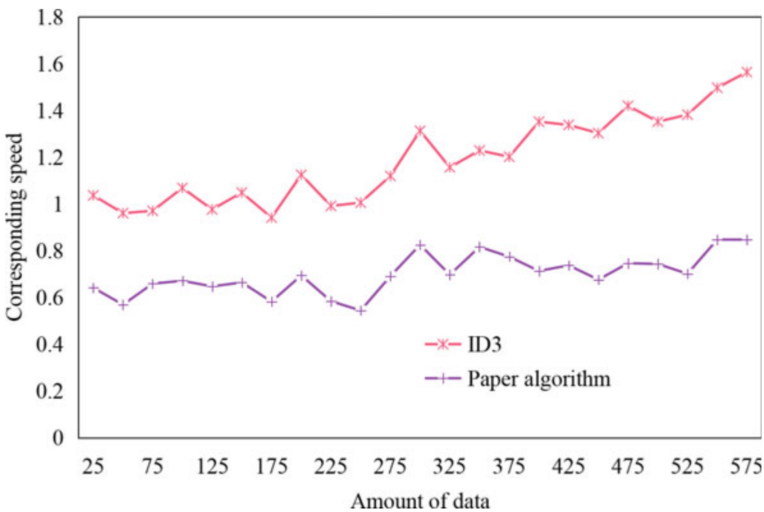


Fig. 49.3 Comparison of response speed

Compare the recall rate and precision of the algorithm in the pricing decision of transborder e-business import supply chain, as shown in Figs. 49.4 and 49.5.

From the test results, it can be seen that the algorithm in this article is more accurate in the pricing decision of transborder e-business import supply chain, the accuracy is improved by 23.07% and the recall rate is improved by 19.88% compared with the traditional ID3 algorithm. Compared with the traditional data analysis and forecasting methods, the pricing decision model in this article has higher decision accuracy and efficiency, and is more intelligent. Cross-border e-business cooperates with suppliers, sharing information, realizing the symmetry of market information between the two sides. Cross-border e-business timely reflects the customer demand analyzed by

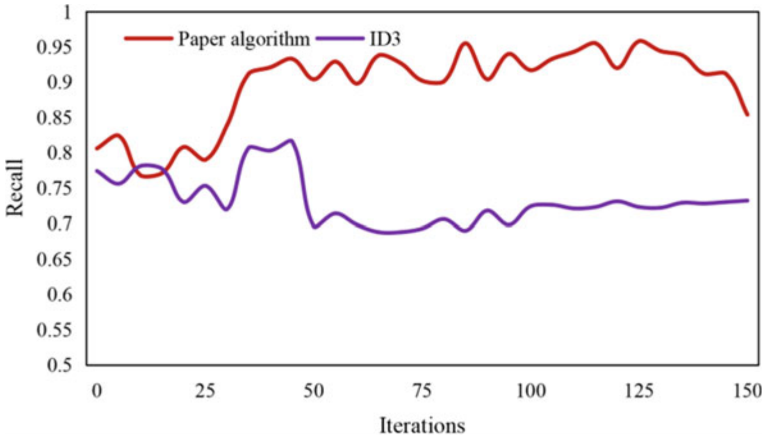


Fig. 49.4 Comparison of recall rate of transborder e-business consumption forecast

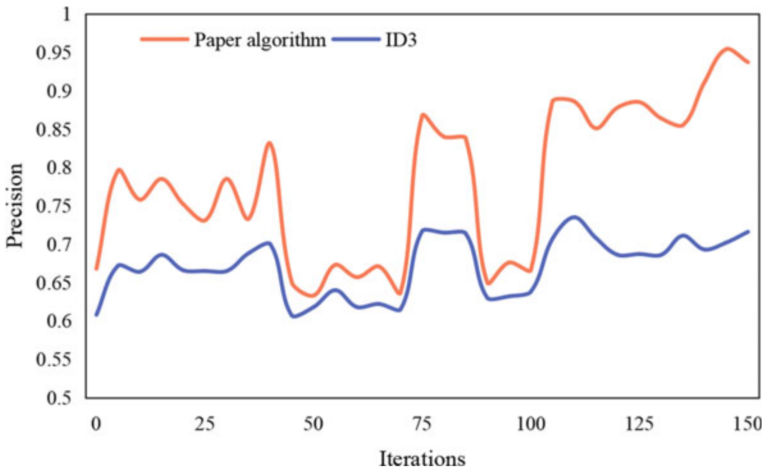


Fig. 49.5 Accuracy comparison of transborder e-business consumption forecast

suppliers, analyzes the potential consumption demand of target customers through data mining, and timely feeds back information to suppliers to promote suppliers to develop new products and improve customer stickiness. For the construction of transborder e-business import and export mode, it is necessary to strengthen the use of bonded areas and do a good job in the storage and safekeeping of commodities, which can greatly improve the operation efficiency and service quality of logistics enterprises. The extensive use of big data analysis technology can enable transborder e-business companies to have a more accurate grasp of market demand through the analysis of relevant data, so as to finely divide their own warehousing management and reduce the costs incurred in the logistics and transportation process.

49.4 Conclusions

In the stage of making operational management decisions and marketing decisions, the attitude of manufacturers and retailers towards risks and fairness will greatly affect their decision-making results. If these related behavioral factors are ignored, it will lead to inconsistency between actual decisions and optimal decisions, thus causing losses to enterprises. From the test results, it can be seen that the algorithm in this article is more accurate in the pricing decision of transborder e-business import supply chain, the accuracy is 23.07% higher than that of the traditional ID3 algorithm, and the recall rate is 19.88% higher. Compared with the traditional data analysis and forecasting methods, the pricing decision model in this article has higher decision accuracy and efficiency. Cross-border e-business must firmly grasp the core big data information resources, realize coordination and cooperation among suppliers, transborder e-business, logistics companies and consumers in the supply chain, and promote a virtuous circle among capital flow, commodity flow and logistics, while recognizing the important role played by the government and financial institutions in the growth of transborder e-business.

References

1. X. Zhang, S. Liu, Action mechanism and model of cross-border e-commerce green supply chain based on customer behavior. Math. Probl. Eng. **2021**, 1–11 (2021)
2. P. He, J. Wen, S. Ye, Z. Li, Logistics service sharing and competition in a dual-channel e-commerce supply chain. Comput. Ind. Eng. **149**, 106849 (2020)
3. O. Durowoju, H.K. Chan, X. Wang, Investigation of the effect of e-platform information security breaches: a small and medium enterprise supply chain perspective. IEEE Trans. Eng. Manag. **69**, 3694–3709 (2020)
4. J. Bolorinos, N.K. Ajami, G. Muñoz Meléndez, R.B. Jackson, Evaluating environmental governance along cross-border electricity supply chains with policy-informed life cycle assessment: the California-Mexico energy exchange. Environ. Sci. Technol. **52**, 5048–5061 (2018)
5. L. Feng, J. Ma, Y. Wang, J. Yang, Supply chain downstream strategic cost evaluation using L-COPRAS method in cross-border e-commerce (2017)

6. W. Su, Y. Wang, L. Qian, Creating a sustainable policy framework for cross-border e-business in China. Sustainability **11**, 943 (2019)
7. S. Li, Structure optimization of e-commerce platform based on artificial intelligence and blockchain technology. Wirel. Commun. Mob. Comput. **2020**, 1–8 (2020)
8. J. Qin, H. Fu, Z. Wang, L. Xia, Financing and carbon emission reduction strategies of capital-constrained manufacturers in e-commerce supply chains. Int. J. Prod. Econ. **241**, 108271 (2021)
9. D. Xiao, X. Kuang, K. Chen, E-commerce supply chain decisions under platform digital empowerment-induced demand. Comput. Ind. Eng. **150**, 106876 (2020)
10. Y. Zhang, Application of improved BP neural network based on e-commerce supply chain network data in the forecast of aquatic product export volume. Cogn. Syst. Res. **57**, 228–235 (2019)
11. Q. Zheng, M. Wang, F. Yang, Optimal channel strategy for a fresh produce e-commerce supply chain. Sustainability **13**, 6057 (2021)
12. R. Batarfi, M.Y. Jaber, S.M. Aljazzar, A profit maximization for a reverse logistics dual-channel supply chain with a return policy. Comput. Ind. Eng. **106**, 58–82 (2017)

Chapter 50
Research on Optimization of Transborder E-business Logistics Network Based on Cloud Computing

Yuanyuan Liu

Abstract With the continuous growth of China's economy, the scope covered by e-business has become larger and larger, and then the logistics and distribution has also made a qualitative leap. In order to achieve further stable development, transborder e-business needs to ensure that it has good logistics, which is the key factor to realize the healthy development of transborder e-business. The rapid growth of transborder e-business has promoted the iterative upgrading of transborder logistics, and an efficient transborder logistics system has become a strong guarantee for transborder e-business. The network carrying capacity represents the maximum number of loading units that the logistics network can handle. Data center provides computing power and storage space to users by using cloud computing, which relieves the pressure of terminal equipment performance for users. Based on the cloud computing environment, this paper proposes an optimization algorithm of transborder e-business logistics network based on deep learning, in order to improve logistics distribution efficiency and realize logistics value-added services. The results show that the errors of this algorithm are small, and the accuracy can reach 94.88%. It is necessary for enterprises to fully understand the transborder e-business logistics mode, and on this basis, make a reasonable choice according to their own actual situation, so as to increase their comprehensive benefits.

Keywords Transborder E-business · Logistics network · Cloud computing · Deep learning

Y. Liu (✉)
Shandong Vocational and Technical University of International Studies, Rizhao 276800, Shandong, China
e-mail: dn911@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_50

50.1 Introduction

With the overall rise of economic globalization and e-business, transborder e-business has gradually developed, becoming a new growth point of global trade economy and a new international business model [1]. In order to achieve further stable development, transborder e-business needs to ensure that it has good logistics, which is the key factor to achieve the healthy growth of transborder e-business. However, at present, the logistics level of most transborder e-business is still difficult to effectively meet the actual demand. In the "internet plus" environment, there are many transborder e-business logistics modes, but for most enterprises, they lack a correct understanding of these modes, which leads to some blindness in the process of choosing logistics modes, which not only increases the operating costs of enterprises, but also affects the image of enterprises [2]. In the process of logistics and transportation, affected by the environment, the package is lost, which can't get the customer's satisfaction [3]. Therefore, in order to better promote the growth of transborder e-business, we need to be able to choose the correct logistics operation mode. The application of cloud computing to the whole transaction activities of e-business brings opportunities and challenges to e-business logistics and distribution, and can realize that user applications are concentrated in cloud computing servers from being dispersed to their respective servers [4]. Users use cloud computing to store data in the network data center of the cloud center, but the data center uses cloud computing to provide users with computing power and storage space, which reduces the pressure of terminal equipment performance for users [5].

The rapid growth of e-business inevitably needs to innovate the traditional trading mode, and this innovation will be concentrated in the circulation field, so it is particularly important to change and adjust the traditional circulation mode. Different from the traditional model, transborder e-business business model has higher requirements for logistics. It is the hub of international logistics transactions, so transborder e-business requires logistics and distribution to be on time, and delivery channels to be safe and stable [6]. As a key link of transborder e-business transactions, transborder logistics industry has also been rapidly rising with the growth of transborder e-business in recent years. The rapid growth of transborder e-business industry has given birth to and promoted the rapid growth of transborder logistics industry, while the efficient and fast-developing transborder logistics system has become a strong guarantee for transborder e-business, making the original virtual transborder e-business transactions and business flow, capital flow and information flow materially realized [7]. It is of great theoretical and practical significance to correctly understand the current situation and relationship of transborder e-business and transborder logistics collaboration, explore their collaboration mechanism and influencing factors, reasonably evaluate the existing collaboration status and put forward corresponding collaboration strategies, which can effectively optimize logistics structure, reduce operating costs and enhance enterprise competitiveness [8]. Based on the cloud computing environment, this paper puts forward an optimization algorithm of transborder e-business logistics network based on deep learning, and extracts the data of transborder e-business logistics network on the basis of theoretical analysis. When the problem becomes complex, the possibility of finding the optimal solution by the algorithm will decrease, which requires adjusting the parameters in the algorithm.

50.2 Methodology

50.2.1 Transborder E-business Logistics Mode

Under the third-party logistics mode, the third-party logistics enterprises can provide high-quality logistics services for buyers and sellers, provide them with equipment and relevant technical guidance, and their logistics services are highly professional. For general foreign trade enterprises, they pay more attention to sales and lack of knowledge of logistics management, while the third-party logistics has high-quality logistics services and the supporting system is more scientific and perfect. In the field of transborder e-business, overseas warehouses play a big advantage, which can promote overseas customers' purchasing confidence, shorten the delivery cycle, reduce the rate of defective transborder logistics transactions, expand the sales categories, improve and perfect the closed-loop after-sales service, and provide flexible and safe return and exchange schemes to customers, thus improving customer satisfaction rate [9]. Through the cloud logistics platform, transborder e-business can get the latest market trends, make scientific, reasonable and targeted planning for the market, and provide appropriate services to customers. In addition, the customs clearance problem of transborder e-business is a major issue in the development process, and different countries and regions have different types of relevant policies.

In addition to building overseas warehouses in transborder e-business, enterprises need to carry out standardized and intelligent warehousing management, formulate unified warehousing management measures and carry out standardized management. It is necessary to apply advanced Internet and other modern communication technologies, manage inventory scientifically and remotely, and use standardized operating systems to effectively connect information flow and logistics. Multi-dimensional collaborative classification of transborder e-business logistics is shown in Fig. 50.1.

Due to different situations, it will take a lot of time to clear customs, which will lead to a long time to transport products. Therefore, cloud logistics platform can provide effective customs clearance services for current transborder e-business and improve logistics and distribution efficiency. In order to realize the reform and innovation of transborder e-business logistics mode, it is necessary to strengthen the construction of cloud logistics platform. Through cloud logistics platform, routes can be optimized and transshipment links can be reduced. At the same time, resources can be effectively shared and costs can be reduced [10]. The General Administration of Customs, in combination with the actual situation, builds the customs clearance service platform for e-business enterprises, effectively connects the customs electronic port platform with domestic and foreign e-business platforms and logistics companies,

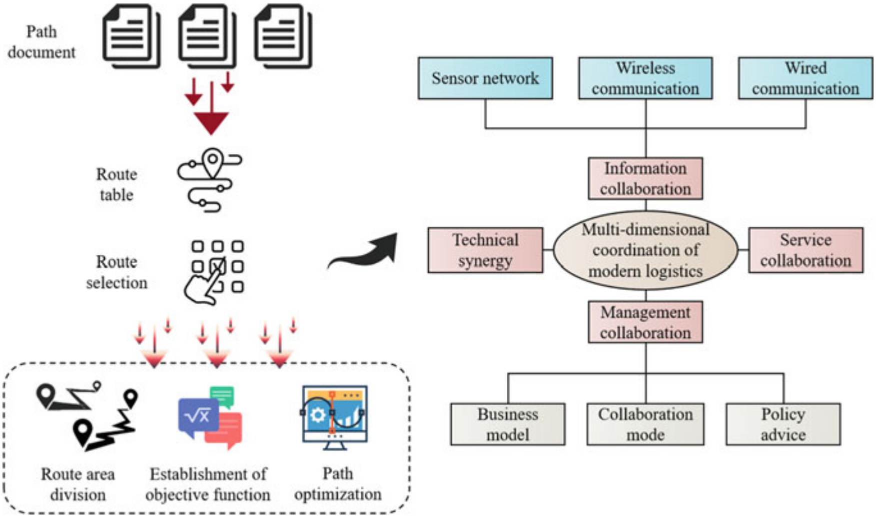


Fig. 50.1 Multi-dimensional collaborative classification of transborder e-business logistics

and tracks transborder e-business logistics throughout the process. Cooperate with other countries to improve the inspection, quarantine and customs clearance mode of transborder e-business logistics, and ensure the normal customs clearance of logistics from the management system. In order to effectively solve the problem of information asymmetry in transborder e-business logistics, it is necessary to build an organic transborder logistics information system. In China's corresponding logistics industry development plan, it is also clearly pointed out that the logistics information platform needs to be built in time.

50.2.2 Optimization Algorithm of Transborder E-business Logistics Network

For transborder e-business, logistics is the core content. More and more enterprises are beginning to realize that the key to the success of transborder e-business lies in the orderly, effective and comprehensive integration of trading resources such as logistics, capital and commodities. Handling capacity includes sorting materials into and out of inventory, loading, unloading and transportation from warehouse. It connects the internal and external flow of goods and different modes of transportation and storage. Loading and unloading capacity refers to the overall operation performance within the specified time, and the transportation capacity depends on the size of the cargo hold and the allowable loading capacity. Cloud logistics platform can provide logistics solutions for the current transborder e-business in the process of development, and can also provide logistics consulting and logistics route planning and other

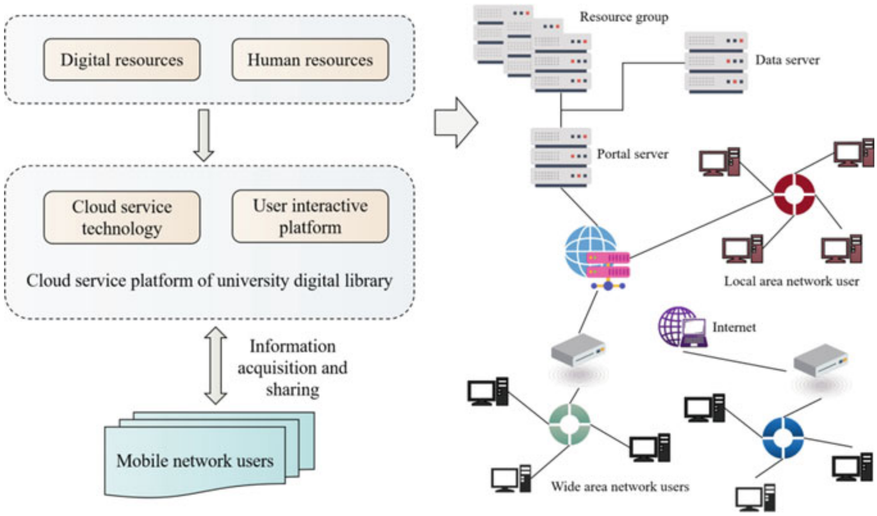


Fig. 50.2 Operation mode of cloud service platform of transborder e-business logistics network

services, which can promote entry optimization and effectively reduce logistics and distribution costs [11]. The freight rate of traditional foreign trade single goods is relatively high, which is easy to cause the problem of relatively high transportation cost. However, it can be realized on the logistics platform and can effectively reduce the no-load rate and logistics distribution cost.

