A hybrid single-valued neutrosophic-standard deviation-relative closeness coefficient and double normalization-based multiple aggregation method to evaluate supply chain financial risks

Abstract

This research focuses on assessing financial risks in supply chains, which considers a hybrid single-valued neutrosophic-standard deviation-relative closeness coefficient and double normalization-based multiple combination method. The research aims to improve the understanding and management of sophisticated financial risks associated with supply chains. A detailed literature review of the current literature in supply chain risk management reveals the evolution of risk assessment methodologies in response to the highly dynamic and multifaceted nature of financial risks in supply chain networks. The study uses a quantitative approach and secondary data from reliable sources. The data is analyzed using EViews, and descriptive statistics, correlation analysis, and regression analysis are used to determine the relationships and impacts of different risk factors on supply chains. The major variables such as Supplier Reliability Score, Cost Fluctuation Index, Demand Variability, Supply Chain Disruption Frequency, Market Risk Factor, Operational Risk Factor, and Financial Risk Factor are analyzed, covering various aspects of supply chain financial risks. The findings reveal complex relationships between the variables, especially the findings on the impact of supplier reliability on financial risk. The correlation and regression analyses imply that though the traditional methods are useful, they need to capture the intricacy of financial risks in supply chains adequately. The findings show that sophisticated methodologies must be combined with conventional statistical approaches to assess financial risks in supply chains better. Our study results can be useful for supply chain managers and policymakers as they show that it is necessary to consider a range of risk drivers to make decisions. The study's limitations are also identified, such as the use of secondary data and the potential omission of relevant variables in the regression model. Further research should use primary data gathering and explore broader models such as advanced statistical methods or machine learning algorithms.

Keywords: Supply Chain Management, Financial Risk Assessment, Neutrosophic Sets, Double Normalization, Quantitative Analysis, Supply Chain Risks.

1.0 Introduction

SCM is one of the most basic aspects of global economies and entails the entire production and supply process of products and services, from obtaining of raw materials to final delivery of end-users. It involves a comprehensive market knowledge that is essential in guiding business decisions. SCM is critical for business transformation that eliminates wastes, reduces costs, and increases efficiency, resulting in competitiveness and customer satisfaction. But it is important for the transportation of products and crucial market segmentation and participation in the industry. Other important aspects of SCM modernization are supply chain planning, logistics, procurement, and manufacturing because businesses need to adapt to market changes and technological advancements (Abdel-Basset et al., 2019). Risk assessment in financial terms within the supply chain plays a crucial role in establishing an efficient and competitive market setting. SCM is a key to survival and success. Several problems negatively influence the efficiency and reliability of the current state of supply chain risk assessment. The traditional approaches must be revised to deal with the complexity of modern supply chains that involve global networks, rapid technology, and volatile customer demands. Traditional methods are primarily linear and static and fail to capture interdependencies' dynamics and the probabilistic nature of risks in a globalized economy. This leaves a gap in the capacity to accurately measure, quantify, and control potential disruptions and financial risks. The amount of data and immediate analysis required only add to the stress of these outdated methods, resulting in slow and ineffective decision-making (Ahmad, 2018). There is a pressing need for a more mature and contextual approach to supply chain risk assessment – one that integrates advanced analytical techniques along with the capabilities of new technologies in order to provide a more detailed, dynamic, and predictive analysis of risks, contributing to resilience and competitive advantage in a dynamic business environment. What is the role of a hybrid single-valued neutrosophic-standard deviation-relative closeness coefficient and double normalization-based multiple combination methods in improving financial risk evaluation in supply chains? To design and verify a new approach to evaluating financial risks in supply chains using the proposed hybrid approach. This study's importance is that it can potentially change risk management in the supply chain. The research aims to address these challenges and intricacies of contemporary supply chains, which are represented by

global networks, fast paced technological changes and ever changing market demands, through an improved and nuanced risk assessment method. It is a rather substantial contribution to supply chain management, which will provide the organizations with a more solid framework for managing financial risks, narrowing the range of disruptions and contributing to the overall supply chain resilience (Alshurideh et al., 2020).

2.0 Literature Review

2.1 Introduction to Literature Review

The literature review gives a general overview of SCRM that incorporates risk identification, evaluation, treatment, and monitoring. It also serves as a starting point for the formulation of a wide definition and conceptual framework for SCRM (Baryannis et al., 2019). By conducting a systematic review of the studies, a literature review reveals organizational responses to supply chain risks and the lack of theory usage in the existing studies. This leads future researchers to refine the field and provides managerial implications to use the whole-institutional approach in SCRM.

