Team Number:	91058
Problem Chosen:	B

2019 APMCM summary sheet

Analysis and Decision-making of Regional Economic Vitality and Its Influencing Factors

Regional economic vitality is an important component of regional comprehensive competitiveness. At present, regional economic vitality is mainly improved through various economic policies. This article is based on the analysis of the influencing factors of the economic vitality of a specific region. The Improved Neural Network Model and Factor Analysis are used to determine the key factors affecting the regional economic vitality.

To solve the first problem, this paper takes the data of Henan Province in the past ten years as an example, and uses an Improved Neural Network Model to extract the principal components of a variety of factors that can affect the vitality of the population and the enterprise. It is concluded that the population, the output value of the enterprise and the number of enterprises all have a great positive correlation with the regional economic vitality, which is approximately linear. Therefore, we propose to formulate policies to attract talents, increase the proportion of employed personnel, introduce foreign-funded enterprises, and reduce corporate costs to improve regional economic vitality.

For the second question, this article still takes Henan Province as the research object, and analyzes the impact of 2008 economic policies on Henan Province. Use the gray prediction method to predict the value after the economic policy change according to the values of the factors before the economic policy change, and compare with the value after the actual policy change, to obtain the analysis result: the region's economic policy has a slower growth rate in the short term. In the long run, the region's economic vitality has grown extremely fast.

According to the third question, to measure the regional economic vitality, we can select representative economic influencing factors and filter based on the correlation between each factor, thereby reducing the complexity of the model. In this paper, a comprehensive index evaluation model based on Factor Clustering Analysis is established, and classification is performed through a tree diagram before factor analysis is performed to calculate the load. Finally, the city's economic vitality ranking based on the vitality of the enterprise is obtained.

In response to question four, we put forward the countermeasures and suggestions for promoting the high-quality economic development of Henan Province in accordance with the conclusions of Questions 1-3 and the strategic deployment of "two high-quality developments". Make Henan's economic vitality maintain sustainable development.

To sum up, with intelligent use of analogy skill, global and partial analysis, qualitative and quantitative analysis, our models have advantage of great robustness and rationality.

Keywords: Factor Analysis Improved Neural Network Grey prediction Model Factor Cluster Analysis Night Light Data MATLAB

Contents

1. Introduction **1**
1.1 Background of the Problem. 1
1.2 Restatement of the Problem 1
2. Model Assumptions. **2**
3. Symbols and Definitions **2**
4. Problem Analysis. **3**
4.1 Question One. 3
4.2 Question Two. 4
4.3 Question Three 4
4.4 Question Four 5
5. Establishment and Solution of Model **6**
5.1 Question One. 6
5.1.1 *Models Establishment* 6
5.1.2 *Models Solution*. 7
5.2 Question Two. 12
5.2.1 *Models Establishment* 12
5.2.2 *Models Solution*. 13
5.2.3 *Models Test* 15
5.3 Question Three 16
5.3.1 *Models Establishment* 16
5.3.2 *Models Solution*. 17
5.3.3 *Extension of Model* 20
5.4 Question Four 22
5.4.1 *Accelerating Industrial transformation and upgrading*. 22
5.4.2 *Promoting Talent-saving strategy* 23
5.4.3 *Deepening Reform and opening up* 23
5.4.4 *Promoting new urbanization* 24
5.4.5 *Adhere to ecological civilization* 25
5.4.6 *Improving supporting policy system* 25
6. Model Adaptability Test **26**
6.1 Analysis of residual normality test 26
6.2 Analysis of error results 26
6.3 Autocorrelation of Error test 27

7. The Evaluation of Model 27
7.1 Strength 27
7.2 Weakness 27
8. References 28
9. Appendix 29

I. Introduction

1.1 Background of the Problem

Since the reform and opening up, China's economy has developed rapidly and society has continued to progress. However, due to economic, social, natural, historical and other reasons, development has been uneven across regions, and regional economic variability also exists. Therefore, an objective and comprehensive evaluation of regional economic vitality, and exploring the causes of such differences, are of great significance for achieving regional coordination in sustainable development.

"Vitality" refers to the degree of support of a city, region or country for vital functions, ecological environment and economic society. Economic vitality, social vitality, environmental vitality and cultural vitality together constitute the entire vitality system, and they are closely related to each other. Economic vitality is mainly manifested in the growth of the economy, its attractiveness to capital labor, entrepreneurship, technological innovation, and the efficiency in using these factors.

The status quo and future trends of regional economic development have been greatly affected by economic vitality. The so-called economic vitality refers to the growth rate and potential of the total supply and demand in the economy of a city or province in a certain period of time. It involves all aspects of GDP, the living environment of the enterprise, and the living standard of the people. Attraction to capital, labor, entrepreneurship, technological innovation, etc., and efficiency in using these factors.