Cloud logistics is an advanced concept in the current social development. Combining cloud computing with cross-border transportation can not only handle some big data well, but also provide corresponding services to customers according to their actual situation, so as to better ensure the safety of goods and reduce the damage of goods. The operation mode of transborder logistics network cloud service platform is shown in Fig. 50.2.

Warehousing can perform different functions: the most important thing in external logistics is balance and protection. Other tasks are mainly related to warehousing and manufacturing logistics, so they will not be described in detail here. Balance function can be defined as the time bridge between the end of production and actual delivery, distribution warehouse or customer. Batch size planning is very important in the production process, and may lead to the need to store in the outward logistics point to overcome the gap between the end of production and the delivery date required by customers. Activities include planning, controlling and monitoring the physical flow of goods and related information flow. It covers the processes of warehousing, transportation, loading and unloading, sorting and packaging. In the process of foreign logistics, goods are usually not physically modified, but used as a bridge between time and space.

Considering the carrying capacity of the whole transborder logistics network, ensuring the performance of the transborder e-business logistics network can effectively prevent the network from being paralyzed. After that, considering that the optimization of transborder e-business logistics network is an upgrade of the existing research, on the basis of theoretical analysis, the data of transborder e-business logistics network is extracted, and then used as the data of the main network optimization research, with cost minimization as the objective function. Assume that $x_i \in R^n$ is the factor that affects the logistics traffic flow forecast, and y_i is the forecast value of logistics traffic flow. The transborder e-business logistics forecasting model based on deep learning is to find the relationship between x_i and y_i:

$$f : R^n \to R \tag{50.1}$$

$$y_i = f(x_i) \tag{50.2}$$

R^n is the factor that affects the traffic flow forecast of transborder e-business logistics. The establishment of traffic flow prediction model seeks the following expression:

$$f(x) = \sum_{i=1}^{k} \left(a_i - a_i^*\right) K(x, x_i) + b \tag{50.3}$$

where x is the factor that affects the traffic flow of e-business logistics, x_i is the i sample among k samples, $K(x, x_i)$ is the kernel function, and the kernel function adopts radial basis function, as shown in the following formula:

$$K(x, y) = \exp\left| -\frac{\|x - y\|^2}{2\sigma^2} \right| \tag{50.4}$$

Through cloud computing, general users don't have to own their own large computer rooms, data centers, servers, etc., and they can deploy software skillfully without buying new servers. They can provide the required software and hardware resources, services and infrastructure through the services customized by the cloud or cloud service providers, which greatly reduces the cost of information system construction and saves resources.

Through technologies such as grid technology, distributed file system or cluster application, cloud storage integrates various storage devices in the network to work together by using application software, and provides business access function and data storage for the outside world. It mainly stores a large amount of data for network users. However, cloud computing automatically splits a huge computing program into numerous smaller subprograms through the network, and then hands them over to a huge system composed of multiple distributed servers, and sends the processing results back to users after searching, calculating and analyzing.

50.3 Result Analysis and Discussion

With the rapid growth of transborder e-business, online cross-border purchase business is gradually increasing, which also makes the transborder e-business logistics network rapidly improved. Many third-party distribution companies carry out cross-border transportation projects to provide services for transborder e-business platforms. Therefore, it is necessary to study the carrying capacity of transborder e-business logistics network. As the orders of shopping platforms will increase year by year, there will also be a short-term surge, so the carrying capacity of the network can play an early warning role for transportation enterprises, and play an important reference value for the optimization of transportation routes of subsequent companies [12]. With the rapid growth of e-business, online shopping has become more and more fashionable. More and more industries have begun to get involved in e-business, and with the help of the huge advantages of the network platform, they have expanded their market share. The sustainable growth of e-business can effectively shorten the supply time and production cycle, reduce the inventory level, simplify the order procedure, and achieve more effective customer relationship management. Carry out interval discretization processing on quantitative data with large differences in data distribution intervals, as shown in Fig. 50.3.

Transborder e-business collects the corresponding data by using the cloud logistics method, so as to better improve the work efficiency. At present, this mode is still relatively new and involves many contents, so it needs to be managed by professionals. If transborder e-business enterprises want to give full play to the role of cloud logistics, they should actively plan the logistics network. Enterprises should also cooperate with each other and make full use of the advantages of cloud logistics to build a cloud logistics platform.

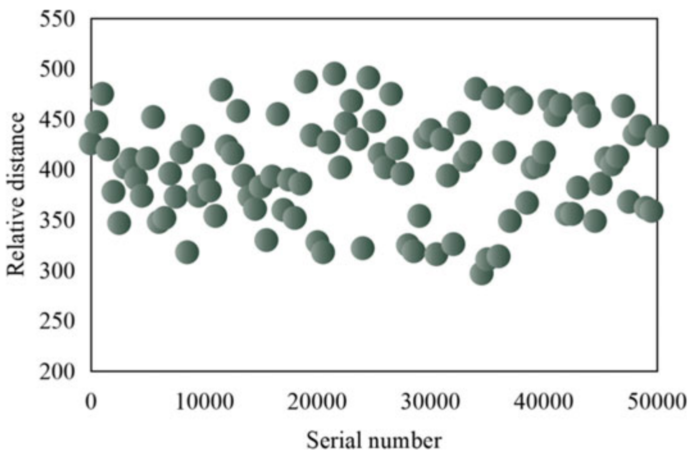


Fig. 50.3 Data outlier removal processing

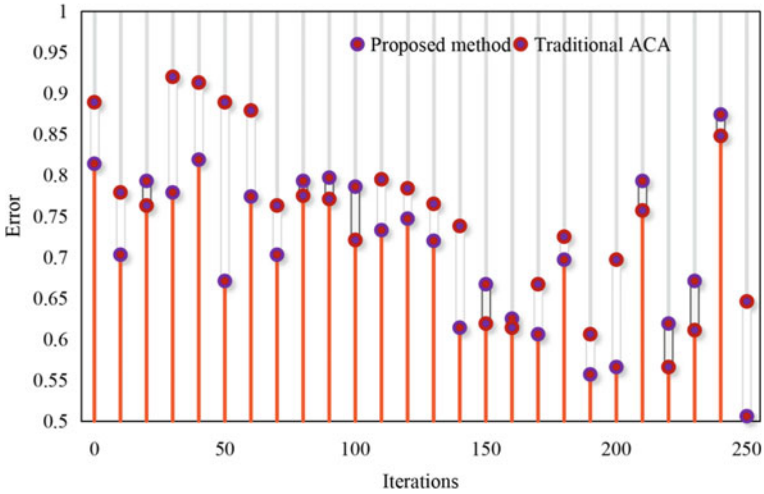


Fig. 50.4 Errors of different algorithms

Logistics hubs mainly focus on outbound logistics and inbound logistics, which can usually be understood as the process related to product movement and storage, from the end of the production line to the end user. Outbound logistics starts from the end of the production line until it is distributed to customers or reaches them. Using the high-speed transmission capability of the Internet, cloud computing moves the data processing of personal computers or servers to the super cluster of computers on the Internet. The computer cluster managed in large-scale data processing is composed of common industrial standard servers all over the world. Experiment with the algorithm under different transaction sets, and the error of the algorithm is shown in Fig. 50.4. The accuracy of the algorithm is shown in Fig. 50.5.

In the distribution model of transborder e-business logistics network, the traffic flow on each road section changes dynamically according to the change of time and space. Therefore, it is necessary to divide the road traffic network or inspection time into smaller intervals, and make the time interval as short as possible. Experiments show that after more than 500 iterations, the errors of this algorithm are obviously reduced, and the average accuracy can reach 94.88%. When the problem becomes complicated, the possibility of finding the optimal solution by the algorithm will be reduced, so it is necessary to adjust the parameters in the algorithm. With the gradual growth of transborder logistics network, more and more transportation routes are produced, but many of them are inefficient, which leads to higher logistics costs. Therefore, it is necessary to optimize the transborder e-business logistics network, which will help the rapid growth of cross-border transportation industry in the future.

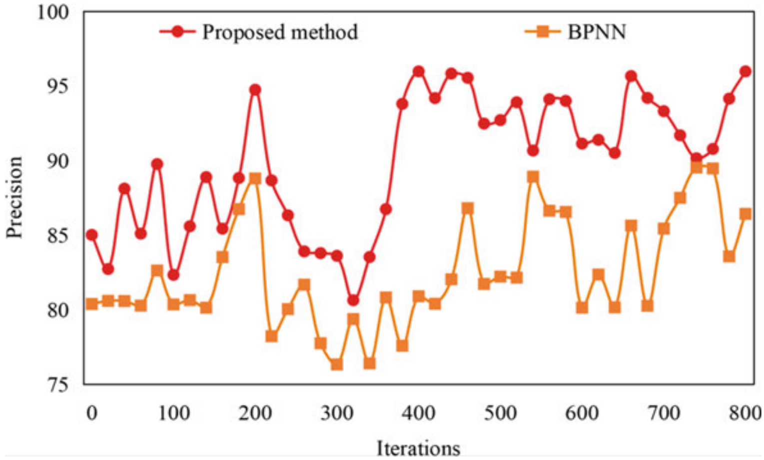


Fig. 50.5 Accuracy of different algorithms

50.4 Conclusions

In the process of transborder e-business industry development, we must be able to fully select the correct logistics operation mode. Affected by cloud logistics, it can better standardize the logistics growth of transborder e-business and better improve the logistics service effect. The application of cloud computing to the whole transaction activities of e-business brings opportunities and challenges to e-business logistics and distribution, and can realize that user applications are distributed to their respective servers and concentrated in the cloud computing servers. Based on the cloud computing environment, this paper proposes an optimization algorithm of transborder e-business logistics network based on deep learning, in order to improve logistics distribution efficiency and realize logistics value-added services. The error of the algorithm is small, and the accuracy can reach 94.88%. When the problem becomes complicated, the possibility of finding the optimal solution by the algorithm will be reduced, so it is necessary to adjust the parameters in the algorithm. The rapid growth of the transborder e-business industry has given birth to and promoted the rapid growth of the transborder logistics industry, while the efficient and fast-developing transborder logistics system has become a strong guarantee for transborder e-business, making the original virtual transborder e-business transactions and business flow, capital flow and information flow materially realized. If an enterprise wants to enhance its competitive advantage, it must fully understand all kinds of transborder e-business logistics modes, make clear the principle of mode selection, and choose the logistics mode reasonably according to its own actual situation.

References

1. Q. Yuan, The construction mechanism and algorithm of cross border E-commerce export logistics mode from the perspective of value chain. J. Intell. Fuzzy Syst. **37**, 3393–3400 (2019)
2. S. Guan, Smart E-commerce logistics construction model based on big data analytics. J. Intell. Fuzzy Syst. **40**, 3015–3023 (2021)
3. D. Geneiatakis, Y. Soupionis, G. Steri, I. Kounelis, R. Neisse, I. Nai-Fovino, Blockchain performance analysis for supporting cross-border E-government services. IEEE Trans. Eng. Manag. **67**, 1310–1322 (2020)
4. X. Chen, Marine transport efficiency evaluation of transborder e-business logistics based on analytic hierarchy process. J. Coastal Res. **94**(9), 682 (2019)
5. J. He, J. Li, L. Ge, Cooperative model simulation of transborder e-business and logistics based on block chain. Basic Clin. Pharmacol. Toxicol. **2019**(1), 124 (2019)
6. Y. He, R. Wu, Y.-J. Choi, International logistics and cross-border E-commerce trade: who matters whom? Sustainability **13**, 1745 (2021)
7. X. Zhang, S. Liu, Action mechanism and model of cross-border e-commerce green supply chain based on customer behavior. Math. Probl. Eng. 1–11 (2021)
8. J. Chen, H. Wu, X. Zhou, M. Wu, C. Zhao, S. Xu, Optimization of internet of things e-commerce logistics cloud service platform based on mobile communication. Complexity 1–11 (2021)
9. M.-C. Chen, P.-J. Wu, Y.-H. Hsu, An effective pricing model for the congestion alleviation of e-commerce logistics. Comput. Ind. Eng. **129**, 368–376 (2019)
10. M. Li, L. Shen, G.Q. Huang, Blockchain-enabled workflow operating system for logistics resources sharing in E-commerce logistics real estate service. Comput. Ind. Eng. **135**, 950–969 (2019)
11. M.H. Akyüz, İ. Muter, G. Erdoğan, G. Laporte, Minimum cost delivery of multi-item orders in e-commerce logistics. Comput. Oper. Res. **138**, 105613 (2022)
12. J. Guo, X. Wang, S. Fan, M. Gen, Forward and reverse logistics network and route planning under the environment of low-carbon emissions: a case study of Shanghai fresh food E-commerce enterprises. Comput. Ind. Eng. **106**, 351–360 (2017)

Chapter 51
Value Chain Analysis of Cross Border E-Business Foreign Trade Driven by Networked Manufacturing Mechanism

Yu Wang

Abstract With the rise of the Internet and the vigorous development of the e-business industry, the theory and practice of cross-border e-business foreign trade guided by networked production are also constantly deepening. With the development of modern information technology and the corresponding development of network sharing technology, it is inevitable to analyze the value chain of cross-border e-business trade in the networked manufacturing model. This article will be based on the networked manufacturing mechanism and develop a model of the foreign trade value chain corresponding to cross-border e-business. And elaborated on the value chain relationships and social status of e-business corresponding to the cross-border e-business value chain of small and medium-sized enterprises. On this basis, a cross-border e-business development strategy for small and medium-sized enterprises in China has been proposed, and corresponding development models have been proposed.

Keywords Cross border e-business of SMEs · Networked manufacturing mechanism · Value chain analysis · Foreign trade · Matrix analysis algorithm

51.1 Introduction

Networked integration is an important way for manufacturing enterprises to achieve networked manufacturing [1–3]. Under the networked manufacturing system, enterprises can use high-end information technology, Internet technology and management technology to organically coordinate relevant manufacturing elements, optimize the allocation of manufacturing resources globally, efficiently organize and

Y. Wang (✉)
Shandong Vocational and Technical University of International Studies, Rizhao 276826, China
e-mail: helios521@163.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_51

arrange a series of intermediate links such as research and development, innovation, production, management, marketing, brand operation, after-sales service, and reduce the fragmentation and regionalization of traditional manufacturing production, Greatly improving the competitive advantage and manufacturing efficiency of various manufacturing enterprises, leveraging their respective specialization and strengths [4–6], thereby responding more flexibly and agile to the personalized needs of global consumers. In the research of cross-border e-business in China's small and medium-sized foreign trade, peripheral theory, systematic serialization theory, and corresponding gap wheel theory dominate [7, 8]. Corresponding to this is the system sequence theory developed by Asian countries such as Japan, which advocates for paying attention to small and medium-sized trade e-business, and the development of small and medium-sized trade e-business is the key. On the other hand, the "gap" theory of developed countries such as Europe and America, represented by the United States, has proposed a new perspective, that is, the market and related technologies are in a dynamic state of change, and they influence and constrain each other. Although large enterprises have huge manpower, material resources, and financial resources, in order for them to bridge the gap between "big" and "big", a large number of small and medium-sized enterprises must fill the gap, this has enabled many small and medium-sized enterprises to grow rapidly [9, 10]. Chinese scholars believe that the healthy development of small and medium-sized foreign trade e-business enterprises is closely related to a country's overall economic situation. Advocate the use of value chain analysis tools to analyze the composition of the value chain in the foreign trade industry, decompose and integrate corresponding activities in the value chain, and reposition corresponding strategic nodes in the value chain, in order to promote the rapid development and progress of small and medium-sized foreign trade e-business enterprises. Through this method, the value creation connotation of small and medium-sized cross-border e-business can be revealed, and the law can be successfully utilized to promote the development and progress of enterprises [11–14]. Networked manufacturing technology is the necessary path for the development of advanced manufacturing technology. Supply chain management (SCM) can provide value-added services for e-business companies. However, with the increasingly complex and unpredictable market environment, traditional supply chain management is becoming increasingly unsuitable for the development of e-business companies. At present, many scholars are committed to dynamic optimization of supply chain research, to quickly respond to market changes and achieve dynamic agile response in the supply chain. In the fierce competition in the e-business industry, each enterprise has its own business scope, but each enterprise also covers each other, with the same business and different characteristics. While competing, from the perspective of cost management, it is necessary for various enterprises to cooperate well. Mutual cooperation can not only generate more profits but also promote more reasonable development of the industry.

Based on the current difficulties faced by the small and medium-sized cross-border e-business in foreign trade, this paper will model the corresponding foreign trade value chain of the corresponding cross-border e-business based on the networked manufacturing mechanism, and analyze the internal advantages, external advantages and related factors of the current small and medium-sized cross-border e-business based on the SWOT matrix analysis algorithm. The development space for China's cross-border e-business exports is enormous, and higher requirements will be put forward for cross-border logistics. Based on the SWOT analysis method, this article presents the external and internal opportunities and challenges of foreign trade e-business for small and medium-sized enterprises, and provides the corresponding value chain relationships and social status of e-business for cross-border e-business value chains of small and medium-sized enterprises. Finally, this article provides the development strategy and corresponding development models of cross-border e-business for small and medium-sized enterprises.

The corresponding arrangement of this article is as follows: the second section of this article will model the corresponding cross-border e-business foreign trade value chain based on the network manufacturing mechanism, and analyze the current development situation of SMEs' foreign trade e-business based on the SWOT analysis method; the third section of this article will give the development strategy of SMEs' cross-border e-business and give the corresponding development mode; the last section will give some suggestions After that, we will summarize this paper.

51.2 Based on the Network Manufacturing Mechanism of Small and Medium-Sized Foreign Trade Cross-Border E-Business Value Chain Analysis

The foreign trade value chain of small and medium-sized cross-border e-business studied in this paper is mainly based on the e-business value chain model, and the corresponding value chain model framework under the networked manufacturing mechanism is shown in Fig. 51.1. From the overall framework of Fig. 51.1, it can be seen that the value chain corresponding to small and medium-sized foreign trade enterprises is mainly composed of virtual value chain, and its main means of survival depends on low cost, cheap labor and a large amount of investment in natural resources. Among them, the corresponding value chain warehousing and goods preparation link is mainly to place orders to the corresponding manufacturers according to the contract; the corresponding commodity storage and transportation link is mainly the logistics management link including customs declaration, transportation, warehousing and corresponding international freight; the corresponding foreign trade marketing level is mainly to participate in various international trade fairs, exhibitions and customer visits.