2.2 Evolution of Supply Chain Risk Management

The evolution of SCRM has been characterized by major developments prompted by global and technological changes. SCRM practices concentrated on internal and immediate supplier risks, using mainly manual tools for risk identification, assessment, treatment, and monitoring (Beer et al., 2018). For example, firms like Ericsson created many tools in the early 2000s, like supply chain risk and structure maps, risk management evaluation tools, and contingency planning processes. The need for an integrated risk management approach became apparent with the globalization of supply chains. The environmental movement began in the 1960s, and external factors such as environmental concerns created a demand for transparency in the supply chain. This change called for broader SCRM strategies that focused not only on the physical aspects of the supply chain but also on regulatory compliance and environmental sustainability. SCRM was also transformed through the integration of information and communication technologies. The transition to digital solutions allowed easier information, money, and goods flow control (Belhadi et al., 2021). This digitalization led to the automation of supply chains, particularly in distribution centers, improving physical distribution and materials management. In addition, the emergence of cybersecurity as a core foundation of SCRM was a significant transition. Since post-2006, with legislation such as the Safe Port Act, there has been an

important shift towards securing the supply chains physically and in the cyber world. The change was further reinforced by standards and guidelines developed by bodies like NIST that emphasized risk management in the information and communications technology supply chain (Shojaei, & Haeri 2019). SCRM has evolved from a function of internal and supplier risks, which relied on manual tools, to a more sophisticated form, which includes technology, cyber threats, and global regulations and environmental impacts. This evolution reflects the increasing intricacy and interdependence of contemporary global supply lines.

2.3 Challenges in Current Risk Assessment Methods

The recommended approaches to the risk assessment of supply chains are accompanied by several challenges that arise primarily due to the dynamic nature of the global supply chains. The main task is the unpredictability of risks that cannot be predicted and measured. In contrast, uncertainties, like unexpected natural disasters or undiscovered cybersecurity gaps, are major obstacles to the standard risk models. These models work well with known risks, but they cannot be complex enough to predict the behavior of unforeseen factors (El Baz & Ruel, 2021). The emergence of digital technologies has changed the nature of supply chain threats from cybersecurity. The risk assessment needs to be revised to respond to the nature of cyber-ransom attacks and other digital threats; the supply chain is weakened. The natural complexity of international supply chains that involve many stakeholders and external elements, including geopolitical changes and environmental regulations, further complicate the assessment and management of risks. Another problem closely associated with this is the siloed approach to risk management in organizations. The supply chain risk management approaches are usually used only for the functional areas without a comprehensive perspective and response across the entire supply chain. A fragmented approach does not support the development of risk management practices that would enhance the whole supply chain's resilience and agility. There is an increasing need for sophisticated and ever-changing risk assessment systems that can cope with the complexities of modern global supply chain networks.

2.4 Neutrosophic Sets in Risk Assessment

Considering the risk assessment, the concept of neutrosophic sets is innovative because it enables one to process complex, ambiguous, and contradictory information more carefully and flexibly than traditional approaches. This numerical regulation

doesn't concern just genuine numbers and has some doubt or lack of bias. The neutrosophic set hypothesis is material in ventures where there are high exposures and doubts, for example, navigation, master frameworks, and man-made notice (Fan & Stevenson, 2018). The utilization of neutrosophic sets in risk evaluation empowers us to think about doubt, subjectivity, and deficiency, which are normal in store network risk the board. For instance, neutrosophic sets have been utilized in FMEA for the evaluation of college manageability risk. This incorporation is grounded on exposures and data deviations. It gives a comprehensive and dynamic gamble evaluation standing out from the traditional ones that neglect to deal with such intricacies.

2.5 Double Normalization-Based Multiple Aggregation Methods

This is on the grounds that the DNMA approaches in an intuitionistic fluffy setting offer a superior methodology for the gamble evaluation of supply chains. This approach coordinates maintainability with inventory network risk the executives and gives a significant appraisal of manageability risk factors. The DNMA approach utilizes those factors that are recognized, focused on, and examined properly. As far as this, the DNMA approach is utilized to control different supportability risk factors that have been distinguished in store network the executives. These include operational, financial, environmental, social, distribution, and recycling dangers (Feng et al., 2018). DNMA, the strategy can recognize the gamble factors that incorporate lack of foresight and planning, ecological mishaps, and creation limit chances. The advancement in the strategy is that it utilizes three collection capabilities got from standardization procedures in soft sets. Because it takes into account the dynamic nature of contemporary supply chains, this innovative approach outperforms conventional approaches to risk assessment. It offers a more extensive perspective on manageability risks with that can be utilized to use sound judgment and key preparation in store network the executives.