1.2 Restatement of the Problem

The regional (or urban or provincial) economic vitality is an important part of regional comprehensive competitiveness. In recent years, in order to improve the economic vitality, some regions have launched many preferential policies for stimulating the economy vitality.However, due to different resource endowments, these policies have different effects in different regions. How to seize the key factors and effectively improve the regional economic vitality is a worth study topic.

In order to study how to improve the regional economic vitality, we have obtained some data. Please build a suitable model and solve the following problems based on these data and your own data obtained through survey:

1. The regional (or urban or provincial) economic vitality is affected by variety of factors. Take a region (or city or province) as an example, please build the suitable relational model of influencing factors of economic vitality, and study the program of action to improve the regional economic vitality. Analyze the effects on the regional economic vitality change from the perspective of changing trend of population and

enterprise vitality.

2. Select a region (or city or province), and analyze the short-term and long-term effects of economic policies transformation on the economic vitality of such region (or city ore province) based on the suitable data surveyed by you.

3. Measuring the regional economic vitality is a complex issue. Please select the suitable index system, establish the mathematical model which analyzes and measures the regional (or urban or provincial) economic vitality, and rank the economic vitality of cities in Attachment 3.

4. If you are a decision-maker of regional economic development, according to the conclusions for Problems 1-3, provide a development proposal for the region (or city or province) discussed in Problem 2 so that the economic vitality in this region presents the benign sustainable development and the regional competitiveness is stronger.

II. Model Assumptions

1. It is assumed that changes in industrial added value can fully reflect changes in industrial output.

2. Assume that the total retail sales of consumer goods is equal to the output value of the tertiary industry enterprises.

3. It is assumed that the changing trend of industrial value added and construction industry output value can reflect the development trend of the secondary industry.

4. Suppose that in a certain area, the enterprises registered by individual industrial and commercial households have little influence on the economic vitality of the area and can be ignored.

III. Symbols and Definitions

Table 1 Symbols and Definitions

Symbol	Definitions
F_i	Evaluation score of the i-th factor
ω_i	Contribution of variance before or after rotation factor
Y	Regional economic vitality GDP
C	Posterior error ratio
P	Small error probability
$L_i j$	Factor analysis load of main factor and evaluation factor
$H_i j$	Factor load in the case of relative importance of main factors

IV. Problem Analysis

4.1 Question One

The title requires us to take a specific region as an example, establish a reasonable analysis model, and analyze the influencing factors of economic vitality changes from two perspectives: population trends and corporate vitality trends.

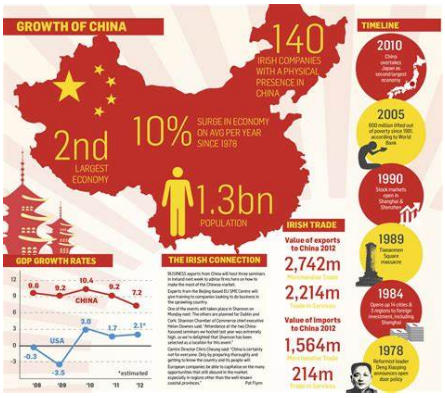


Figure 1 Growth of China

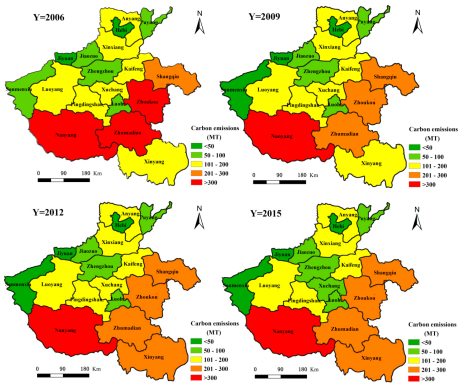


Figure 2 Growth of Henan

As the total GDP of Henan Province ranks fifth in the country, but the large population and insufficient per capita are fundamental. This is similar to the situation in China today. The total GDP ranks second in the world and the average per capita is low, as shown in Figure 3. Moreover, Henan Province has a superior geographical location and sufficient economic development potential. Therefore, this article selects Henan Province as the research area. Second, we analyze to determine the representation of the dependent and independent variables of the problem. We use the number of people, the number of employed persons, and the natural change of the population to represent the population change of the independent variable. We use the number of enterprises, the output value of the enterprise, and the value added of the industry to represent the vitality of another independent variable.