The virtual production mode refers to the production mode that breaks traditional spatial concepts by fully utilizing computer and internet technologies to quickly respond to market demand, forms dynamic alliances with flat management, and combines competition and cooperation, and carries out production activities around their respective core competitiveness. Its main characteristics include: throughout the entire production process, goods, information, and services are highly personalized

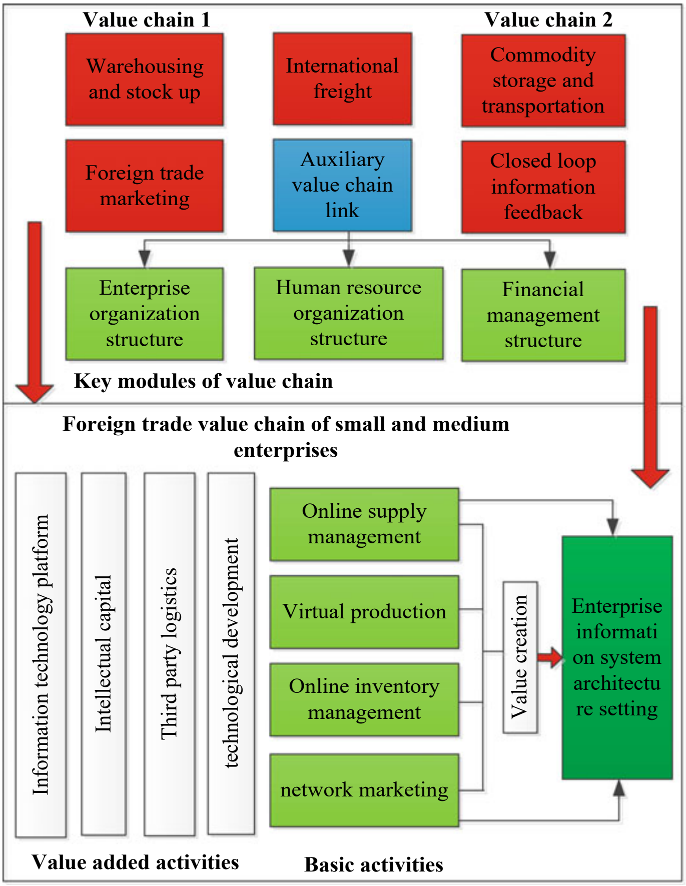


Fig. 51.1 Framework diagram of corresponding value chain model under networked manufacturing mechanism

and integrated, and whether it is products, services, or prices, they are all functions chosen and given by consumers; The production department can quickly respond to customer needs and customize products of different types and any batch according to customer requirements; Integrate opinions from customers, sellers, suppliers, and producers, and conduct dynamic personalized design in the network until the demand is satisfied; The corresponding closed-loop information feedback link is mainly to collect the relevant international market, sort out and summarize the corresponding decision-making basis; the corresponding auxiliary value chain link of small and medium-sized foreign trade cross-border e-business includes the setting of enterprise organization structure, human resource organization structure, financial management and fund management structure, and enterprise information system structure.

The value chain is composed of various economic links of an enterprise, but not every link will bring value added. Only the core strategic links can bring value added.

There are differences in the value chain activities of enterprises in different industries. The e-business value chain integrates the online and offline links, including the transfer from the traditional value chain to the virtual value chain transfer. By analyzing the traditional value chain and the virtual value chain, we study the problems in the e-business value chain link, optimize the value chain, and enhance the competitiveness of enterprises. In the value chain of small and medium-sized foreign trade cross-border e-business, the corresponding network manufacturing constraints should be added, and the corresponding enterprise organization and management structure of each link should be changed, so as to support the economic activities of the whole foreign trade cross-border e-business, and make the corresponding advanced production management concepts cover all links of the whole life cycle, so as to realize the rapid response to the market Should. Modern enterprises face two types of value chains: one is the physical value chain, which is a material world composed of various resources that managers can truly touch; Another type is a virtual value chain composed of information, which originates from traditional value chains and shifts competition between enterprises from the consumption of material resources to the improvement of information utilization efficiency. Traditional value chains mainly rely on physical products to achieve value appreciation, while virtual value chains mainly rely on information products to achieve value appreciation. They are interconnected and parallel to each other.

The penetration details of networked manufacturing of the corresponding small and medium-sized cross-border e-business in each link are shown in Fig. 51.2. As can be seen from Fig. 51.2, networked manufacturing has transformed the value chain of cross-border e-business in seven levels by using the Internet and the internal network of enterprises. In the level of enterprise innovation, three levels of innovation mechanism are added, namely market innovation, management innovation and product innovation; in the corresponding level of enterprise digital management, information highly integrated, market operation digital innovation and corresponding product display and marketing digital innovation are added; in the corresponding level of cross-border enterprise integration, enterprise integration is introduced, and the enterprise matches the environment At the same time, it emphasizes the organic integration of enterprise management and technology; at the corresponding enterprise operation management network level, network manufacturing introduces the concepts of design network, marketing network and procurement network; at the corresponding cross-border e-business level, it introduces the concept of modularization, which requires product modularization, enterprise modularization and process modularization At the corresponding level of intelligence, network manufacturing introduces dynamic adaptive integration intelligence, self-coordination intelligence and self-learning intelligence into the value chain of small and medium-sized foreign trade cross-border e-business. The value chain is composed of various economic links of an enterprise, but not every link will bring value added. Only the core strategic links can bring value added. There are differences in the value chain activities of enterprises in different industries. The e-business value chain integrates the online and offline links, including the transfer from the traditional value chain to the virtual value chain transfer. By analyzing the traditional value chain and the virtual value chain, we study the problems in the e-business value chain link, optimize the value chain, and enhance the competitiveness of enterprises. Driven by the whole network manufacturing mechanism, small and medium-sized foreign trade cross-border e-business needs to focus on international concurrent engineering control, global distributed manufacturing management control, global flexible production system control and life cycle management control in the process of value chain operation.

Based on the above analysis of the value chain of cross-border e-business under the network manufacturing mechanism, it can be concluded that: in the development and management of small and medium-sized foreign trade cross-border e-business enterprises, we need to pay attention to the corresponding intelligence, networking and integration of enterprises, consider the development of enterprise value chain from the internal and industrial environment of enterprises, and constantly integrate advantageous resources, and focus on the development of enterprises in order to

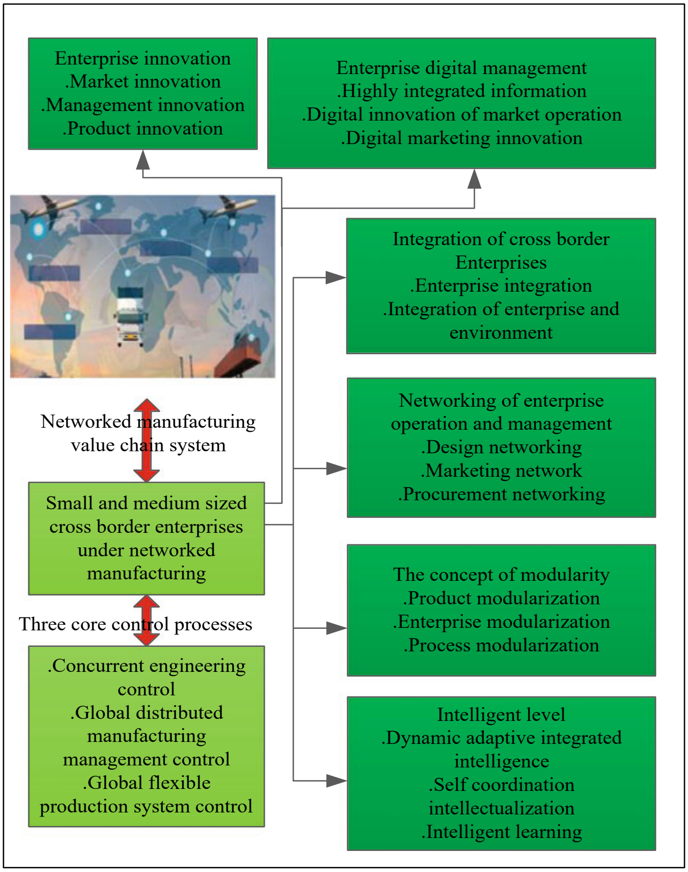


Fig. 51.2 Details of network manufacturing penetration in each link of small cross border e-business value chain

realize the value-added development of the value chain. At the same time, based on the above analysis of small and medium-sized foreign trade e-business under network manufacturing, the corresponding value chain constraint formula can be obtained. The corresponding core formula is shown in Formula 51.1, where the corresponding M represents the country's output vector, the corresponding B is a constant dimensional matrix, and the corresponding N is the international consumption vector. The expression of the corresponding vector x is shown in Formula 51.2, and the expression of the corresponding vector y is shown in Formula 51.3.

$$M = BM + N \tag{51.1}$$

$$M = \begin{bmatrix} M_{11} & ... & M_{1j} \\ ... & ... & ... \\ M_{i1} & ... & M_{ij} \end{bmatrix} \tag{51.2}$$

$$N = \begin{bmatrix} N_{11} & ... & N_{1j} \\ ... & ... & ... \\ N_{i1} & ... & N_{ij} \end{bmatrix} \tag{51.3}$$

51.3 Development Strategy of Cross-Border E-Business

Taking the e-business of a developing country in an Asian region mainly engaged in rubber foreign trade industry as the analysis object, the corresponding income and profit situation of the company in recent years are shown in Figs. 51.3 and 51.4. According to Figs. 51.3 and 51.4, and considering the actual production and operation situation of the company, it can be seen that the corresponding environment has natural advantages, and the corresponding international environment of rubber industry is relatively good in recent years. At the same time, the management of the company has a high degree of education and a good entrepreneurial spirit. Therefore, the company's business philosophy is also relatively advanced, and the professional quality of employees is also relatively poor. At the same time, from relevant practices, it can be seen that employees in enterprises have good concepts of market development, service, and market competition. However, due to the raw material industry in which the company operates, its corresponding customers are mostly foreign. Due to factors such as local production, environmental policies, and origin protection, its profit margin is relatively limited. At the same time, the corresponding level of collaboration is also relatively low, and the products are relatively single. The corresponding enterprises in the regional industrial value chain have a relatively high degree of homogenization, facing competition in terms of price, market, talent, and other aspects. Based on the above actual situation, SWOT analysis is carried out for the company in the region, and the corresponding analysis results are shown in Table 51.1.

Based on this analysis, the core factors supporting the company's corresponding development strategy are: policy opportunities, low cost, deep management background and relatively clear market objectives.

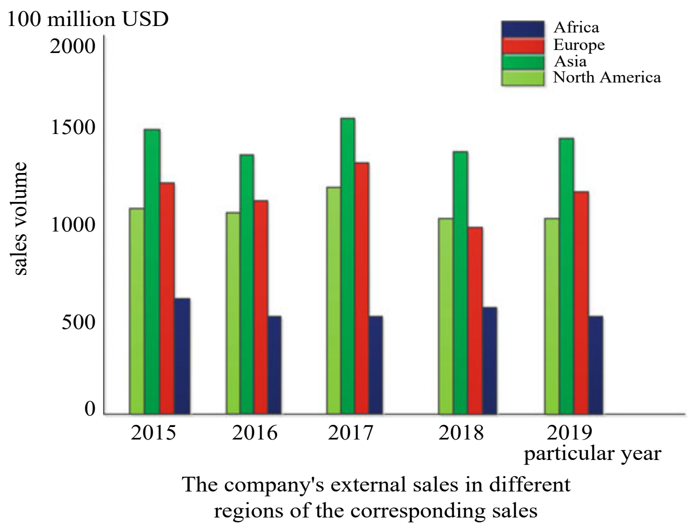


Fig. 51.3 The company's external sales volume histogram of different regions

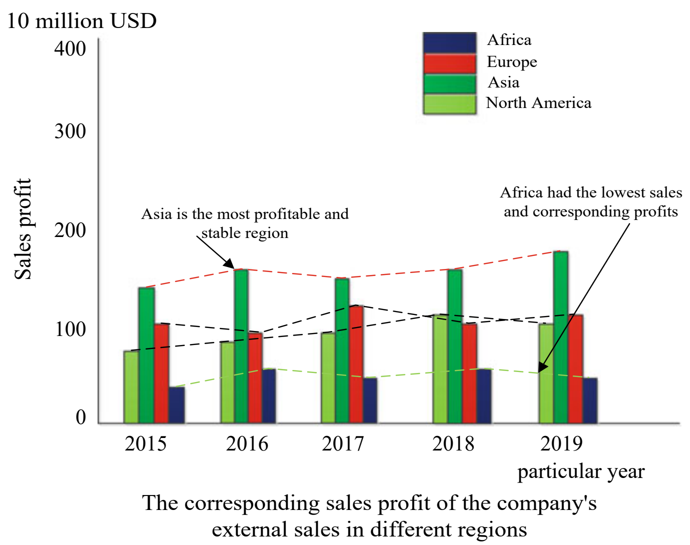


Fig. 51.4 The corresponding profit distribution histogram of the company

Table 51.1 SWOT analysis of the company in the region

SWOT analysis index	Situation description
There are opportunities for the company	1. The quality of management personnel is high, the background is superior, the company is easy to accept new management concepts, dare to innovate 2. The corresponding international market environment is good, the region encourages opening up, and the policy has certain advantages 3. Labor is cheap and sufficient 4. The international market demand is strong, the automobile industry, especially the new energy automobile industry, is developing rapidly, and the corresponding auto parts and tires are in great demand
Threats to the company	1. The financing environment is relatively bad, and the corresponding capital reserve of the company is not enough 2. There is fierce competition in the value chain of the company 3. The price and quality competition in the same industry is fierce
The company's current advantages	1. The quality of management personnel is high, the background is superior, the company is easy to accept new management concepts, dare to innovate 2. The company's corresponding customer evaluation is high, and the company's staff have a strong sense of service, competition and market development 3. There are many orders at present, and the company has core technology
The company's current weaknesses	1. The employment cost of core personnel is increasing, and there is a problem of core personnel loss 2. The product structure is single, and the profit source is single 3. The company has spent a lot of money and energy on policy issues in the region, resulting in the tension of the company's capital chain 4. The slogans of corporate culture are relatively homogeneous and lack of specific strategic objectives and long-term strategic planning

(continued)

Table 51.1 (continued)

SWOT analysis index	Situation description
Objective policy problems faced by the company	1. At present, the region where the company is located encourages opening to the outside world, and the policy encourages the development of small and medium-sized foreign trade enterprises, especially e-business enterprises 2. Financial policy is friendly to small and medium-sized enterprises, which is conducive to the development of small and medium-sized enterprises and the solution of financial problems 3. The environmental protection policy is relatively severe, and the company is on the cusp of the storm. It needs to further improve its awareness of environmental protection and green means of production
Conclusion: The company's relevant value chain needs further analysis and transformation	

The suggestions for the later development strategy of the company are as follows:

1. Focus on the limited funds, technology and core talents, focus on the target market under the segmentation, make the enterprise develop in the direction of "specialized, refined, special, new" and other related directions, at the same time, continuously launch the corresponding derivative products in the corresponding refined field, shape the core force of product quality, so as to improve the economic scale of the whole enterprise.
2. Abandon the logistics link that the company is not good at, outsource it to the professional company team for operation, integrate the advantage link for development, fully investigate the international market customer demand, and fully investigate the core competitiveness of related industries in the value chain. Focus on their own areas of expertise, the establishment of a complete information system, while strengthening the corresponding e-business capabilities, to enhance the corresponding professional training of existing personnel.
3. Strengthen the company's talent management concept, strengthen the construction of the company's organizational structure, and take the corresponding talent strategy as the basis and guarantee strategy of enterprise development.

51.4 Conclusion

This article focuses on analyzing the value chain issues involved in cross-border e-business for small and medium-sized foreign trade in China, and compares different research methods. Based on the current development strategy of small and medium-sized foreign trade e-business and the networked manufacturing mechanism, this article accurately models the corresponding cross-border e-business foreign trade value chain and analyzes its internal advantages. Based on the corresponding economic environment, combined with the SWOT matrix analysis algorithm, a detailed explanation was given on the external advantages and related factors of current small and medium-sized enterprises' foreign trade e-business. On this basis, this article also analyzes its position in international trade. On this basis, combined with the actual situation in China, a cross-border e-business development strategy for small and medium-sized enterprises in China has been proposed, and relevant development models have been proposed. This project will also conduct application research on relevant algorithms for large-scale cross-border e-business.