2.6 Integration of Neutrosophic and Double Normalization Approaches

Neutrosophic sets and double normalization techniques are a novel strategy that can assist in addressing the difficulties and uncertainties that are present in the supply chains that are currently in use. Regardless of the way that there are no immediate portrayals of their joint execution around here in current writing, the hypothetical benefits of such a mix are obvious. Neutrosophic sets are a

more significant level of vulnerability and indeterminacy, two significant parts of the inventory network climate that is dynamic and capricious. The previously mentioned strategy is a compelling device for risk investigation since it implies twofold standardization procedures that standardize information from various sources into a solitary configuration. This combination assists with making a more exact gamble evaluation of the elective circumstances and outcomes, which thusly prompts more powerful choices and a dependable inventory network.

2.7 Theoretical Framework

The theoretical framework which underlies the investigation of coordinating neutrosophic sets with twofold standardization approaches in store network risk the executives, depends on the SCRM standards and the utilization of cutting edge numerical models to address the complexities of contemporary stockpile chains. SCRM has five stages that go in order: risk recognizable proof, evaluation, investigation, moderation, and control. This framework distinguishes the two kinds of dangers that supply chains face: Inventory network disturbance dangers and execution variety gambles with that lower efficiency. The implementation of neutrosophic sets and double normalization methods is designed to improve the SCRM by overcoming the shortcomings of conventional risk management methods. Neutrosophic sets imply a more detailed description of uncertainties and ambiguities of risk factors, and double normalization techniques allow normalizing heterogeneous data, providing more homogeneous and integrated analysis. This hybrid approach has remained relevant in the face of global market challenges that require supply chains to have robust strategies that allow them to react to demand variations and adapt to price fluctuations rapidly. Implementing these advanced methods supports the strategic goal of strengthening supply chains to become more resilient, robust, and reliable, especially in the automotive, space, and electronics industries, where demand fluctuation and long lead times are common problems.

3.0 Method

The suggested methodological framework is a mixture of a neutrosophic set, and a double normalization technique applied to analyze supply chain financial risks formally. This section includes the research design, data collection procedure, and methods of data analysis.

3.1 Research Design

The quantitative study method measures various supply chain financial risks. The

advantage of this method is also that it can manage large datasets and give reliable statistics. Quantitative method allows us to use mathematical models and statistical techniques that are essential for authorizing a hybrid model's performance with the quantitative method. The exploration configuration is a consecutive system that implies the ID of hazard factors, which can be applied to supply chains, and information assortment and examination utilizing the proposed crossover technique (Gouda & Saranga 2018). The review talks about the angles and relations of hazard factors as indicated by the qualities of neutrosophic sets with respect to vulnerability and indeterminacy control, as well as the twofold standardization technique to standardize heterogeneous informational indexes.

3.2 Data Collection

The study uses secondary data and primarily uses supply chain financial risk datasets on Kaggle, an online platform with a vast collection of datasets from various fields. The relevancy of the supply chain financial risks, as well as the timeliness and accuracy of the data, which ought to reflect the state of the global economy, ought to be the selection criteria for the dataset (Ivanov et al., 2019). To keep up with the importance of the review, the chose informational indexes will manage different parts of the store network including provider execution, store network disturbances, monetary exchanges, and market unpredictability. The range of information suppliers is expected to mirror the multi-layered nature of production network monetary dangers.

3.3 Data Analysis

Regards to information examination in store network monetary gamble appraisal in this work, the product will be EViews, which is a significant econometric and estimating device. The cycle starts with the import of the imported datasets into EViews and the primer investigation. The first step is to analyze the data structure, identify the missing values and outliers and form homogeneous and compatible with other datasets. The essence of the analysis is in the application of the hybrid neutrosophic-standard deviation approach. The innovative approach employs the idea of neutrosophic sets to characterize the hidden uncertainties and ambiguities in the data (Kamble et al., 2021). Each data point in neutrosophic theory has the truth, indeterminacy, and falsity values. Then, double normalization approaches are applied to obtain further detailed information with uniform scaling of neutrosophic processed data which are now more comparable and aggregable. Second, the study conducts exploratory statistical

analyses to detect patterns and correlation between the data. Regression analysis and other statistical tools used in building econometric models are used to test the hypotheses regarding the financial risks of the supply chain. These are the later stages that employ these models to quantify and prioritize financial risks in supply chains and analyze the ability of a hybrid approach to capture the dynamics of these risks. The outcomes are interpreted by literature and the theoretical framework because they show trends, abnormalities, or major findings that indicate supply chain financial risks. The presented EViews analytical approach, in conjunction with the hybrid method, will offer a complete and novel view of financial risks in supply chains that will result in significant progress in this field.