References

1. N. Chen, J. Yang, Mechanism of government policies in cross-border e-commerce on firm performance and implications on e-commerce. Int. J. Mob. Commun. **15**, 69–84 (2017)
2. D. Golightly, G. Kefalidou, S. Sharples, A cross-sector analysis of human and organisational factors in the deployment of data-driven predictive maintenance. Inf. Syst. E-Bus. Manag. **16**, 627–648 (2018)
3. J. Anson, M. Boffa, M. Helble, Consumer arbitrage in cross-border e-commerce. Rev. Int. Econ. **27**, 1234–1251 (2019)
4. Y. Wang, Y. Wang, S.H. Lee, The effect of cross-border e-commerce on China's international trade: an empirical study based on transaction cost analysis. Sustainability **9**, 2028 (2017)
5. K. Reddy, E. Xie, Y. Huang, The causes and consequences of delayed/abandoned cross-border merger and acquisition transactions: a cross-case analysis in the dynamic industries. J. Organ. Chang. Manag. **29**, 917–962 (2016)
6. J. Mou, Y. Cui, K. Kurcz, Trust, risk and alternative website quality in B-buyer acceptance of cross-border E-commerce. J. Glob. Inf. Manag. (JGIM) **28**, 167–188 (2020)
7. J. Zhang, P. Wong, P. Lai, A geographic analysis of hosts' irritation levels towards mainland Chinese cross-border day-trippers. Tour. Manag. **68**, 367–374 (2018)
8. J. Li, J. Xia, Z. Lin, Cross-border acquisitions by state-owned firms: how do legitimacy concerns affect the completion and duration of their acquisitions? Strat. Manag. J. **38**, 1915–1934 (2017)
9. A. Loiudice, G. Grancini, A. Taurino, M. Corricelli, M.R. Belviso, M. Striccoli, A. Agostiano, M.L. Curri, A. Petrozza, P.D. Cozzoli, Three-dimensional self-assembly of networked branched TiO_2 nanocrystal scaffolds for efficient room-temperature processed depleted bulk heterojunction solar cells. ACS Appl. Mater. Interfaces **6**, 5026–5033 (2014)
10. J. Davis, T. Edgar, J. Porter, J. Bernaden, M. Sarli, Smart manufacturing, manufacturing intelligence and demand-dynamic performance. Comput. Chem. Eng. **47**, 145–156 (2012)
11. T.Q. Dinh, K.K. Ahn, J. Marco, A novel robust predictive control system over imperfect networks. IEEE Trans. Indus. Electron. **64**, 1751–1761 (2016)
12. L.G. Fahad, S.F. Tahir, W. Shahzad, M. Hassan, H. Alquhayz, R. Hassan, Ant colony optimization-based streaming feature selection: an application to the medical image diagnosis. Sci. Program. **2020**, 1–10 (2020)
13. M. Sachithanadam, S.C. Joshi, High strain recovery with improved mechanical properties of gelatin–silica aerogel composites post-binding treatment. J. Mater. Sci. **49**, 163–179 (2014)
14. N. Guo, D. Hu, H. Wang, R. Wang, Y. Xiong, Functional poly (ethylene terephthalate) materials prepared by condensation copolymerization with ionic liquids. Polymer Bull. **70**, 3031–3040 (2013)

Chapter 52
Research on Business Data Protection Strategy Based on SVM Algorithm

Yineng Xiao

Abstract For modern enterprises, the development trend of information electronization means that data is an asset, and it is also the embodiment of the core competitiveness of enterprises. This article combines the advantages of support vector machine (SVM) algorithm in big data analysis and prediction, normalizes the data of intrusion detection system, log files, firewalls, network devices and so on through data fusion, and then makes further situation assessment and prediction based on these unified data, and compares different algorithms in network safety situation awareness assessment and prediction effect and data training time. The simulation results show that after many iterations, the error of network safety situation awareness assessment and prediction algorithm gradually decreases and tends to be stable. The results show that this method improves the accuracy of network safety risk estimation, has important reference value for defending network safety risks, and can provide technical support for enterprise business data protection.

Keywords Business data · Support vector machine · Network safety · Situation assessment

52.1 Introduction

For modern enterprises, the development trend of information electronization means that data is an asset, and it is also the embodiment of the core competitiveness of enterprises. Effective protection of enterprise's key sensitive data will enable the enterprise to stabilize its position in the fierce commercial competition [1]. Since the new century, the information industry has begun to rise, and various information technologies have gradually been widely used, which has brought qualitative

Y. Xiao (✉)
The Global Intellectual Property Institute, Nanjing University, Suzhou 215163, China
e-mail: xiaoyineng@pku.edu.cn

Advanced Institute of Information Technology, Peking University, Hangzhou 311200, China

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_52

changes to the operating state of enterprises, but also brought certain security risks to enterprise information data, which directly or indirectly threatened the interests of enterprises in all aspects [2]. In the real society, the loss of sensitive data not only means economic loss to enterprises, but also may bring more trouble to enterprises [3]. More and more enterprises are beginning to pay attention to the protection and storage security of data information, but facing the huge enterprise database, the process of solving the problem has become more and more bumpy [4]. In the past, network defense methods only used the information contained in data packets to obtain the risk estimation results, and the accuracy of the obtained risk estimation results was low [5]. In order to ensure the safety of network operation, it is an important basis to ensure the safe operation of the network, so that the network administrator can make clear the network operation status in real time, make clear the network safety risks in advance, and adopt corresponding defensive measures to resist risks. Network safety situation awareness is an environment-based, dynamic and holistic data fusion method, which can fuse data from a macro perspective. By finding the correlation between data through machine learning algorithm, rather than making rules artificially, we can find the potential relationship between data [6].

To meet the needs of information development, various enterprises have also started to establish their own information network platforms, including e-commerce and website management systems [7]. In the increasingly complex network environment, network attacks are becoming more and more diverse and complicated, and new attack methods emerge one after another [8]. Mining useful network safety risk data from massive network big data is the key to accurate network safety risk assessment. When there are attacks in the network, a large number of alarm messages will be formed, which will improve the difficulty of data mining. Efficient big data mining methods are extremely important for improving the accuracy of network safety risk assessment [9].

Wang et al. generalized sensitive attributes into a tree, and set corresponding difference constraints on each node according to the privacy protection requirements, and established a personalized anonymous model of data, further improving the personalized requirements in data publishing [10]. Jiang et al. discovered the functional dependence between sensitive data when studying the K-anonymous model, and solved the problems of identifier selection and data integrity in anonymous data [1]. Zhao et al. proposed an information leakage detection method based on the whitelist of enterprise websites, which calculated the best detection entry first, located the filter position by hiding the directory leakage source, and used the filter to complete the information leakage detection of enterprise websites [11]. Hussain et al. proposed a method to detect private data based on the smoothness of document context according to the internal correlation of published data and the extended algorithm of privacy sensitivity, and combined data smoothing and extended query to detect private data, but this method has low retrieval efficiency under a large number of data [12]. In this article, a network safety situation awareness method based on SVM algorithm is proposed. The data of intrusion detection system, log file, firewall and network equipment are normalized by data fusion, and then the situation is further evaluated and predicted based on these unified data.

52.2 Methodology

52.2.1 Business Data Protection

Business data protection system is a new and safe product, which is based on careful content inspection and analysis. It can not only protect the moving data on the Internet, but also protect the static data on the Internet and the important data stored in the computer. As a new direction of information security development, commercial data protection has developed into a unique technical system based on the original security technology, in which the key technologies used to include content analysis, terminal control technology and encryption and decryption technology. Content analysis technology can deeply analyze network traffic and files, and identify various key contents according to pre-established policies. The development of commercial data protection technology has become a general term for a class of products, which mainly refers to preventing the data information of enterprises from being leaked through centralized management based on the data security protection strategy formulated by enterprises [13]. This kind of technical product has begun to take the inspection and analysis of data information as the basis, protecting the data stored in solid-state storage devices. At the same time, it has strong protection ability for enterprise cloud data. The solutions to secure access to enterprise electronic data mainly include logical encryption disk technology, file system monitor and electronic file safe. Among them, the basic idea of logical encryption disk technology is to add the kernel service of device management to the operating system to provide users with virtual disks for saving electronic documents. The encryption and decryption technology used in commercial data protection system mainly encrypts sensitive data, and the encrypted object can be a specific area of a document or a disk.

The protection scheme for internet data leakage is generally placed where the internal and external networks are connected, and all the data are checked safely. The protection scheme for data leakage in the computer should be placed on the host computer with key data. If the data to be protected is found to be transferred, the commercial data protection system will intercept it immediately [14]. When the self-diagnosis of commercial data protection is completed, enterprises can start to carry out protection work according to the specific scheme of commercial data protection [15]. In the process of work, it is of course efficient to achieve one-step effect, but if you use a step-by-step scheme, it will be more conducive for enterprises to understand the business data protection technology, and constantly ask questions during the implementation of the scheme, and then make optimization and improvement. The encryption and decryption technology used in the commercial data protection system also encrypts sensitive and key data, and the encrypted object is usually the range specified in the document. Before choosing commercial data protection, enterprises need to conduct self-diagnosis as the first step. The contents of self-diagnosis include determining the protection target, the location of the target and the channel of its output. It is very important and crucial to do these contents well in the implementation of commercial data protection system. For enterprises, it is certainly good to implement business data protection in one step, but adopting a gradual strategy can enable enterprises to better understand new technologies, adjust internal workflows and optimize them.

52.2.2 Network Safety Situation Awareness Algorithm

When there are many sensitive attributes, the sensitive attributes are first classified reasonably, and then the sensitive attributes in each category are grouped separately, which can reduce the loss and concealment rate of additional information of data, thus improving the efficiency of data. Through the correlation analysis between sensitive attributes, the sensitive attributes with high correlation are put in a table, so that the published data protect the sensitive data with high correlation, and the sensitive attribute data with low correlation may be hidden, and the usability of the commercial data protection system is improved through the correlation analysis of sensitive attributes [16]. In this method, the single-class SVM is extended to semi-supervised mode by combining labeled data, and the model performance is optimized by combining active learning method with small labeling cost. The security events collected from massive network data are quite different in format, so it is necessary to normalize the security events to facilitate mining the association rules contained in them. By using the mined association rules, the attack behaviors such as similar viruses and similar vulnerabilities of network safety risks are analyzed, and the accuracy of network safety risk assessment is improved. The regression prediction process of SVM is shown in Fig. 52.1.

The main function of the abnormal behavior assessment module is to monitor the operation information and running status of each program of the current host computer in real time through script recording, and complete the assessment of the recorded running status information according to the SVM algorithm. The internal state information of enterprise Information System is obtained indirectly by analyzing the external observation values of the system:

$$\theta_k = f(\theta_{k-1}, v_k) \tag{52.1}$$

$$y_k = h(\theta_k, n_k) \tag{52.2}$$

Among them, θ_k is the N_θ-dimensional state vector at the t_k moment; y_k is the N_y-dimensional observation vector at the t_k moment; v_k and n_k represent the state transition noise vector and the observation noise vector, respectively.

Assume that each node takes values between sets $\{0, 1\}$, that is:

$$\forall i, j, v_i \in \{0, 1\}, h_j \in \{0, 1\} \tag{52.3}$$

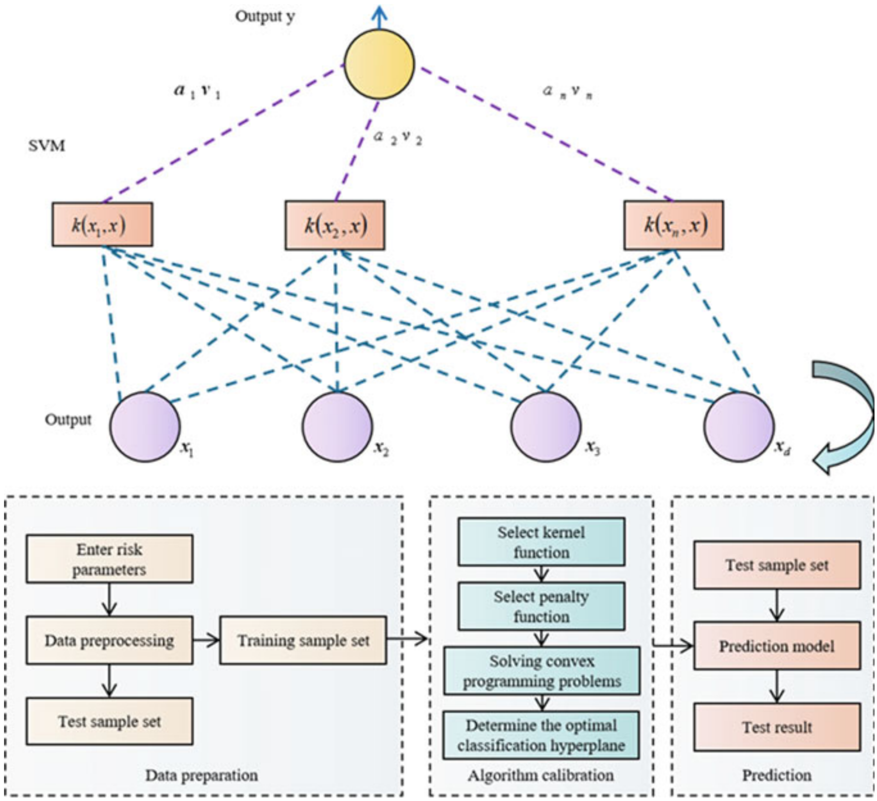


Fig. 52.1 SVM regression prediction process

The i th visible layer node state is v_i; j hidden layer node status is h_j; The energy function of the network state (v, h) is calculated as follows:

$$E(v, h|\theta) = -\sum_{i=1}^{n} a_i v_i - \sum_{j=1}^{m} b_j h_j - \sum_{i=1}^{n} \sum_{j=1}^{m} v_i W_{ij} h_j \tag{52.4}$$

In which W_{ij} is the connection weight between the visible node i and the hidden node j; a_i is the offset of the visible node i; b_j is the offset of hidden node j.

Scientifically judge the existing error of the fitness value of the system. If it has exceeded the allowable error limit, it is necessary to end the training work, otherwise, it will continue training until it reaches the limit value.

According to the classification of data sensitivity, the circulation process of sensitive data in enterprise intranet is comprehensively analyzed, including data generation, circulation mode, circulation control, data storage mode and storage location. When the intranet is connected with the Internet or other networks, a network-based data leakage prevention system should be selected to check the compliance at the network boundary. As a passive network monitoring tool, this kind of equipment generates a fingerprint database of information filtering according to the key words of sensitive information in the enterprise, a specific file template or a specific file format, and monitors information leakage on the communication channel between the enterprise intranet and the external network.

52.3 Result Analysis and Discussion

Using machine learning to study network safety situation awareness requires sufficient data sets. The data set used in this article is KDD CUP99 data set. This data set is the network connection data collected from a simulated US Air Force LAN, which is divided into marked training data and unmarked test data. In order to avoid the loss of important information caused by excluding special commercial data, quantitative data with large differences in data distribution intervals can be discretized, as shown in Fig. 52.2.

Using these data to train the designed assessment model can get better network weights, and then substituting the obtained network weights into the assessment model can become the basic model for network safety situation awareness assessment and prediction. Firstly, a single classification SVM model is established in an unsupervised way, and then some data request tags are found by using active learning strategy, and the model is expanded and optimized in a semi-supervised way by using these tag data to determine new classification boundaries. Secondly, the selection strategy and termination conditions of active learning are studied. The confidence and representativeness of samples are considered when selecting samples, and the functions of labeled samples and unlabeled samples are considered when setting

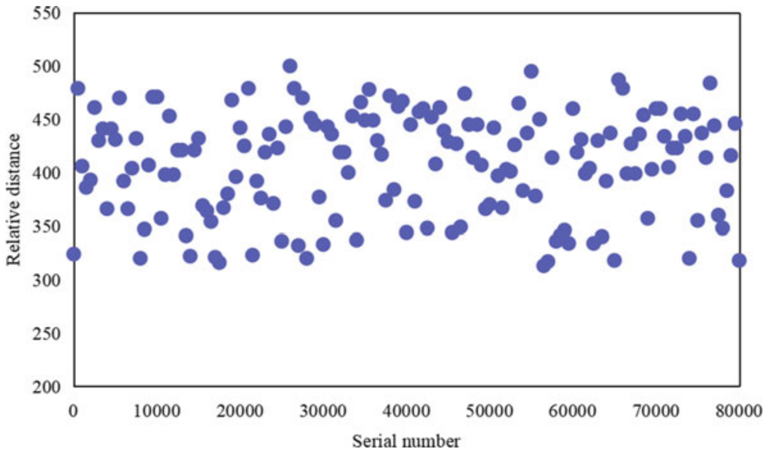


Fig. 52.2 Data outlier removal processing

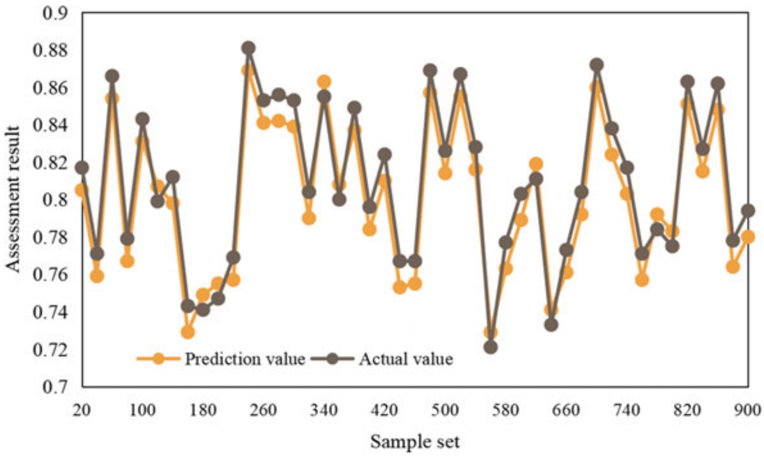


Fig. 52.3 Learning results of machine learning

termination conditions. Compare the output data of the assessment model with the real risk data, as shown in Fig. 52.3.

It is not difficult to see from Fig. 52.3 that the learning result of the assessment model is convergent, which can approximate the original data well and has a basis for predicting the network safety situation. The modeling process of traditional quantitative prediction method does not have the ability of learning data samples and pattern recognition, and its modeling process is an abstract process of original data, which is completed in numerical calculation. Through the training of assessment model, the relationship between system variables can be highly fitted, which is beneficial to the analysis of the related influence between system variables, so as to find the regularity of the relationship between system variables. The time-consuming comparison of algorithm training is shown in Fig. 52.4.

It can be seen that this method has obvious advantages in training time-consuming. The commercial data protection system adopts centralized management, identifies, monitors and protects static, active and in-use data through in-depth content analysis and robust event processing flow, and prevents users' designated data or information assets from intentionally or unintentionally flowing out in violation of security policies. At the same time, in order to adapt to the complex environment in the network, commercial data protection, as a new security product, is based on in-depth content inspection and analysis, which not only protects the data moving on the network, but also protects the stored static data and the data used in the desktop. Figure 52.5 is a comparison of the errors of different network safety situation assessment algorithms at different training stages.