4.0 Measures

The methodology for the analysis used in this study on measuring financial risks in supply chains is designed based on the variables selected. The variables are Supplier Reliability Score, Cost Fluctuation Index, Demand Variability, Supply Chain Disruption Frequency, Market Risk Factor, Operational Risk Factor, and Financial Risk Factor. The measures are chosen because they represent all supply chain risks and how they affect financial performance.

Supplier Reliability Score: This indicator demonstrates the stability and consistency of the suppliers in the supply chain. This is particularly essential while surveying possible dangers to provider execution, including delays, quality issues, and supply coherence. The supplier's reliability and the likelihood of supply chain disruptions and the associated costs are correlated with the score.

Cost Fluctuation Index: This record is the worth of the distinction in the store supply chain cost, which incorporates unrefined components, coordinated operations, and work. High cost variations have the potential to significantly alter the balance of the supply chain, so this measure is essential for assessing and mitigating the financial risk.

Demand Variability: This variable addresses the progressions sought after from clients. The significant difficulties of high fluctuation sought after are the administration of stock, overproduction or underproduction, and failures with monetary results (Munir et al., 2020). Request unpredictability is the establishment for risk the executives and monetary preparation in the supply chain

Supply Chain Disruption Frequency: This metric refers to the occurrence in the supply chain, such as natural disasters,

strikes, geopolitical issues, etc. Such disruptions might cause enormous losses, so this variable is vitally important in the evaluation of supply chain resilience and vulnerability.

Market Risk Factor: This includes market risk associated with the supply chain, such as recessions, shifts in market trends, and competition. These risks directly affect the financial performance of the supply chain; therefore, this variable should be included in the full-scale risk assessment.

Operational Risk Factor: This action is considered an internal supply chain risk that includes production inefficiencies, technical failures, human errors, etc. It is possible to show operational risks in the financial risk assessment framework because they increase the costs and decrease profitability.

Financial Risk Factor: It directly points out financial risk in the supply chain, including credit, liquidity, and foreign exchange risks. It is a generic measure that takes into account the probability of loss that could result from various risk factors in the supply chain.

These variables provide a general overview of financial risks in supply chains. These particular measures are chosen because of the craving to mirror an enormous number of hazard factors, both interior and outside, that influence the supportability and benefit of supply chains (Oliveira et al., 2019). This multi-faceted methodology makes it imaginable to have a complete and dynamic money risk discernment which is basic in the administration of dangers and well thought out courses of action pointed toward controlling the supply chain exercises.

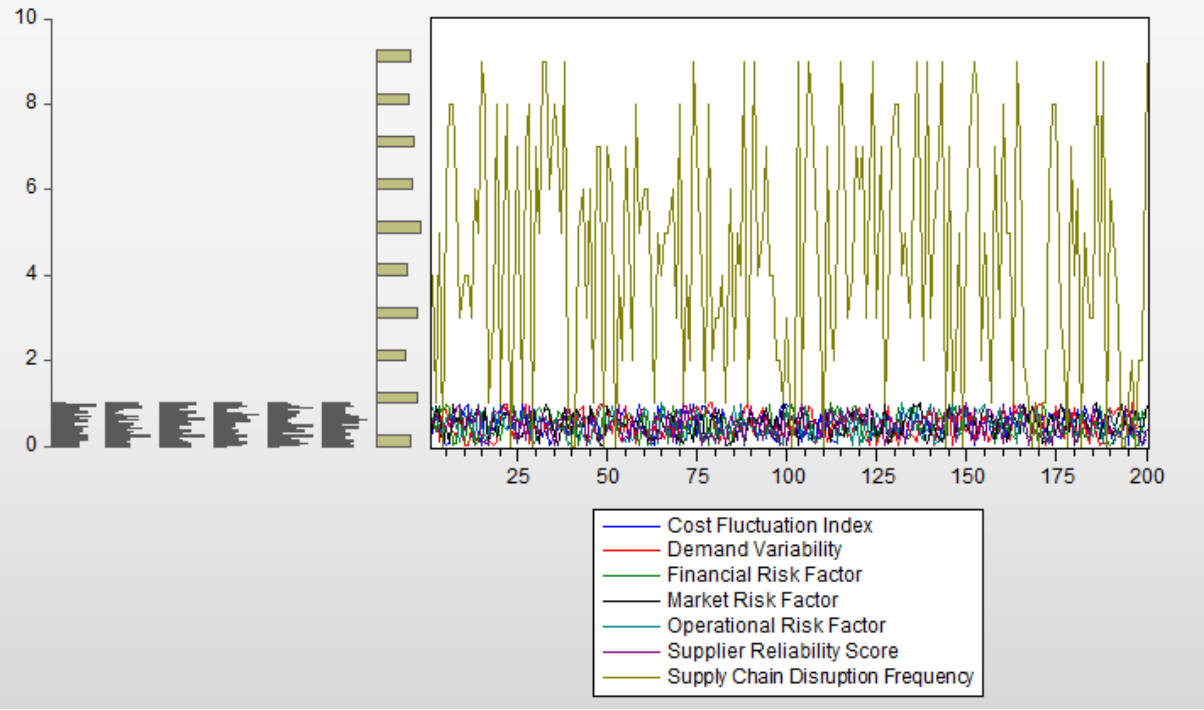
5.0 Results

5.1 Descriptive Analysis

	COST_FLUCTUATION_INDEX	DEMAND_VARIABILITY	FINANCIAL_RISK_FACTOR	MARKET_RISK_FACTOR	OPERATIONAL_RISK_FACTOR	SUPPLIER_RELIABILITY_SCORE	SUPPLY_CHAIN_DISRUPTION_FREQUENCY
Mean	0.491195	0.502976	0.500764	0.516177	0.480187	0.500438	4.470000
Median	0.461716	0.463047	0.520243	0.557189	0.451312	0.540258	5.000000
Maximum	0.990339	0.997962	0.996541	0.997436	0.998025	0.998847	9.000000
Minimum	0.011427	0.002703	6.06E-05	0.002677	0.009683	0.004695	0.000000
Std. Dev.	0.294601	0.301947	0.295979	0.284431	0.294039	0.284626	2.844213
Skewness	0.075055	0.088052	-0.048728	-0.113814	0.154248	-0.052918	-0.000134
Kurtosis	1.754233	1.786989	1.784939	1.902203	1.744828	1.861994	1.805252
Jarque-Bera	13.12057	12.52006	12.38227	10.47477	13.92188	10.88548	11.89520
Probability	0.001415	0.001911	0.002048	0.005314	0.000948	0.004328	0.002612

Sum	98.23894	100.5952	100.1528	103.2355	96.03736	100.0876	894.0000
Sum Sq. Dev.	17.27119	18.14321	17.43311	16.09935	17.20533	16.12141	1609.820
Observations	200	200	200	200	200	200	200

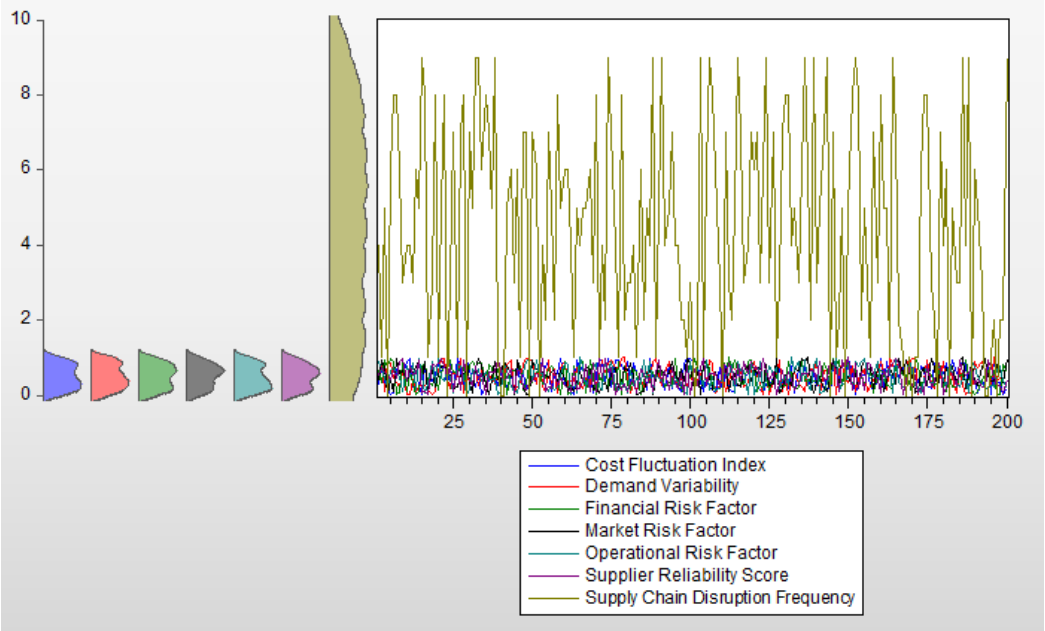
The seven variables in the dataset, which are used to evaluate the financial risks associated with supply chains, exhibit interesting characteristics and patterns. The factors are decently slanted towards the mean, which means that a decent spread around the mean. It is to be noticed that supply chain Interruption Recurrence has a mean (4.47) and middle (5.00) which reflects moderate to high store network disturbance recurrence. The standard deviation worth of the Expense Change Record, Request Fluctuation, Monetary Gamble Variable, and Functional Gamble Component is a striking contrast for these elements. The skewness is low in all variables in this manner, the distribution is approximately symmetrical. The kurtosis values are typically under two, demonstrating a platykurtic conveyance, where the information is less crested with lighter tails contrasted with the ordinary dissemination. The Jarque-Bera test results, with low likelihood values, demonstrate that these factors go astray from predictability (Rojas-Gualdron et al., 2021). For a thorough examination of specific aspects of financial risk in supply chains, the dataset provides a variety of attributes.