After many iterations, the error of network safety situation awareness assessment and prediction algorithm gradually decreases and tends to be stable. Fully consider the attack situation in the network operation process, apply SVM algorithm to network

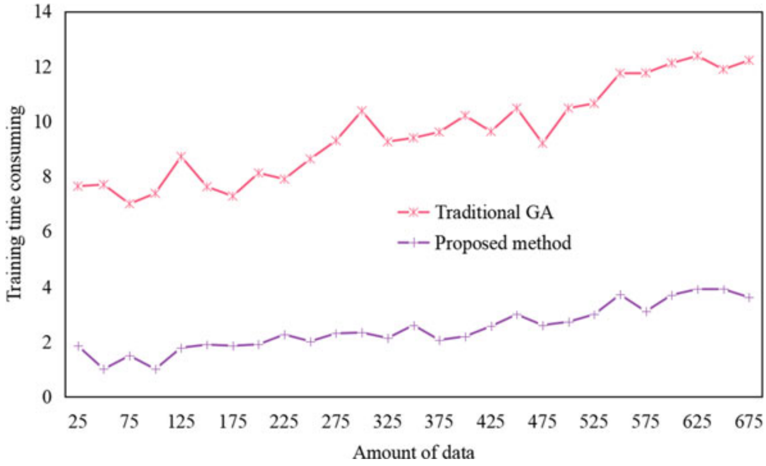


Fig. 52.4 Comparison of training time consumption

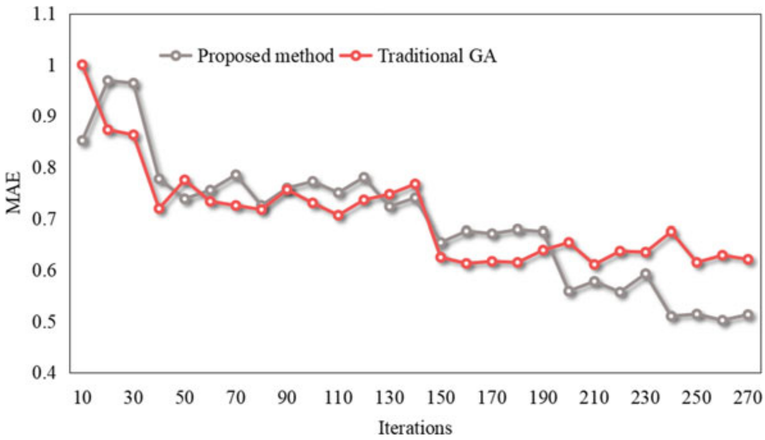


Fig. 52.5 Comparison of algorithm MAE

safety risk estimation, and make full use of the advantages of big data analysis technology to deal with massive data, fully mine the association rules existing in network safety events and estimate network safety risks. The experimental results show that the research method can effectively estimate the network safety risk and ensure the effective protection of commercial data in the mass data operation environment.

52.4 Conclusions

Since the new century, the information industry has begun to rise, and various information technologies have gradually been widely used, which not only brings qualitative changes to the operating state of enterprises, but also brings certain security risks to enterprise information data. Network security situation awareness is an environment-based, dynamic and holistic data fusion method, which can fuse data from a macro perspective. By studying the correlation between data through machine learning algorithm, the potential relationship between data can be discovered. In this paper, a network security situation awareness method based on SVM algorithm is proposed, which normalizes the data of intrusion detection system, log files, firewalls, network devices and so on through data fusion, providing technical support for business data protection of enterprises. After many iterations, the error of network security situation awareness assessment and prediction algorithm gradually decreases and tends to be stable. Using the advantages of big data analysis technology to deal with massive data can fully mine the association rules existing in network security incidents. The protection of enterprise data information and the optimization of safe storage technology can not only protect the information copyright of enterprises, but also help enterprises to stabilize their position in the fierce market competition. With the increase of data and real-time requirements, it is considered to design and build a faster network security monitoring and decision-making platform for big data under the cloud platform to prepare for the sharp increase of data storage in the future.

References

1. W. Jiang, Z. Yang, Z. Zhou, J. Chen, Lightweight data security protection method for AMI in power Internet of Things. Math. Probl. Eng. **2020**, 1–9 (2020)
2. S. Amutha, Design and Implementation of novel security approach designed for cloud computing with load balancing. Solid State Technol. **64**, 1877–1889 (2021)
3. Q. Liu, M. Zeng, Network security situation detection of internet of things for smart city based on fuzzy neural network. Int. J. Reason.-Based Intell. Syst. **12**, 222–227 (2020)
4. H. Wang, D. Zhao, X. Li, Research on network safety situation assessment and forecasting technology. J. Web Eng. **2022**, 19 (2020)
5. P. Lin, Y. Chen, Network security situation assessment based on text simhash in big data environment. Int. J. Netw. Secur. **21**, 699–708 (2019)
6. C. Huang, C. Wang, Network security situation awareness based on the optimized dynamic wavelet neural network. Int. J. Netw. Secur. **20**, 593–600 (2018)
7. L. Xu, C. Jiang, J. Wang, J. Yuan, Y. Ren, Information security in big data: privacy and data mining. IEEE Access **2**, 1149–1176 (2014)
8. V. Attasena, J. Darmont, N. Harbi, Secret sharing for cloud data security: a survey. VLDB J. **26**, 657–681 (2017)
9. A.K. Singh, H. Zhou, S. Berretti, Guest editorial: medical data security solution for healthcare industries. IEEE Trans. Indus. Inf. **18**, 5558–5560 (2022)
10. Z. Wang, N. Wang, X. Su, S. Ge, An empirical study on business analytics affordances enhancing the management of cloud computing data security. Int. J. Inf. Manag. **50**, 387–394 (2020)

11. L. Zhao, D. Zhu, W. Shafik, S.M. Matinkhah, Z. Ahmad, L. Sharif, A. Craig, Artificial intelligence analysis in cyber domain: a review. Int. J. Distrib. Sens. Netw. **18**, 15501329221084882 (2022)
12. F. Hussain, R. Hussain, B. Noye, S. Sharieh, Enterprise API security and GDPR compliance: Design and implementation perspective. IT Prof. **22**, 81–89 (2020)
13. L. Teng, H. Li, S. Yin, Y. Sun, A modified advanced encryption standard for data security. Int. J. Netw. Secur. **22**, 112–117 (2020)
14. K. Gai, L. Qiu, M. Chen, H. Zhao, M. Qiu, SA-EAST: security-aware efficient data transmission for ITS in mobile heterogeneous cloud computing. ACM Trans. Embed. Comput. Syst. (TECS) **16**, 1–22 (2017)
15. P. Zhao, K. Bian, T. Zhao, X. Song, J.-M. Park, X. Li, F. Ye, W. Yan, Understanding smartphone sensor and app data for enhancing the security of secret questions. IEEE Trans. Mob. Comput. **16**, 552–565 (2016)
16. Y. Liu, H.T. Liu, Integrated monitoring algorithms for software data security situation on private cloud computing platform. Int. J. Internet Protoc. Technol. **14**, 1–9 (2021)

Chapter 53
Understanding Cyber Terrorism with a Special Focus on Zero-Day Attacks

Nischal Das, Deepika Gupta, Isha Chaudhary, Rashmi Fulmali, Sumit Kishore, and Vijay Sandeep

Abstract The world is becoming increasingly digitalized and automated that adds to ease and comfort to everyone, but threats of security, data leakage, website hacking, attacks, phishing, zero-day attacks and other forms of cyber-terrorisms are also becoming major concerns not only for organizations, businesses and society but also for the government across the globe. This paper is an attempt to understand basics of cyber-terrorism with special focus on zero-day attacks. This paper is a preliminary literature review attempt of these concepts and looks at the growing destructions economically and financially by zero-day attacks. This paper attempts to explore various types of zero-day attacks, steps taken by various international organizations to deal with these issues and certain recommendations made by them. In addition, the paper looks at the impact of these externalities on policy making and society. As cyber-security gains importance as an agenda item for the business and policy makers, we intend to look deeper into this aspect that has the power to threaten national security, public life, economic and financial stability of developed, developing and even under-developing economies.

Keywords Cyber-terrorism · Zero-day attacks · Impact on society

53.1 Introduction

Cyberterrorism refers to use of technology and cyberspace, particularly information and computer system and networks to conduct an act of terrorism. Cyberterrorists may employ various malicious activities, such as hacking, cyber-attacks, spreading malware, conducting DDoS (Distributed Denial of Service) attacks, and other forms

This literature review paper is developed on the basis of group project done by students as part of the MBA Program course requirements at IIM Visakhapatnam.

N. Das · D. Gupta (✉) · I. Chaudhary · R. Fulmali · S. Kishore · V. Sandeep
IIM Visakhapatnam, Visakhapatnam, India
e-mail: deepikag@iimv.ac.in

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_53

of digital sabotage with the intent to cause widespread fear, panic, disruption, or damage to critical infrastructure, economies, or societies.

It can target a wide range of sectors, including government agencies, financial institutions, healthcare facilities, transportation systems, communication networks and other critical infrastructure. The motivation behind cyber terrorism can vary and may include political, ideological, religious and financial motives.

It poses a significant threat to national security, public safety and economic stability resulting in significant loss to sensitive data such as disruption of essential services, financial loss and potential loss of life.

53.2 Literature Review

The paper looks at the literature review of cyber-terrorism with special focus on zero-day attacks. With growing digitalization across all sectors and industries globally, cyber threats and vulnerability has now become one of the major concerns of all organizations. This issue has gained high significance with the top management and is an essential agenda item for governance and ethics of the organization. It has implications for all of us and may have various motivations aligned with personal, political, religious, financial and others.

Cyberterrorism is a type of terrorism that uses digital and cyberspace to do harm, incite fear, and advance political, social, or economic goals. Cyberterrorism has grown in importance as a danger to national security over the past few decades, drawing more attention from practitioners, scholars, and politicians. An overview of the present body of knowledge regarding cyberterrorism, including its definitions, traits, motives, strategies, effects, and countermeasures, is intended to be provided through this literature review.

Although there is no universally accepted definition of cyberterrorism, it is defined based on the perspectives of the researchers. According to [7, 21], cyber terrorism is use of cyberspace by non-state actors to create chaos or anarchy by inflicting harm to people, property or critical infrastructure for political, ideological or financial purposes. According to studies by [1, 19], cyber terrorism as a form of information warfare or a subset of terrorism achieving similar goals through cyber space.

The use of cutting-edge technology, the possibility of anonymity and distant attacks, the exploitation of holes in digital systems, and the desire to sow fear and cause havoc in society can all be traits of cyberterrorism. Attacks by cyberterrorists can target a range of industries, including the military, government, financial institutions, energy, transportation, and communication systems, as well as key infrastructures.

Cyberterrorists might have a variety of objectives, and it can be difficult to pin down their exact goals. According to some academics, political, ideological, or religious objectives are the primary drivers of cyberterrorism. These motivations attempt to advance a specific agenda, undermine the status quo of power, or denounce perceived injustices [8, 21]. Others contend that financial gain, including extortion, fraud, or the theft of sensitive data, can be a driving force behind cyberterrorism [3, 5].

Cyberterrorists can use a wide variety of ways to carry out their assaults. Malware attacks, distributed denial of service (DDoS) attacks, social engineering scams, insider threats, and other cutting-edge techniques for gaining unauthorised access, upsetting systems, stealing data, or causing harm are some examples of these. To incite fear, panic, and misinformation, cyberterrorists may also use psychological manipulation, propaganda, and social media.

With growth of digital tools like internet, network security has become a subject of importance for business and government organisations. Utilisation of internet has many advantages but there many possibilities to negate these advantages by being hacked. At the same time with growing amount of internet utilisation there are lots of data that are being stored and exposed to the world thereby increasing the risk of security breaches. One of the security breach hackings is zero-day attacks.

53.2.1 Zero-Day Attacks

Zero day is term used to describe vulnerabilities that hackers used to attack system. It basically means that the flaw was just discovered, and vendors have zero days to fix it and hackers have already exploited this opportunity. Most zero-day attacks are caused by Black hat hackers or hacktivists or state sponsored hackers. There are types of zero-day attacks:

1. **Zero-day vulnerability**: It is the most likely to succeed attack, because no patch exists for vendors to rectify the flaws.
2. **Zero-day exploit**: Attacking the system with previously unidentified vulnerability.
3. **Zero-day attack**: It is the use of a zero-day exploit to cause damage to steal data from a system affected by a vulnerability.

They can take any of the above form and can any manifest any type of software vulnerability. For example, "missing data encryption, SQL injection, buffer overflows, missing authorisations, broken algorithms, URL redirects, bugs or problems with password security".

World's first zero-day attack, "Stuxnet", a malware that was used to break into Iran's nuclear enrichment facilities. The attack was basically to alter the speed of the centrifuge remotely eventually leading to nuclear catastrophe with an ulterior motive of hampering Iran's nuclear agreement.

Zero-day attacks were wild and rare in 2006.According to an intelligence report by [20], the number of zero-day vulnerabilities discovered in 2015 was the highest than it had been in the previous five years. This trend has continued in the years since then. According to "Trend Micro (website) Zero-Day Initiative" by the end of 2021 new zero-day attack will be discovered every day. Another report by "Ponemon

Institute (2020), 80% of zero days fell into Zero-Day category". Some of the features of zero-day attacks are:

- **Detection and Prevention**: They are difficult to detect and prevent because of lesserknown vulnerability to developers and vendors, thereby no patches or fixes are available to prevent attacks.
- **Targeted attacks**: Most of the zero-day attacks are used in targeted attacks against specific organization or individuals. These attacks are often part of advanced persistent threat (APT) campaigns.
- **Consequences**: Zero-day attacks can be used to install malware or ransomware, steal sensitive data, or even take over entire systems. These attacks can have serious implications, including monetary loss, harm to one's character, and legal penalties.
- **Defence**: Organisations must put in place a number of security measures, such as network segmentation, application whitelisting, and intrusion detection and prevention systems, to effectively protect against zero day attacks.
- **Collaboration**: Independent security researchers or white hat hackers find many zero-day vulnerabilities. These researchers must exchange information with vendors and other security experts in order to stop assaults.

53.3 Methodology of Zero-Day Attacks

The process is cyclic in nature and involves identifying vulnerability in the target system or application, involving source code, reverse engineering, or using any other techniques. Once the vulnerability is identified the attacker will exploit the advantage of the flaw to attack the system. Figure 53.1 highlights the methodology used by the attacker to follow system penetration for initiating zero-day attack.

1. **Reconnaissance**: Called as foot printing where hacker collects all information required for mapping and network vulnerability etc.
2. **Scanning**: In this stage hacker makes outline of target network such as IP address of the end or target market and other services.
3. **Gaining access**: Hacker in this stage basically owns the system. A special type of software called "zombie" which can be distributed leading to damage of machines.
4. **Maintaining access**: In this stage hacker basically in inject Trojan into the system there-by serving as launchpad and scan other systems and damage them. By this entire organisation can be disrupted.
5. **Clearing task**: This is the last and final stage where hackers damages or clears the evidence of their activities.

Fig. 53.1 Security life cycle [18]

53.4 Laws and Regulations

The exponential development in artificial intelligence, internet of things and large quantity of data to be analysed and understood have made cyber space more and more vulnerable. In response to these threats, governments around the world are developing policies, laws and regulations. One of them, being USA Patriot Act, 2001, passed after 9/11 attack by the United States Congress. Another important law is Cybersecurity Information Sharing Act (CISA) which was passed by the US Congress in 2015. Other economies are also collaborating together to form networks to deal with cyber security laws. As cyber terrorism makes boundaries non-existing, the laws and regulations cannot be confined to one nation but need to be collaborated together to combat such serious issues. Some of the initiatives in this regard are:

- **UN Resolution and Declaration**: UN General Assembly has adopted resolutions such as the "International Code of Conduct for Information Security" in 2015 and the "United Nations Global Counter-Terrorism Strategy" in 2006, which include provisions on preventing the use of information and communication technologies (ICTs) for terrorist purposes.
- **Budapest Convention**: First international treat that addresses cybercrime, adapted in 2001 and ratified by 60 countries. The Convention includes provisions related to criminalizing cyberterrorism, enhancing cooperation among states in investigating and prosecuting cyberterrorism offenses, and facilitating the exchange of information and evidence
- **The G7 24/7 Cybercrime Network**: "The G7 nations (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States)" have established a network to share information and practices to eliminate hacking activities. The

network also aims to facilitate international cooperation in investigating and prosecuting cybercrime cases.

- **ASEAN Regional Forum Cybersecurity**: "The Association of Southeast Asian Nations (ASEAN)" established the ASEAN Regional Forum on Cybersecurity in 2016 to enhance cooperation among its members in preventing and combating cybercrime, including hacking.
- **CERT-In**: National agency of India for cybersecurity and incident response has published guidelines for vulnerability disclosure and handling, which aim to establish a framework for responsible vulnerability disclosure and handling by all stakeholders, including researchers, vendors, and users. It has further established guidelines with respect to vulnerability reporting by the vendor to the authority. If the vendor is unable to report it, then the agency may disclose it to the public.

53.5 Impact on Policy Making and Society

Cyberterrorism has the potential to disrupt society at large, resulting in financial losses, harm to vital infrastructures and a loss of public faith in electronic systems [11, 16].

- **Privacy and security**: Personal information and sensitive data can be compromised leading to breach of data, affecting individuals and businesses substantially leading to financial losses and reputational damage. Attacks on military systems, governmental institutions, and vital infrastructure sectors are just a few examples of how cyberterrorism can represent a serious danger to national security on a global scale [5, 8].
- **Intellectual Property theft**: Breach of intellectual property, includes trade secrets and patented technology. This can harm businesses and discourage innovation.
- **Cyberwarfare**: Hacking can be used in cyberwarfare between countries leading to geopolitical tensions and potentially catastrophic consequences.
- **At organisational level**: cyberterrorism can lead to monetary losses, reputational damages, legal liabilities, and potential harm to clients, staff members, and other stakeholders for targeted businesses [3, 6].

53.6 Recommendations

Cyberterrorism, in various forms, is here to stay along with technological developments. As innovations rise to next levels, cyberterrorism too shall find new techniques and mechanisms to make systems vulnerable to breach data, manipulate and misuse them. Cyberterrorism cannot be totally eliminated but its impact can be controlled, reduced or concentrated through proper checks and balances. Here, it is the responsibility of businesses, cyber experts, policy makers, government at national and international levels to ensure protection through cyber security methods. There are various recommendations suggested by different agencies as enumerated. However, each stakeholder mustcreatively think beyond of protecting digital data through serious and novel recommendations.

- **Improved data protection laws**: Introduction of stricter data protection laws by government can help businesses to adapt additional measures to protect sensitive data.
- **Mandatory cyber security training**: Companies should provide cyber security training to their employees to acknowledge them with respect to latest threats and consequences of those threats.
- **Increases collaboration between public and private sector**: Collaboration between both the parties along with information sharing agreement regarding loopholes in the cyberspace will establish a forum of information required to counter cyber-attacks.
- **Keep your software up to date**: Make sure to update your operating system, software, and security updates on a regular basis. In order to resolve vulnerabilities that have been identified, developers frequently release patches. As a result, updating your software will ensure that you have the most modern security precautions.
- **Security software**: Use reliable firewall and antivirus software, this will help detect and block attack including zero day.
- **Use strong passwords**: Password such as date of birth, vehicle number, hometown etc. has been the most hacked accounts. A strong password with better combination of words, number and alphanumeric without linkage towards personal experiences is amongst the least possible accounts to be attacked.
- **Be cautious of suspicious emails and attachments**: Opening of suspicious emails or attachments from unknown senders, may inject malware that could exploit vulnerabilities in your system.
- **Use two-factor authentication**: Enable two-factor authentication on all your accounts to provide an extra layer of security.
- **Backup your data**: This will help in data retrieval in event of such attacks thereby sensitive information are not compromised.
- **Increased funding**: Governments may invest more resources into researching new technologies and strategies to prevent and mitigate cyber-attacks.