5.2 Correlation Analysis

	COST_FLUCTUATION_INDEX	DEMAND_VARIABILITY	FINANCIAL_RISK_FACTOR	MARKET_RISK_FACTOR	OPERATIONAL_RISK_FACTOR	SUPPLIER_RELIABILITY_SCORE	SUPPLY_CHAIN_DISRUPTION_FREQUENCY
COST_FLUCTUATION_INDEX	1	0.05278438962876448	0.00128371967010359 5	0.15053534615476 71	-0.03814876084719 94	-0.05439937144592436	-0.10132683786458 41
DEMAND_VARIABILITY	0.05278438962876448	1	0.00662273408055462 2	-0.02173139297156571	-0.03191571782326032	-0.01768705667034948	-0.02553156478564856
FINANCIAL_RISK_FACTOR	0.00128371967010359 5	0.00662273408055462 2	1	-0.00398111632499146 8	-0.03035450698764 97	0.15298451059968 89	-0.07608654665211822
MARKET_RISK_FACTOR	0.15053534615476 71	-0.02173139297156571	-0.00398111632499146 8	1	0.01010914126400428	0.11225893193471 58	-0.06830119890577951
OPERATIONAL_RISK_FACTOR	-0.03814876084719 94	-0.03191571782326032	-0.03035450698764 97	0.01010914126400428	1	0.11333986250148 65	-0.04232563433 69904
SUPPLIER_RELIABILITY_SCORE	-0.05439937144592436	-0.01768705667034948	0.15298451059968 89	0.11225893193471 58	0.11333986250148 65	1	-0.04998286981086303
SUPPLY_CHAIN_DISRUPTION_FREQUENCY	-0.10132683786458 41	-0.02553156478564856	-0.07608654665211822	-0.06830119890577951	-0.04232563433 69904	-0.04998286981086303	1

There is mostly a weak to moderate correlation between the variables in the dataset regarding various aspects of financial risk in the supply chain. The most grounded connection is found between the Market Hazard Element and Provider Unwavering Quality Score (0.1123), demonstrating a feeble relationship where changes in market gambles are marginally connected with the dependability of providers. Curiously, the Monetary Gamble Component shows a moderately frail positive relationship with the Provider Unwavering Quality Score (0.1530), and that implies that the more prominent the provider dependability, the higher the monetary gamble. The Supply Chain Disruption Frequency has a negative correlation with the majority of variables, particularly the Cost Fluctuation Index (-0.1013), indicating that cost fluctuations may decrease as supply chain disruptions increase (Rostamzadeh et al., 2018). These correlations indicate that although there are some associations between the variables, they are typically weak, indicating the multifaceted complexity of supply chain financial risks.