The paper is a preliminary work of understanding cyber world in terms of security, terrorism, attacks, hacking with special focus on zero-day attacks. We intend to take this work further with more understanding of the increasing impact of this domain and its impact on all the spheres of business and society including policy making by the governments at all local, regional, national and global levels. We also intend to extend this work to understand how the lesser known space of cyber-security is being significant to national security, public life, economic and financial stability as the sensitive data gets accumulated in various forms of digitalized mechanisms thereby assuming highest level of safe haven apparatuses for developed, developing and even under-developing economies.

References

1. J. Arquilla, D. Ronfeldt, Cyberwar is coming! in *Athena's Camp: Preparing for Conflict in the Information Age*, eds. by J. Arquilla, D. Rnfeldt (RAND, Santa Monica CA, 1997)
2. C. Ashraf, Defining cyberwar: towards a definitional framework. Def. Secur. Anal. **37**(3), 274–294 (2021)
3. Y. Cherdantseva, P. Burnap, A. Blyth, P. Eden, K. Jones, H. Soulsby, K. Stoddart, A review of cyber security risk assessment methods for SCADA systems. Comput. Secur. **56**, 1–27 (2016)
4. M. Conway, *Reality Bytes: Cyberterrorism and Terrorist 'Use' of Internet*. DCU Online Research Access Service (2002)
5. M. Conway, *Is cyberterrorism a Real Threat?–Yes* (2018). https://doras.dcu.ie/22241/1Pro-Cyberterrorism_Ch_Doras_Version.pdf. Last accessed 2 April 2023
6. M. Daud, R. Raisah, M. George, D. Asirvatham, G. Thangiah, Bridging the gap between organisational practices and cybersecurity compliance: can cooperation promote compliance in organisations? Int. J. Bus. Soc. **19**(1), 161–180 (2018)
7. D. Denning, Cyberterrorism: the logic bomb versus the truck bomb. Glob. Dialogue, Nicos. **2**(4), 29–37 (2000)
8. D. Denning, Terror's web: How the internet is transforming terrorism. Handbook Internet Crimes 194–213 (2010)
9. O. Franklin, M. Ismail, The zero-day vulnerability. Int. J. Inf. Syst. Eng. **9**(1), 65–76 (2021)
10. D. Halder, *Information Technology Act and Cyber Terrorism: A Critical Review*. (Centre for Cyber Victim Counselling, 2011). https://ssrn.com/abstract=1964261
11. T. Holt, M. Stonhouse, J. Freilich, S. Chermak, Examining ideologically motivated cyberattacks performed by far-left groups. Terror. Polit. Violence (2018). https://doi.org/10.1080/09546553.2018.1551213
12. https://www.trendmicro.com/en_us/devops/22/I/zero-day-threat-protection.html. Last accessed 24 April 2023
13. C. Lee, K. Choi, R. Shandler, Kayser, Mapping global cyberterror networks; An empirical study of Al-Qaeda and ISIS Cyberterroris. J. Contemp. Crim. Justice. (Forthcoming)
14. M. Kilger, Anticipating the nature and likelihood of a cyberterror community, in *Cyber Infrastructure Protection Volume III, Strategic Studies Institute* (US Army War College, 2017)
15. P. Sullivan, Privacy Report May 2020. https//ponemonsullivanreport.com/2020/05. Last accessed 25 April 2023
16. G. Rattray, *Strategic Warfare in Cyberspace* (MIT Press, 2001)
17. K. Samuel, W. Osman, Cyber terrorism attach of the contemporary information technology age: issues, consequences and panacea. Int. J. Comput. Sci. Mob. Comput. **3**(5), 1082–1090 (2014)
18. P. Sankardas, M. Raeez, B. Baby, Ethical hacking: impacts on society. Int. J. Adv. Res. Comput. Commun. Eng. **9**(1), 212–215
19. M. Stohl, Cyber terrorism: a clear and present danger, the sum of all fears, breaking point or patriot games? Crime Law Soc. Chang. **46**(4–5), 223–238 (2007)
20. Symantec Intelligence Report, August 2015, Symantec Corporation World Headquarters, CA 94043, USA.
21. G. Weimann, *Cyberterrorism: How Real is the Threat?* (2004)
22. What is zero-day attack?—Definition and explanations, https://www.kaspersky.co.in/resource-center/definitions/zero-day-exploit. Last accessed on 24 April 2023

Chapter 54
Thriving in Uncertainty: Effective Financial Analytics in the Age of VUCA

Itishree Behera, Pragyan Nanda, Manisha Behera, and Tanushree Bhoi

Abstract The current scenario has been marked by unprecedented uncertainty and volatility in financial markets owing to the COVID-19 pandemic and its economic fallout. Financial analysts have had to adapt to this rapidly changing business environment characterized by high volatility, uncertainty, complexity, and ambiguity. The pandemic has led to significant disruptions in global supply chains, caused major shifts in consumer behaviour, and prompted unprecedented levels of government intervention in financial markets. Financial analysts must be able to quickly analyze data and make informed decisions in response to rapidly changing market conditions. The ability to effectively analyze data, identify patterns, and make informed decisions is more critical than ever in the current scenario. Financial analytics must handle large amounts of data from multiple sources, including market data, economic indicators, and social media. By adapting to the VUCA environment and effectively analyzing data, financial analysts can succeed in the current scenario, despite the challenges posed by the pandemic and its economic fallout. Furthermore, the pandemic has also led to significant shifts in investment patterns and asset prices, adding to the complexity and ambiguity of financial markets. Financial analytics must remain agile and adaptable to effectively navigate the VUCA landscape and make informed decisions in this challenging and rapidly evolving environment.

Keywords Uncertainty · Volatility · Complexity · Adaptability · Economic fallout · Informed decisions

I. Behera (✉) · P. Nanda · M. Behera · T. Bhoi
Interscience Institute of Management and Technology, Bhubaneswar, Odisha, India
e-mail: Itishreebehera054@gmail.com

R. Gupta et al. (eds.), *Recent Advancements in Computational Finance and Business Analytics*, Learning and Analytics in Intelligent Systems 32,
https://doi.org/10.1007/978-3-031-38074-7_54

54.1 Introduction

Financial analytics refers to using statistical and quantitative techniques to analyze financial data to gain insights and inform decision-making. This data can include financial statements, market data, economic indicators, and other relevant information. Financial analytics aims to provide insights into financial performance, risk management, and investment strategies [1]. Organizations can identify trends, make forecasts, and optimize financial performance by analyzing financial data. Some typical financial analytics techniques include ratio analysis, trend analysis, forecasting, and risk management. These techniques can be applied to various financial activities, including investment management, financial planning, and accounting. Financial analytics has become increasingly important in today's data-driven business world, where companies generate and collect large amounts of financial data. Financial analytics allows organizations to make better decisions, manage risks more effectively, and optimize their financial performance. This involves applying statistical and quantitative techniques to analyze financial data, including a wide range of information, such as financial statements, market data, economic indicators, and other relevant financial data. The main goal of financial analytics is to provide insights into financial performance, risk management, and investment strategies. Organizations can identify trends, make forecasts, and optimize financial performance by analyzing financial data. This can involve using various techniques, such as ratio analysis, trend analysis, forecasting, and risk management, all of which are critical in helping organizations make informed decisions. Ratio analysis, for example, involves the analysis of critical financial ratios to gain insights into a company's financial performance. This includes ratios such as profitability, liquidity, and debt ratios, which can help organizations understand their financial position and make decisions accordingly. Trend analysis involves analyzing historical data to identify trends and patterns that inform future decisions. This can involve looking at financial statements over time, such as income statements, balance sheets, and cash flow statements. Forecasting is another essential technique used in financial analytics. This involves using statistical models to predict future financial performance based on historical data and other relevant factors. This can help organizations plan for future growth, identify potential risks, and make informed decisions about investments and other financial activities. Financial analytics has become increasingly important in today's data-driven business world, where companies generate and collect large amounts of financial data. Financial analytics allows organizations to make better decisions, manage risks more effectively, and optimize their financial performance. As a result, financial analytics has become an essential tool for any organization looking to stay competitive in today's fast-paced business environment.

54.1.1 Background

VUCA, an acronym for Volatility, Uncertainty, Complexity, and Ambiguity, represents a framework developed by the U.S. Army War College in the late 1980s to describe the characteristics of the rapidly changing global environment. Here is the explanation of each word in a more elaborate way:

1. **Volatility** refers to the degree of fluctuation and instability observed in various aspects of the business environment. This can include market conditions, prices of assets and commodities, technological advancements, customer preferences, and more. Volatility signifies the speed and magnitude of changes that occur, often unexpectedly, which can significantly impact organizations and markets.
2. **Uncertainty**: Uncertainty denotes the lack of predictability and the difficulty in determining future outcomes with a high confidence level. It arises from factors such as incomplete information, unforeseen events, changing regulations, geopolitical risks, and market dynamics. Uncertainty makes making accurate forecasts or plans challenging because the future is subject to multiple possible outcomes. It emphasizes the need for decision-makers to be comfortable with ambiguity and develop strategies resilient to unforeseen circumstances.
3. **Complexity** refers to the intricate and interconnected nature of systems, processes, and relationships within organizations and their external environments. It reflects the presence of multiple variables, dependencies, and non-linear interactions that collectively shape the business landscape. In complex environments, cause-and-effect relationships are often difficult to discern, and actions in one area can lead to unexpected consequences in others.
4. **Ambiguity** refers to multiple interpretations or conflicting meanings in situations or information. It arises when there needs to be more clarity, differing perspectives, contradictory data, or mixed signals. Ambiguity can hinder decision-making processes, as it introduces uncertainty and makes it challenging to determine the most appropriate course of action.

Therefore, the elements of VUCA characterize an environment that is challenging, uncertain, and dynamic. The concept of VUCA serves as a reminder that more than traditional approaches to decision-making and planning may be needed in such contexts. Organizations and individuals need to develop adaptive and resilient strategies that acknowledge the presence of volatility, uncertainty, complexity, and ambiguity. This involves fostering agility, embracing flexibility, encouraging continuous learning, and maintaining the ability to respond quickly and adjust to changing conditions. By doing so, they can navigate and thrive in VUCA environments [2].

54.2 Significance of VUCA in Financial Analytics

In financial analytics, the concept of VUCA is highly relevant and essential due to its implications for decision-making, risk management, and navigating the complexities of the financial market. Financial markets operate in an uncertain environment, where various unpredictable factors can impact investment decisions. Financial analytics plays a crucial role in decision-making under uncertainty by providing tools and techniques to assess potential outcomes and evaluate associated risks. By leveraging financial analytics, analysts can make more informed decisions, considering multiple scenarios and quantifying uncertainties to navigate the unpredictable nature of the market. Volatility is a fundamental aspect of financial markets, and managing market volatility is essential for successful investment strategies. Financial analytics enables the measurement and analysis of volatility, helping analysts identify patterns, trends, and potential opportunities. Understanding market volatility allows for adjustments in investment strategies, optimized portfolio allocations, and the development of risk management approaches that account for the potential impact of volatile market conditions. Financial markets are complex systems with numerous interconnected variables. Financial analytics helps analysts handle this complexity by providing tools and models to analyze data, identify meaningful patterns, and gain insights into market behaviour. By effectively analyzing complex data sets, financial analysts can gain a deeper understanding of market dynamics, enhance forecasting accuracy, and make more informed decisions to navigate the complexities of the financial market. Ambiguity in financial markets arises from conflicting information, varying interpretations, and mixed signals. Financial analytics addresses ambiguity by integrating diverse data sources, applying advanced statistical techniques, and employing robust data analysis methodologies. By leveraging financial analytics, analysts can reduce ambiguity, uncover hidden insights, and enhance decision-making accuracy in complex and uncertain environments. Effective risk management is crucial in financial markets, and VUCA emphasizes its significance. Financial analytics is vital in risk assessment, quantification, and mitigation.

Financial analysts can use advanced risk modelling and analysis techniques to identify potential risks, evaluate their impact on investment portfolios, and implement appropriate risk management strategies. Financial analytics enables institutions to optimize risk-reward trade-offs, understand potential downside risks, and proactively manage risks in a VUCA environment. VUCA is highly relevant in financial analytics as it acknowledges the uncertainties, volatilities, complexities, and ambiguities inherent in financial markets. Financial analytics provides valuable insights and tools to navigate these challenges, enabling analysts and institutions to make more informed decisions, manage risks effectively, and adapt to the dynamic nature of the financial landscape. VUCA highlights the challenges and uncertainties inherent in financial markets. Financial analytics provides valuable tools and insights to navigate these complexities. By leveraging financial analytics, analysts and institutions can make more informed decisions, manage risks effectively, and adapt to the dynamic nature of the financial landscape. It enables them to stay ahead in a rapidly changing environment and seize opportunities while mitigating potential risks. This paper provides a comprehensive examination and analysis of the concept of VUCA in the context of financial markets and its implications for financial analytics. This paper explores the various dimensions of VUCA—volatility, uncertainty, complexity, and ambiguity—and their significance in financial analytics. It attempts to understand VUCA and its relevance in financial analytics clearly. It will define and explain each element of VUCA and how they apply to the financial market environment. This section may delve into the origin and evolution of VUCA, its adoption in different industries, and its specific application to financial analytics. Another objective is to analyze the impact of VUCA on financial markets. The paper will examine how VUCA affects investment decision-making, risk management, and overall financial strategies. It will explore the implications of VUCA on market dynamics, investor behaviour, and financial institutions. This section may include case studies, empirical research, or industry examples to illustrate the impact of VUCA in financial analytics. The review paper will also highlight the role of financial analytics in addressing VUCA challenges. It will explore the methodologies, tools, and techniques used in financial analytics to analyze and mitigate volatility, uncertainty, complexity, and ambiguity in the financial markets. This section may discuss data-driven approaches, statistical models, machine learning algorithms, and other analytical methods utilized in financial analytics to navigate VUCA conditions.

Moreover, the paper may offer insights into best practices and strategies for leveraging financial analytics to manage VUCA in financial markets effectively. It may discuss risk management frameworks, portfolio optimization techniques, predictive modelling approaches, and adaptive strategies to enhance decision-making and performance in VUCA environments. The review paper will discuss emerging trends, challenges, and opportunities in applying VUCA and financial analytics. It may identify areas for further research and advancements in financial analytics methodologies and technologies to address the evolving VUCA landscape. Another purpose of the review paper is to provide a comprehensive and informative analysis of VUCA in the context of financial analytics. It aims to contribute to the existing body of knowledge by synthesizing relevant research, theories, and practical insights and offering recommendations for practitioners, researchers, and policymakers in finance.

54.3 Related Works

Although VUCA (Volatility, Uncertainty, Complexity, Ambiguity) was initially introduced in the military context in the 1990s, it has since been applied to the business world. The economic environment has particularly affected the VUCA industry, and financial analysts have had to adapt to rapidly changing market conditions and increasing amounts of complex data. One relevant related research work by [3] investigates how principles and models from statistical physics can shed light on the dynamics of financial markets. The author delves into criticality in financial systems, where minor disturbances can significantly impact market behaviour. The author further examines the presence of criticality in financial markets by analyzing power-law distributions, long-range correlations, and phase transitions. It presents various statistical physics models and frameworks utilized to study criticality in financial markets, aiming to capture the complex interactions among market participants and the emergence of collective behaviour. It discusses empirical evidence and case studies that support the existence of criticality in financial markets, offering insights into market stability, volatility, and the occurrence of financial crises. By applying a statistical physics perspective, the research contributes to a deeper understanding of financial markets underlying mechanisms and dynamics, which can inform risk management practices and regulatory policies.

Yang et al. [4] investigate the forecasting of realized volatility in stock indices while considering the presence of structural breaks. The authors employ a multiple mean break model to identify potential structural breaks in daily realized volatility series using high-frequency data from the Shanghai Stock Exchange Composite Index and sectoral stock indices in Chinese stock markets. They conduct in-sample tests and find multiple breaks in all the realized volatility series. For out-of-sample forecasts, the authors examine the performance of ARFIMAX-FIGARCH models with different estimation window sizes to accommodate potential structural breaks. The results indicate that combination forecasts with time-varying weights across individual forecast models perform well. Nonlinear combination forecasts with weights chosen through a non-parametric kernel regression and linear combination forecasts with weights chosen based on non-negative restricted least squares and Schwarz information criterion are found to be the most accurate methods for point forecasting under structural breaks. The authors also conduct an interval forecast for the combination approaches and find that the nonlinear combination approach with weights chosen through a non-parametric kernel regression provides the best interval forecast among the competing models. Overall, the research provides valuable insights and methodology for forecasting realized volatility, considering the presence of structural breaks. In the subsequent related research work from the literature, [5] aim to investigate the predictive power of implied volatility in commodity and significant developed stock markets for individual BRICS stock markets' implied volatility. The analysis covers the period from March 2011 to October 2016 and employs the Bayesian Graphical Structural Vector Autoregressive (BGSVAR) model. Their study findings suggest that the predictability of implied volatilities in BRICS stock markets is influenced by both global and within-group stock market implied volatilities. This indicates that fluctuations in global and regional stock market volatilities impact the implied volatilities of individual BRICS markets.

Additionally, the study reveals that the role of commodity market volatility in predicting individual BRICS stock market volatilities is generally marginal, except for South Africa. This implies that commodity market volatility has limited predictive power for the implied volatilities of most BRICS markets, except in the case of South Africa, where it plays a more significant role. Finally, the authors discuss the implications of these findings for policymakers and portfolio managers, highlighting the importance of considering both global and regional stock market volatilities in predicting the implied volatilities of individual BRICS markets. Again, these insights can be valuable for policymakers and portfolio managers to formulate effective strategies and manage risk in the BRICS markets. Overall, this research contributes to understanding implied volatility dynamics in the BRICS stock markets and provides insights into the predictive power of global stock market volatilities and the role of commodity market volatility in this context.