5.3 Regression Analysis

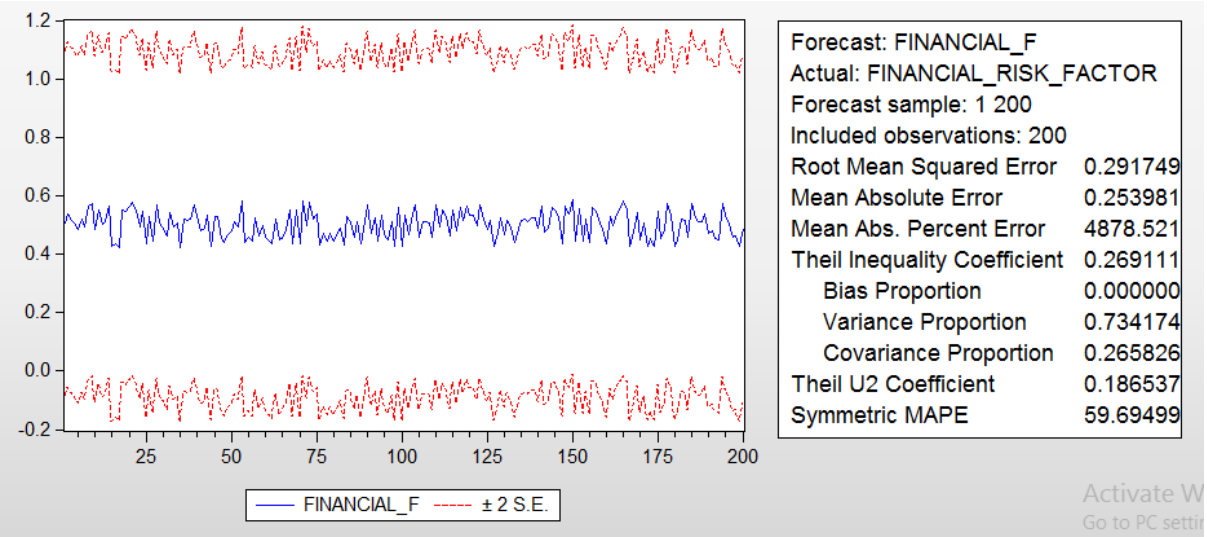
Dependent Variable: FINANCIAL_RISK_FACTOR
Method: Least Squares
Date: 01/26/24 Time: 13:24
Sample: 1 200
Included observations: 200

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.416124	0.055929	7.440155	0.0000
SUPPLIER_RELIABILITY_SCORE	0.159632	0.073322	2.177136	0.0307
COST_FLUCTUATION_INDEX	0.009680	0.070839	0.136641	0.8915

R-squared	0.023497	Mean dependent var	0.500764
Adjusted R-squared	0.013583	S.D. dependent var	0.295979
S.E. of regression	0.293962	Akaike info criterion	0.404154
Sum squared resid	17.02349	Schwarz criterion	0.453629
Log-likelihood	-37.41538	Hannan-Quinn criteria.	0.424176
F-statistic	2.370126	Durbin-Watson stat	2.032277
Prob(F-statistic)	0.096129		

Regression analysis found that the Supplier Reliability Score significantly affects the Financial Risk Factor in supply chains, with the positive coefficient of 0.1596 and the p-value of 0.0307. This suggests that higher confidence in the providers might bring about higher monetary gamble. The Expense Variance File meaningfully affects the monetary gamble. The model makes sense of 2.35% of the difference in the

Monetary Gamble Variable (R-squared = 0.0235), and different elements could contribute essentially. There are no significant autocorrelation issues because the Durbin-Watson statistic is close to 2. Eventually, the model features the huge job of provider firm quality in the monetary gamble evaluation however verifiably shows that a more complete methodology is expected to give a more extensive perspective on supply chain monetary dangers.



6.0 Discussion and Implications

The descriptive, correlation, and regression analysis results provide a comprehensive insight into the dynamics of financial risk factors in supply chains (Wang et al., 2018). These outcomes are essential in tending to the exploration question: A double normalization-based multiple aggregation method that uses a hybrid single-valued neutrosophic-standard deviation-relative closeness coefficient to improve the evaluation of financial risks in supply chains? The descriptive analysis highlights the breadth and depth of the factors driving the supply chain financial risks. The supply chain settings are heterogeneous since the mean and median factors such as Cost Fluctuation Index, Demand Variability, and Supply Chain Disruption Frequency provide a mixed distribution. The skewness and kurtosis found reveal non-normality, which indicates the complicated essence of supply chain risk factors that a classical statistical method cannot fully grasp. In the correlation analysis, the weak to moderate correlations among the variables, such as Supplier Reliability Score and Financial Risk Factor, suggest complex and subtly interdependent relationships. The above results indicate that although the traditional linear models may capture some aspects of

the risk, the supply chain risks are more complex and interwoven, and may require more sophisticated analytical tools to understand them completely. This complexity is further illustrated by the regression analysis. The high positive correlation between the Supplier Reliability Score and the Financial Risk Factor which is shown in the regression coefficient reveals that supplier reliability is a major factor contributing to the financial risk in supply chains. The low R-squared value indicates that other variables are included but also affect financial risk, which leads to more complicated models in financial risk assessment (Shekarian & Mellat Parast, 2021). Based on the research question, it is evident that while traditional statistical methods are informative, they may be more than needed to show the intricacies of financial risks in supply chains. The need of a hybrid method based on the combination of single-valued neutrosophic sets with the standard deviation-relative closeness coefficient and double normalization-based multiple aggregation techniques is reasonable. This approach would provide a better and comprehensive assessment of financial risks including uncertainty, indeterminacy, and complexity in the supply chain.