Again, [6], in their paper, focus on the relationship between survey-based expectations of the future Chilean exchange rate and the returns of primary non-ferrous metals and the London Metal Exchange Index. Their work investigates and finds that these expectations have a predictive power in forecasting the returns of metals such as aluminium, copper, lead, nickel, tin, and zinc. Previous research has shown that the Chilean exchange rate can predict copper returns, world commodity indexes, and base metal prices. However, this study further demonstrates that expectations about the Chilean peso have an even more vital predictive ability than the actual currency. The findings are accurate both within the sample and in out-of-sample analysis. By focusing on expectations related to a commodity currency rather than the currency itself, the paper provides novel evidence of the ability of commodity currencies to forecast commodity prices. The outcomes of the research work also align with the present-value model of exchange rate determination, reinforcing the importance of expectations in explaining exchange rate movements. Overall, this study contributes to our understanding of the linkages between exchange rates and commodity markets, emphasizing the role of expectations in predicting commodity returns and supporting existing theories of exchange rate determination. In yet another work, [7] examines the relationship between the CBOE VIX (Volatility Index) and stock market volatility in 13 stock markets of the G20 countries. The authors present several key findings based on their research. Firstly, they find that the VIX and its primary component statistically impact stock market volatility in most countries. This suggests that changes in the VIX can lead to higher levels of volatility in the stock markets.

Furthermore, the authors compare the explanatory power of the VIX and its component with other variables by assessing their R-squares. They find that the VIX is more vital to explain international stock market volatility. Secondly, the authors conduct out-of-sample tests to assess the forecast accuracy of the VIX. The results indicate that incorporating the VIX, especially the significant VIX component, improves the accuracy of the volatility forecasts. This suggests that the VIX can be a valuable tool for forecasting stock market volatility. Lastly, the study conducts robust tests to support the main conclusions. These tests provide further evidence to confirm the statistical significance and reliability of the findings. Overall, the research highlights the significant impact of the VIX on stock market volatility in various international markets while emphasizing the usefulness of the VIX, particularly its significant component, in enhancing the accuracy of volatility forecasts.

Khalatur et al. focus on developing a model for analyzing the financial stability of banks in the VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) world. The paper likely discusses the challenges banks face in a VUCA environment and the importance of assessing their financial stability under such conditions. It introduces a specific methodology proposed to analyze and evaluate the financial stability of banks operating in volatile, uncertain, complex, and ambiguous settings [8]. The proposed model involves various factors or indicators used to assess and measure the financial stability of banks. It may consider internal and external factors that impact a bank's stability, such as financial performance, risk management practices, regulatory environment, market conditions, and macroeconomic factors. The authors may provide empirical evidence or case studies to support the effectiveness and applicability of the proposed model. They also discuss the model's implications for banks, regulators, and stakeholders regarding managing financial stability in a VUCA world. Nurdiani [9] focuses specifically on the case of banking state-owned enterprises in Indonesia, namely MANDIRI, BRI, BTN, and BNI. The author investigates the relationship between marketing and finance functions and their impact on company performance within the challenging VUCA environment. The paper adopts a case study approach, analyzing the four state-owned banks in Indonesia to understand how integrating marketing and finance can drive improved performance. The study's findings suggest that integrating marketing and finance functions is crucial for enhancing company performance in the VUCA world. By aligning marketing strategies with financial goals and integrating marketing and finance decision-making processes, the state-owned banks in Indonesia can better navigate the volatile and uncertain business landscape and achieve improved performance outcomes.

The paper emphasizes the importance of collaboration and synergy between marketing and finance departments to address the challenges posed by VUCA conditions. It highlights the need for a holistic approach that combines marketing insights and financial analysis to make informed decisions and develop strategies that drive sustainable performance. Overall, the paper underscores the significance of integrating marketing and finance functions in the VUCA world and provides insights from the case of banking state-owned enterprises in Indonesia. Companies can enhance their performance by aligning marketing and finance efforts and leveraging the synergies between the two functions. Again [10] focus on analyzing the bivariate jump process involving the S&P 500 and the Euro Stoxx 50 using high-frequency data in their recent work. They employ Hawkes processes to examine various aspects of the jump dynamics. The findings of this research work indicate that there is no evidence of contagion across different markets. This suggests that jumps in one market, such as the S&P 500, do not significantly impact or influence jumps in the Euro Stoxx 50, and vice versa. However, the analysis also reveals significant jump clustering effects, but only within intraday time scales. This implies that jumps occur in clusters within short time intervals during the trading day.

Furthermore, their study finds that the relative contribution of jumps to the total price variance is more substantial during tranquil market conditions compared to periods of stress. This empirical observation is particularly evident during the subprime mortgage and European sovereign debt crises, indicating that jumps play a more significant role in price movements during calmer market periods. Most importantly, the authors ensure the robustness of their results by employing different jump detection methods, and the findings remain consistent across these different approaches. Overall, their research contributes to understanding volatility in financial markets, providing valuable insights into the dynamics of jumps and their implications for market behaviour.

54.4 Volatility in Financial Market

Volatility refers to the rapid and unpredictable changes in market conditions, prices, and other financial variables. Financial analytics helps measure and analyze volatility by examining historical market data, identifying trends, and calculating metrics such as standard deviation and volatility indices. Understanding volatility is crucial for assessing the risk of different investment options and optimizing portfolio allocations. Understanding volatility is crucial for financial decision-making as it directly affects risk and potential returns. Higher volatility implies more significant uncertainty and risk, which may lead to larger price swings and increased potential for losses.

Conversely, lower volatility suggests a more stable market environment, which may be associated with lower risk but potentially lower returns. By analyzing volatility, financial analysts can assess the risk-reward trade-offs of different investment options, evaluate the potential impact of volatility on investment returns, and adjust strategies to align with market conditions. Financial analytics also plays a vital role in portfolio management by optimizing asset allocations based on volatility analysis. Diversification is a crucial strategy to manage volatility and mitigate risks. By spreading investments across different asset classes with varying levels of volatility, such as stocks, bonds, commodities, or alternative investments, analysts can aim to achieve a balance between risk and return. Financial analytics provides the tools and models to optimize portfolio allocations, considering the desired level of risk tolerance and return objectives.

Again, volatility, a key element of VUCA, is a critical concept in financial analytics due to its significant impact on investment decisions and risk management strategies. Financial analytics provides various tools and techniques to measure, analyze, and interpret volatility in the financial markets. Analyzing historical market data is one of the primary methods used in financial analytics to assess volatility. To identify patterns and trends, financial analysts examine past price movements, trading volumes, and other relevant variables. By studying historical data, analysts can calculate statistical measures such as standard deviation and quantify the dispersion of returns or price changes. These measures provide insights into the level of volatility and help assess the potential risks associated with different investment options. Volatility indices, such as the VIX (Volatility Index), are widely used in financial analytics to gauge market volatility. These indices track the market's expectations of future volatility levels by reflecting the prices of options on various financial instruments. Financial analysts closely monitor volatility indices to assess market sentiment, identify periods of heightened uncertainty, and evaluate potential risks. Volatility indices serve as essential indicators in financial analytics, helping analysts make informed decisions and adjust strategies accordingly. Therefore, volatility is a crucial element of VUCA, and financial analytics is instrumental in measuring, analyzing, and interpreting volatility in the financial markets. By leveraging financial analytics, analysts can gain insights into market dynamics, assess risk levels, make informed investment decisions, and optimize portfolio management strategies to navigate the dynamic and uncertain nature of the financial landscape.

54.4.1 Tools and Techniques for Managing Volatility

Managing volatility in financial markets requires the use of various tools and techniques. Here are some commonly employed methods:

(i) **Standard Deviation**: Standard deviation measures the dispersion of returns or price changes from the average. It helps assess the volatility of a financial instrument or portfolio. By analyzing historical data, financial analysts can calculate the standard deviation to understand the level of volatility and make informed decisions.

(ii) **Volatility Indices**: Volatility indices, such as the VIX (Volatility Index), provide insights into market sentiment and expectations of future volatility levels. These indices measure implied volatility derived from options pricing. Monitoring and analyzing volatility indices can help financial analysts assess market uncertainty and potential risks.

(iii) **Historical Volatility Analysis**: Financial analysts use historical volatility analysis to study the past price movements of financial instruments. By examining historical data, they can identify patterns, trends, and periods of high or low volatility. This analysis helps in understanding the behavior of the instrument and forecasting future volatility.

(iv) **GARCH Models**: Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models are statistical models commonly used to analyze and forecast volatility. GARCH models capture the time-varying nature of volatility by incorporating lagged volatility and other relevant variables. Financial analysts can utilize GARCH models to estimate future volatility and manage risk effectively.

(v) **Option Pricing Models**: Option pricing models, such as the Black-Schools model, can help in estimating the implied volatility of an option. These models calculate the expected future volatility based on the option's pricing inputs. Financial analysts can use option pricing models to assess the market's expectation of future volatility and adjust their strategies accordingly.

(vi) **Volatility Trading Strategies**: Financial analysts may employ volatility trading strategies to take advantage of volatility fluctuations. These strategies involve buying or selling options, utilizing volatility derivatives, or constructing volatility-based portfolios. Volatility trading strategies aim to profit from changes in volatility levels and can be used to hedge against market risks.

(vii) **Risk Management Techniques**: Effective risk management techniques, such as diversification, stop-loss orders, and position sizing, can help mitigate the impact of volatility on investment portfolios. Financial analysts employ these techniques to reduce exposure to highly volatile assets and maintain a balanced risk-return profile.

It is important to note that managing volatility is a complex task, and the choice of tools and techniques may vary depending on the specific investment objectives, risk tolerance, and market conditions. Financial analysts should carefully analyze the available data, assess the limitations of each method, and consider a holistic approach to volatility management.

54.5 Uncertainty

Uncertainty relates to the lack of predictability and the inability to determine future outcomes with a high degree of confidence. Financial markets are influenced by various unpredictable factors such as economic indicators, geopolitical events, and technological advancements. Financial analytics helps in managing uncertainty by analyzing data, evaluating different scenarios, and conducting sensitivity analysis. It provides tools and techniques to assess the range of potential outcomes and make more informed decisions in the face of uncertainty. Uncertainty, as a component of VUCA, holds significant relevance in financial analytics as it acknowledges the unpredictable nature of financial markets and the challenges it presents for decision-making. Financial analytics provides valuable tools and techniques for managing uncertainty and making informed decisions in uncertain conditions.

One of the primary ways financial analytics addresses uncertainty is through data analysis. By analyzing historical market data, financial analysts can identify patterns, trends, and relationships that help in understanding market behavior. This analysis helps to quantify the uncertainty by assessing the variability of past outcomes and establishing a basis for predicting future scenarios. Advanced machine learning algorithms and artificial intelligence techniques are increasingly being used in financial analytics to manage uncertainty. These techniques can analyze vast amounts of data, identify patterns, and make predictions based on complex relationships. Machine learning models can adapt to changing market conditions and provide insights into potential risks and uncertainties. Another technique used in financial analytics to manage uncertainty is scenario analysis. Analysts create multiple hypothetical scenarios based on different assumptions and market conditions to assess the potential outcomes and associated risks. This approach helps in evaluating the impact of different variables on investment decisions and allows for more comprehensive risk assessment. Another technique used in financial analytics to manage uncertainty is scenario analysis. Analysts create multiple hypothetical scenarios based on different assumptions and market conditions to assess the potential outcomes and associated risks. This approach helps in evaluating the impact of different variables on investment decisions and allows for more comprehensive risk assessment. Financial analytics offers a range of tools and techniques for managing uncertainty in financial markets. By leveraging data analysis, scenario analysis, sensitivity analysis, simulation methods, statistical models, and advanced machine learning algorithms, analysts can assess the range of potential outcomes, evaluate associated risks, and make more informed decisions in the face of uncertainty. These techniques enable financial professionals to navigate the uncertainties of the financial landscape and optimize their investment strategies.

54.5.1 Tools and Techniques for Managing Uncertainty

Managing uncertainty in financial markets requires the use of various tools and techniques. Here are some commonly employed methods:

(i) **Scenario Analysis**: Scenario analysis involves creating multiple hypothetical scenarios to assess the potential impact of different future events or circumstances on financial markets. Financial analysts can construct various scenarios based on different economic, political, or industry-related factors and evaluate the potential outcomes and associated risks. This helps in understanding the range of possibilities and preparing contingency plans.

(ii) **Sensitivity Analysis**: Sensitivity analysis examines the sensitivity of financial models or investment strategies to changes in specific variables or assumptions. It helps identify the key drivers of uncertainty and their impact on financial outcomes. By analyzing how changes in variables affect the results, financial analysts can assess the robustness of their models or strategies and make adjustments to manage uncertainties.

(iii) **Monte Carlo Simulation**: Monte Carlo simulation is a statistical technique that generates multiple random scenarios to model the possible range of outcomes for an investment or portfolio. It allows financial analysts to incorporate uncertainty by using probability distributions for different variables. By running simulations, analysts can assess the probability of achieving certain financial goals or estimate the potential downside risks.

(iv) **Bayesian Analysis**: Bayesian analysis is a statistical approach that combines prior knowledge and available data to update and refine probability estimates. It is particularly useful in situations with limited data or when there is a need to incorporate subjective judgments. Financial analysts can use Bayesian analysis to update their beliefs and quantify uncertainty based on new information or observations.

(v) **Decision Trees**: Decision trees are graphical tools that help analyze and make decisions under uncertainty. They map out different possible outcomes and associated probabilities, facilitating the evaluation of alternative courses of action. Financial analysts can use decision trees to assess the potential risks and rewards of different investment options and determine the optimal path based on their risk appetite and objectives.

(vi) **Expert Judgment and Delphi Method**: In situations with high uncertainty, financial analysts may seek expert opinions and employ the Delphi method. This approach involves gathering input from multiple experts, anonymously aggregating their opinions, and iteratively refining the group consensus. Expert judgment can provide valuable insights and help manage uncertainties by considering diverse perspectives and domain expertise.

(vii) **Risk Mitigation Strategies**: Implementing risk mitigation strategies are essential in managing uncertainty. These strategies may include diversification, hedging, and insurance. By spreading investments across different asset classes, regions, or industries, financial analysts can reduce the impact of uncertainty on their portfolios. Hedging strategies, such as using derivatives or options, can provide protection against adverse market movements.

It is important for financial analysts to consider the limitations and assumptions associated with these tools and techniques. Uncertainty is inherent in financial markets, and effective management requires a combination of analytical approaches, domain knowledge, and continuous monitoring of market conditions.

54.6 Complexity

Financial markets are complex systems with numerous interrelated variables and dependencies. Financial analytics helps in unraveling the complexity by analyzing vast amounts of data, identifying patterns, and understanding the relationships between different variables. It enables financial analysts to gain insights into market behavior, assess the impact of various factors, and make informed decisions based on a comprehensive understanding of the complex financial landscape. Complexity, as a component of VUCA, is a critical aspect of financial markets that requires careful analysis and understanding.

Financial analytics addresses complexity is through data analysis. With the vast amount of data available in financial markets, analysts can leverage analytical tools and techniques to process and analyze this data effectively. Techniques such as data mining, pattern recognition, and statistical analysis help in identifying meaningful patterns, trends, and correlations within complex financial datasets. These analyses provide insights into market behavior, investor sentiment, and the interdependencies among various financial variables. Machine learning algorithms and artificial intelligence techniques are also utilized in financial analytics to manage complexity. These advanced techniques can process and analyze large and complex datasets, identify hidden patterns or nonlinear relationships, and make predictions based on the discovered insights. Machine learning models can adapt to changing market conditions and capture the complex interactions between various financial variables. Financial analytics also utilizes advanced modeling techniques to manage complexity. Quantitative models, such as financial econometric models or network models, are employed to represent and capture the complexity of financial systems. These models help in understanding the relationships and dependencies between different financial variables and provide a framework for analyzing the impact of changes in one variable on others. By incorporating these models into financial analytics, analysts can gain a deeper understanding of the complex dynamics at play in the financial markets. Network analysis is another tool used in financial analytics to understand the complexity of financial markets. By representing financial systems as networks, where nodes represent different financial entities (e.g., companies, investors) and edges represent relationships or connections between them, analysts can analyze the structure and dynamics of the network. Network analysis helps in identifying key players, systemic risks, and the propagation of shocks or disruptions within the financial system. By employing data analysis, advanced modeling techniques, machine learning algorithms, network analysis, and visualization techniques, analysts can gain a comprehensive understanding of the complex relationships and dynamics within the financial landscape. These techniques empower financial professionals to make more informed decisions, identify opportunities, and mitigate risks in complex and ever-evolving financial markets.

54.6.1 Tools and Techniques for Managing Complexity

Managing complexity in financial analytics requires the utilization of various tools and techniques. Here are some commonly employed methods:

(i) **Data Visualization**: Data visualization tools help financial analysts simplify complex data sets and present them in a visually intuitive manner. Charts, graphs, and interactive dashboards allow for a better understanding of relationships and patterns within the data. Visualizing complex financial information aids in identifying key insights and facilitating effective decision-making.

(ii) **Network Analysis**: Network analysis techniques help in understanding the complex relationships and dependencies among various financial entities such as stocks, companies, or market participants. By visualizing and analyzing the network structure, financial analysts can identify influential nodes, detect clusters, and assess systemic risks. Network analysis provides insights into the interconnectedness and complexity of the financial system.

(iii) **Machine Learning and Artificial Intelligence**: Machine learning algorithms and artificial intelligence techniques are increasingly utilized to analyze complex financial data. These technologies can process large volumes of data, identify hidden patterns, and generate predictive models. Financial analysts can leverage machine learning for tasks such as credit risk assessment, fraud detection, portfolio optimization, and sentiment analysis.

(iv) **Advanced Statistical Modeling**: Advanced statistical modeling techniques, such as multivariate analysis, factor analysis, and time series analysis, enable financial analysts to capture and understand the complexity of financial data. These models help identify underlying factors, relationships, and trends, providing insights into market behavior and enabling more accurate forecasts.

(v) **Optimization Techniques**: Optimization techniques assist financial analysts in addressing the complexity of portfolio management and asset allocation. Through mathematical programming and optimization algorithms, analysts can determine the optimal combination of assets that maximizes returns while considering various constraints and risk preferences. These techniques aid in managing the complexity of investment decisions.

(vi) **Text Mining and Natural Language Processing**: Text mining and natural language processing techniques help extract information and insights from unstructured data sources such as news articles, social media, and financial reports. By analyzing textual data, financial analysts can uncover sentiment, extract key information, and gain a deeper understanding of market dynamics and investor sentiment.