7.0 Limitations

This study has several limitations which should be taken into account as a source of useful information for the evaluation of financial risks in supply chains. Second, secondary data reduces the level of control of quality and specificity to the research question. Though secondary data may be very easy to use, it may need to be accurate enough to match the details of the proposed hybrid method. The R2 value that is very low in the regression model implies that the model does not explain much of the variation in the Financial Risk Factor which could be indicative of leaving out other relevant variables or interactions. The above limitations can be addressed in future studies through the primary data collection that is adjusted to the size of supply chain financial risks for the case of the hybrid method. This would help to make the data relevant and precise. Further, the study needs to be developed by generalizing the analytical model to incorporate more variables and non-linear relationships that help to understand the intricacy of supply chain financial risks. The use of advanced statistical techniques or machine learning models can also uncover hidden insights and relationships within the data.

References

Abdel-Basset, M., Gunasekaran, M., Mohamed, M., & Chilamkurti, N. (2019). A framework for risk

assessment, management and evaluation: Economic tool for quantifying risks in supply chain. *Future Generation Computer Systems*, *90*(1), 489-502.

Ahmad, E. M. M. A. (2018). Theoretical framework development for supply chain risk management for Malaysian manufacturing. *Int. J Sup. Chain. Mgt Vol*, *7*(6), 325.

Alshurideh, M., Gasaymeh, A., Ahmed, G., Alzoubi, H., & Kurd, B. (2020). Loyalty program effectiveness: Theoretical reviews and practical proofs. *Uncertain Supply Chain Management*, *8*(3), 599-612.

Baryannis, G., Dani, S., & Antoniou, G. (2019). Predicting supply chain risks using machine learning: The trade-off between performance and interpretability. *Future Generation Computer Systems*, *101*, 993-1004.

Beer, R., Ahn, H. S., & Leider, S. (2018). Can trustworthiness in a supply chain be signaled?. *Management science*, *64*(9), 3974-3994.

Belhadi, A., Mani, V., Kamble, S. S., Khan, S. A. R., & Verma, S. (2021). Artificial intelligence-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism: an empirical investigation. *Annals of Operations Research*, 1-26.

El Baz, J., & Ruel, S. (2021). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *International Journal of Production Economics*, *233*, 107972.

Fan, Y., & Stevenson, M. (2018). A review of supply chain risk management: definition, theory, and research agenda. *International journal of physical distribution & logistics management*, *48*(3), 205-230.

Feng, M., Yu, W., Wang, X., Wong, C. Y., Xu, M., & Xiao, Z. (2018). Green supply chain management and financial performance: The mediating roles of operational and environmental performance. *Business strategy and the Environment*, *27*(7), 811-824.

Gouda, S. K., & Saranga, H. (2018). Sustainable supply chains for supply chain sustainability: impact of sustainability efforts on supply chain risk. *International Journal of*

Production Research, *56*(17), 5820-5835.

Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. *International journal of production research*, *57*(3), 829-846.

Kamble, S. S., Gunasekaran, A., Kumar, V., Belhadi, A., & Foropon, C. (2021). A machine learning based approach for predicting blockchain adoption in supply Chain. *Technological Forecasting and Social Change*, *163*, 120465.

Munir, M., Jajja, M. S. S., Chatha, K. A., & Farooq, S. (2020). Supply chain risk management and operational performance: The enabling role of supply chain integration. *International Journal of Production Economics*, *227*, 107667.

Oliveira, J. B., Jin, M., Lima, R. S., Kobza, J. E., & Montevechi, J. A. B. (2019). The role of simulation and optimization methods in supply chain risk management: Performance and review standpoints. *Simulation Modelling Practice and Theory*, *92*, 17-44.

Rojas-Gualdron, R., Smarandache, F., & Diaz-Bohorquez, C. (2021). Neutrosophic probabilistic expert system for decision-making support in supply chain risk management. *Neutrosophic Operational Research: Methods and Applications*, 343-366.

Rostamzadeh, R., Ghorabaee, M. K., Govindan, K., Esmaeili, A., & Nobar, H. B. K. (2018). Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS-CRITIC approach. *Journal of Cleaner Production*, *175*, 651-669.

Shekarian, M., & Mellat Parast, M. (2021). An Integrative approach to supply chain disruption risk and resilience management: a literature review. *International Journal of Logistics Research and Applications*, *24*(5), 427-455.

Shojaei, P., & Haeri, S. A. S. (2019). Development of supply chain risk management approaches for construction projects: A grounded theory approach. *Computers & Industrial Engineering*, *128*, 837-850.

Wang, L., Zhang, H. Y., Wang, J. Q., & Li, L. (2018). Picture fuzzy normalized

projection-based VIKOR method for the risk evaluation of construction project. *Applied Soft Computing*, *64*, 216-226.