(vii) **Risk Modeling and Stress Testing**: Risk modeling and stress testing techniques help assess the potential impact of complex scenarios and events on financial portfolios. Through the use of historical data, statistical models, and scenario analysis, analysts can simulate and measure the potential risks and vulnerabilities in their portfolios. This aids in identifying areas of high complexity and developing risk mitigation strategies.

It is crucial for financial analysts to continuously update their knowledge and skills in using these tools and techniques for managing complexity. Additionally, they should be aware of the limitations and assumptions associated with each method and consider the specific context and objectives of their analysis.

54.7 Ambiguity

Ambiguity refers to situations where there are multiple interpretations or conflicting meanings. In the financial domain, ambiguity can arise from contradictory information, differing perspectives, or mixed signals. Financial analytics helps in addressing ambiguity by integrating diverse datasets, applying statistical techniques, and conducting thorough analysis. It enables financial analysts to reconcile conflicting information, uncover hidden insights, and make decisions based on a clearer understanding of the situation. Financial analytics plays a crucial role in managing ambiguity by leveraging various tools and techniques to enhance decision-making and reduce uncertainty. Financial analytics addresses ambiguity via data integration and analysis. Financial analysts gather data from diverse sources, such as market reports, financial statements, news articles, and social media, to obtain a comprehensive view of the market. By integrating these datasets and applying statistical techniques, analysts can uncover hidden insights, identify patterns, and reveal underlying trends that may help resolve ambiguity. For example, sentiment analysis can be used to gauge market sentiment by analyzing social media data, providing additional context and perspectives on market conditions. Moreover financial analytics employs advanced statistical techniques to handle ambiguity. Techniques such as regression analysis, hypothesis testing, and scenario analysis enable analysts to evaluate different perspectives and assess the robustness of their findings. These techniques help in quantifying uncertainties and understanding the potential impact of different factors on financial outcomes. Monte Carlo simulation is another powerful tool used in financial analytics to model multiple scenarios and assess the range of potential outcomes, thereby reducing ambiguity. Machine learning algorithms and natural language processing (NLP) techniques are also employed in financial analytics to manage ambiguity. These techniques can analyze unstructured data, such as textual information from news articles or research reports, and extract relevant insights. By applying NLP algorithms, financial analysts can identify key information, sentiment, and relationships within textual data, thereby reducing ambiguity and gaining a clearer understanding of market dynamics. Visualization techniques are valuable in managing ambiguity in financial analytics. By presenting complex data in visual formats, such as interactive charts, graphs, or heat maps, analysts can identify patterns and trends, and compare different scenarios or perspectives. Financial analytics provides a range of tools and techniques to address ambiguity in the financial domain. By integrating diverse datasets, applying statistical analysis, leveraging machine learning algorithms, and utilizing visualization techniques, financial analysts can reduce uncertainty, reconcile conflicting information, and make decisions based on a clearer understanding of the market. These techniques enable more effective risk management, improved forecasting, and better decision-making in the face of ambiguity.

54.7.1 Tools and Techniques for Managing Ambiguity

Managing ambiguity in financial analytics requires the application of specific tools and techniques. Here are some commonly employed methods:

(i) **Sensitivity Analysis**: Sensitivity analysis involves assessing the impact of varying assumptions or inputs on financial outcomes. By systematically testing different scenarios and adjusting key variables, analysts can understand the range of potential outcomes and identify areas of ambiguity. Sensitivity analysis helps in evaluating the robustness of financial models and decision-making processes.

(ii) **Probabilistic Modeling**: Probabilistic modeling techniques, such as Monte Carlo simulations, allow for the consideration of uncertainty and ambiguity in financial analysis. By incorporating probability distributions for uncertain variables, analysts can generate a range of possible outcomes and their associated probabilities. This helps in quantifying and managing ambiguity by providing a clearer understanding of potential risks and returns.

(iii) **Expert Judgment and Delphi Method**: When faced with ambiguous situations, financial analysts often rely on expert judgment. The Delphi method involves collecting input from a panel of experts and iteratively refining their opinions to reach a consensus. By harnessing the knowledge and insights of subject matter experts, analysts can reduce ambiguity and make more informed decisions.

(iv) **Scenario Analysis**: Scenario analysis involves constructing and analyzing different hypothetical scenarios that capture potential future states of the market or economy. By considering various scenarios with different levels of ambiguity, analysts can assess the potential impacts on financial outcomes and devise appropriate strategies. This technique helps in identifying critical uncertainties and their implications for decision making.

(v) **Decision Trees**: Decision trees are graphical representations of decision-making processes that incorporate uncertainty and ambiguity. By mapping out different possible outcomes and their associated probabilities, analysts can evaluate the expected value of various decision paths. Decision trees help in managing ambiguity by providing a structured approach to decision making and identifying the most favorable choices under different conditions.

(vi) **Bayesian Inference**: Bayesian inference is a statistical technique that allows analysts to update their beliefs and quantify uncertainty based on both prior knowledge and observed data. By incorporating prior beliefs and updating them with new information, analysts can arrive at more accurate estimates and make decisions under conditions of ambiguity. Bayesian inference helps in refining understanding and reducing ambiguity through an iterative learning process.

(vii) **Scenario Planning**: Scenario planning involves developing multiple plausible future scenarios based on different assumptions and narratives. This technique helps in managing ambiguity by exploring various potential outcomes and their implications. Through scenario planning, analysts can consider multiple perspectives, uncover hidden risks, and develop strategies that are robust across a range of ambiguous situations.

It is important for financial analysts to choose the appropriate tools and techniques based on the specific context and nature of ambiguity they are dealing with. Each method has its strengths and limitations, and analysts should exercise judgment and critical thinking to effectively manage ambiguity in financial analytics.

54.8 Open Research Problems

The future directions of VUCA in financial analytics are expected to evolve and expand as the financial industry continues to face new challenges and opportunities. Here are some potential future directions:

54.8.1 Emerging Technologies for VUCA Analysis

Emerging technologies play a crucial role in enhancing VUCA analysis in the field of financial analytics. Here are some notable technologies that contribute to analyzing and managing volatility, uncertainty, complexity, and ambiguity:

(i) **Artificial Intelligence (AI) and Machine Learning (ML)**: AI and ML algorithms can process vast amounts of financial data, identify patterns, and uncover insights. These technologies enable predictive modeling, anomaly detection, and automated decision-making, enhancing the accuracy and efficiency of VUCA analysis. AI and ML can also assist in risk assessment, portfolio optimization, and fraud detection.

(ii) **Natural Language Processing (NLP)**: NLP enables the analysis and interpretation of unstructured textual data, such as news articles, social media posts, and analyst reports. By extracting sentiment, extracting relevant information, and understanding context, NLP enhances the understanding of market dynamics and investor sentiment. It can be utilized to capture market ambiguity and incorporate qualitative data into quantitative analysis.

(iii) **Big Data Analytics**: The abundance of data in financial markets requires robust big data analytics techniques to process and analyze vast datasets. Big data analytics platforms leverage distributed computing and parallel processing to handle large volumes of structured and unstructured data. These technologies enable the identification of patterns, correlations, and anomalies that contribute to VUCA analysis.

(iv) **Cloud Computing**: Cloud computing provides scalable and flexible computational resources for data storage and processing. It enables financial institutions to store and access large datasets securely while leveraging on-demand computational power for complex analytics tasks. Cloud-based analytics platforms allow for faster data analysis, collaborative work, and easy integration with other technologies.

(v) **Blockchain Technology**: Blockchain technology offers transparent and secure decentralized ledgers for financial transactions and record-keeping. In the context of VUCA analysis, blockchain can enhance transparency, traceability, and accuracy of financial data, reducing the risk of data manipulation and improving trust among market participants. Smart contracts based on blockchain can automate and enforce complex financial agreements.

(vi) **Quantum Computing**: Quantum computing has the potential to revolutionize financial analytics by providing exponential computational power. Quantum algorithms can solve complex optimization problems and perform rapid data analysis. While still in the early stages, quantum computing shows promise for tackling complex VUCA challenges that traditional computing approaches struggle to handle.

(vii) **Robotic Process Automation (RPA)**: RPA involves automating repetitive and rule-based tasks using software robots. It frees up human analysts' time, allowing them to focus on higher-value activities such as data analysis, strategy formulation, and decision-making. RPA can be applied to data gathering, data cleaning, and report generation, streamlining VUCA analysis processes.

These emerging technologies offer exciting opportunities to enhance VUCA analysis in financial analytics. Their integration can enable more accurate predictions, real-time insights, and efficient decision-making, empowering financial institutions to navigate the complexities and uncertainties of the financial markets effectively.

54.8.2 Implications for Financial Decision Making

The implications of VUCA in financial analytics have significant implications for financial decision-making. Here are some key implications:

(i) **Informed Decision-Making**: Financial analytics provides the necessary tools and insights to make informed decisions in the face of volatility, uncertainty, complexity, and ambiguity. By leveraging data analysis, statistical models, and predictive algorithms, decision-makers can evaluate various scenarios, assess risks, and identify potential opportunities. This helps in making decisions based on data-driven evidence rather than relying solely on intuition or guesswork.

(ii) **Risk Management**: VUCA analysis is crucial for effective risk management in financial decision-making. By understanding and quantifying the risks associated with different investment options, financial institutions can develop risk mitigation strategies, optimize portfolio allocations, and ensure regulatory compliance. Financial analytics helps in identifying potential vulnerabilities, conducting stress testing, and implementing risk management frameworks to protect against adverse market conditions.

(iii) **Adaptive Strategies**: VUCA conditions require adaptive strategies that can quickly respond to changing market dynamics. Financial analytics facilitates the development of adaptive strategies by providing real-time data, monitoring market trends, and identifying signals of potential disruptions. This enables decision-makers to adjust their investment strategies, asset allocations, and risk exposures to capitalize on emerging opportunities or mitigate potential risks.

(iv) **Long-Term Planning**: VUCA analysis helps in long-term planning and strategic decision-making. By understanding the potential scenarios and uncertainties that lie ahead, financial decision-makers can develop robust long-term plans that consider various contingencies and adaptability. Financial analytics provides tools and techniques to assess the long-term impact of market trends, regulatory changes, and technological advancements, enabling organizations to make strategic decisions that align with their goals and objectives.

(v) **Investor Confidence**: VUCA analysis contributes to building investor confidence and trust. By demonstrating a thorough understanding of the market dynamics and risks, financial institutions can provide transparent and reliable information to investors. This helps in building trust, attracting investments, and maintaining long-term relationships with clients. Financial analytics plays a vital role in generating insights, conducting risk assessments, and communicating the rationale behind investment decisions to instill confidence in investors.

(vi) **Agility and Responsiveness**: VUCA conditions require agility and responsiveness in financial decision-making. Financial analytics provides real-time data, advanced modeling techniques, and scenario analysis capabilities that enable decision-makers to respond quickly to market changes and adapt their strategies accordingly. This agility helps in seizing opportunities, managing risks, and staying competitive in a rapidly evolving financial landscape.

VUCA implications in financial decision-making highlight the importance of data-driven insights, risk management, adaptive strategies, long-term planning, investor confidence, and agility. Financial analytics plays a crucial role in providing the necessary tools and capabilities to navigate VUCA challenges and make informed decisions that drive sustainable financial success.

54.8.3 Challenges and Opportunities for VUCA in Financial Analytics

Challenges:

(i) **Data Quality and Availability**: One of the significant challenges in applying VUCA in financial analytics is ensuring the availability and quality of relevant data. Financial markets generate vast amounts of data, and it can be challenging to gather accurate and comprehensive data for analysis. Incomplete or unreliable data can hinder the effectiveness of financial analytics and limit the accuracy of predictions and insights.

(ii) **Complex Interdependencies**: Financial markets are complex systems with intricate interdependencies between various factors and variables. Capturing and understanding these interrelationships can be challenging. Analyzing the impact of one variable on others and identifying causal relationships requires advanced modeling techniques and robust analytical frameworks.

(iii) **Uncertain and Dynamic Market Conditions**: Financial markets are inherently volatile and subject to rapid changes. Market conditions can shift quickly due to economic indicators, political events, technological advancements, or investor sentiment. Adapting financial analytics models and strategies to the evolving market conditions and capturing real-time data can be challenging, as it requires agility and responsiveness.

(iv) **Managing Ambiguity and Uncertainty**: Ambiguity and uncertainty are inherent in financial markets, and incorporating these factors into financial analytics poses challenges. Interpreting and reconciling conflicting information, multiple perspectives, and subjective judgments can be difficult. Dealing with ambiguity requires sophisticated analytical approaches and the ability to integrate diverse datasets and sources of information.

Opportunities:

(i) **Advanced Analytics and Machine Learning**: Advances in technology, such as machine learning and artificial intelligence, present significant opportunities for VUCA in financial analytics. These tools can process large volumes of data, identify patterns, and generate predictive models that assist in decision-making and risk management. Machine learning algorithms can uncover hidden insights and automate processes, improving the efficiency and effectiveness of financial analytics.

(ii) **Real-time Data and High-Frequency Trading**: The availability of real-time data and the increasing prevalence of high-frequency trading provide opportunities for VUCA in financial analytics. Analyzing real-time data allows for more accurate and timely decision-making, enabling financial institutions to respond swiftly to changing market conditions and capture emerging opportunities.

(iii) **Alternative Data Sources**: VUCA in financial analytics can benefit from the incorporation of alternative data sources beyond traditional financial data. Social media sentiment, satellite imagery, consumer behavior data, and other non-traditional data can provide valuable insights and enhance predictive models. Integrating alternative data sources can help capture the complexities and uncertainties of the market more comprehensively.

(iv) **Risk Management and Compliance**: VUCA principles can be applied to enhance risk management and compliance practices in the financial industry. By incorporating VUCA factors into risk models, financial institutions can access and manage risks more effectively. This approach enables proactive risk mitigation, regulatory compliance, and a better understanding of potential threats and vulnerabilities.

Therefore, while there are challenges associated with incorporating VUCA into financial analytics, there are also significant opportunities to leverage advanced analytics, real-time data, alternative data sources, and improved risk management practices. Embracing these opportunities can enhance the accuracy, responsiveness, and effectiveness of financial analytics in navigating the uncertainties and complexities of the financial landscape.

54.9 Conclusion

In this study we find out that VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) has significant implications for financial analytics. Financial analysts and practitioners are increasingly recognizing the importance of incorporating VUCA principles into their decision-making processes to navigate the complexities and uncertainties of the financial landscape. By leveraging advanced data analytics techniques, they can gain deeper insights, improve risk management, and optimize investment strategies. Finally we conclude, incorporating VUCA principles into financial analytics is essential for navigating the complexities and uncertainties of the financial landscape. Future research should focus on developing advanced predictive models, exploring social media sentiment analysis, investigating ethical considerations, and integrating non-financial factors. Financial analysts and practitioners should embrace continuous learning, collaboration, ethical practices, and technological advancements to leverage the full potential of VUCA in financial analytics. Future research should focus on developing advanced predictive models that can effectively capture and forecast VUCA elements in financial markets. These models should integrate diverse data sources, including alternative data, and leverage machine learning and AI algorithms to enhance accuracy and reliability. With the proliferation of social media, future research can explore the impact of social media sentiment analysis on financial analytics. Understanding how social media sentiment influences market behavior and investment decisions can provide valuable insights for financial analysts. As financial analytics increasingly relies on data-driven decision-making, future research should delve into ethical considerations, fairness, and bias in analytics processes. Developing frameworks and guidelines for responsible and ethical financial analytics practices is essential to maintain trust and integrity in the industry.

Future research can investigate the integration of non-financial factors, such as environmental, social, and governance (ESG) metrics, into financial analytics models. Understanding the impact of ESG factors on investment performance and risk management can help financial analysts make more informed decisions that align with sustainability goals. Financial analysts and practitioners should prioritize continuous learning and keep up with advancements in data analytics technologies and methodologies. This will enable them to effectively analyze VUCA elements and adapt their strategies in response to changing market conditions. Collaboration between financial analysts, data scientists, and domain experts is crucial for comprehensive and accurate financial analytics. By working together, they can incorporate diverse perspectives, knowledge, and expertise into the analysis process, leading to more robust and insightful results. Financial analysts and practitioners should prioritize ethical considerations in data usage, privacy, and security. Adhering to responsible analytics practices builds trust with stakeholders and ensures compliance with regulations and industry standards. Leveraging technology and automation tools can streamline data analysis processes, improve efficiency, and enable financial analysts to focus on higher-value tasks, such as interpreting results and making strategic decisions.

References

1. C.C. Millar, O. Groth, J.F. Mahon, Management innovation in a VUCA world: challenges and recommendations. Calif. Manag. Rev. **61**(1), 5–14 (2018)
2. R. Vecchiato, Scenario planning, cognition, and strategic investment decisions in a turbulent environment. Long Range Plan. **52**, 1–17 (2019)
3. T. Bury, A statistical physics perspective on criticality in financial markets. J. Stat. Mech: Theory Exp. **2013**(11), P11004 (2013)
4. K. Yang, L. Chen, F. Tian, Realized volatility forecast of stock index under structural breaks. J. Forecast. **34**(1), 57–82 (2015)
5. E. Bouri, R. Gupta, S. Hosseini, C.K.M. Lau, Does global fear predict fear in BRICS stock markets? evidence from a Bayesian graphical structural VAR model. Emerg. Mark. Rev. **34**, 124–142 (2018)

6. P.M. Pincheira, N. Hardy, *The Predictive Relationship Between Exchange Rate Expectations and Base Metal Prices* (2018). Available at SSRN 3263709
7. H. Wang, VIX and volatility forecasting: a new insight. Physica A **533**, 121951 (2019)
8. S. Khalatur, L. Velychko, O. Pavlenko, O. Karamushka, M. Huba, *A Model for Analyzing the Financial Stability of Banks in the VUCA-World Conditions* (2021)
9. T.W. Nurdiani, Integrating marketing and finance to increase company performance in VUCA world: a case study on banking state-owned enterprise in Indonesia (MANDIRI, BRI, BTN, BNI). Eur. J. Bus. Innov. Res. **9**(5), 27–32 (2021)
10. F. Ferriani, P. Zoi, The dynamics of price jumps in the stock market: an empirical study on Europe and U.S. Eur. J. Financ. **28**(7), 718–742 (2022). https://doi.org/10.1080/1351847X.2020.1740288