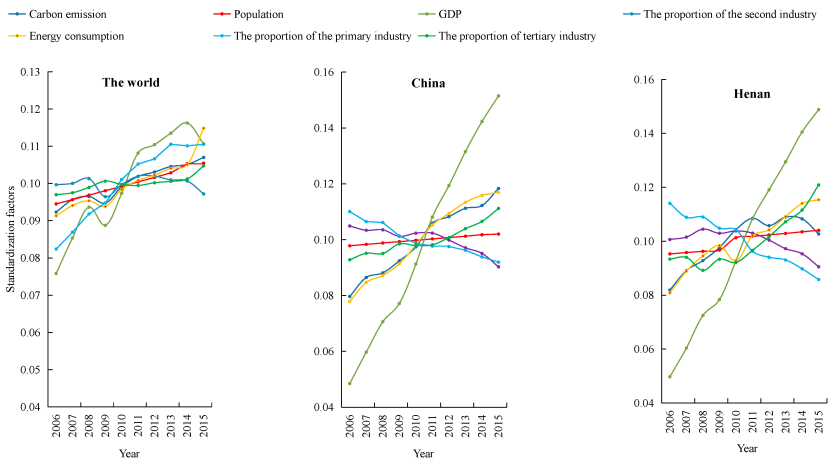


Figure 3 Economic Comparison between Henan Province and China

We analyze the factors that affect economic vitality and the GDP of Henan Province in the past 10 years, use Neural Network Models for fitting, and use the fitted results to analyze the degree of influence of these factors on economic vitality. After consulting the Henan Statistical Yearbook 2018, we found that the indicators affecting regional economic vitality are redundant. To ensure the convergence and stability of Neural Network Model training, we use an Improved Neural Network Model, which uses Factor Analysis to optimize the input of Neural Networks. Variable, select the more relevant indicator as the Network input of the model. By analyzing the output of the model, the rationality of the model is verified and the influence of various indicators on regional economic vitality is obtained.

From the key factors affecting regional economic vitality obtained from the analysis of the above models, we can work out effective plans to increase regional economic vitality.

4.2 Question Two

The title still requires us to choose a regional analysis and analyze the short-term and long-term effects of economic policy changes on regional economic vitality based on survey data.

After data survey and related information query, we decided to analyze the economic policy adopted by Henan Province in 2008 to quantitatively analyze the economic vitality change of Henan Province before and after the implementation of this economic policy change. First, we should choose appropriate indicators to measure regional economic vitality. In order to ensure a comprehensive evaluation of economic vitality, we mainly select indicators from the economic, social, and environmental perspectives. This article selects dozens of factors such as per capita GDP, per capita GDP growth rate, number of industrial enterprises, enterprise output value, per capita fiscal income and growth rate, etc.

What's more, we uses the gray prediction model to predict the next 10 years based on data from the first 10 years of economic policy change. The analysis compares the values of various factors in the 10 years after the actual economic policy change, and analyzes the differences between the various factors to obtain the degree of influence of the economic policy change on different factors reflecting economic vitality, and the economic policy transition to the region Short-term and long-term effects of economic vitality.

4.3 Question Three

The title requires us to select reasonable indicators, establish a mathematical model that can analyze and measure regional economic vitality, and sort the economic vitality of cities in Annex III.

First, to measure regional economic vitality, economic aggregate and economic growth are the most intuitive indicators. Secondly, according to the conclusion of Question 1, it can be seen that regional economic vitality has a strong correlation with population and corporate vitality. Therefore, the number of enterprises, the average annual revenue of the enterprise, and the registered capital of the enterprise can be selected as the main indicators of corporate vitality. According to the statistical yearbook, indicators such as the income and expenditure of residents and foreign investment can be used to reflect economic growth. By screening the correlation of the indicators, a mathematical model can be directly established to calculate the factor load. Due to the large gap between the economic level of the first-tier cities and the second-tier cities, we consider to classify the cities according to the main indicators first, and then further refine the selected indicators. Factor calculation to get the city's economic ranking.

In addition, we also use the Night Light Data to build a model to evaluate and analyze the economic vitality of the cities, and use the obtained economic vitality values to sort the cities.

4.4 Question Four

The title requires us to propose developments to the areas discussed in Question 2 based on the conclusions of Questions 1-3 in order to enhance regional competitiveness and maintain sustainable economic development in the region.

Therefore, based on the results of the model, we provide suggestions and suggestions for improving regional economic development, and mainly propose rationalization suggestions from the following aspects.

(1) Accelerate industrial transformation and upgrading and build a modern industrial system;

(2) Promote the strategy of strengthening provinces by talents and build regional innovation highlands;

(3) Deepen reform and opening up and vigorously cultivate development momentum;

(4) Continue to promote new urbanization and promote coordinated regional development;

(5) Adhere to the thought of ecological civilization and achieve green and low-carbon development;

(6) Improve supporting policy system and create a good development environment.

V. Establishment and Solution of Model

5.1 Question One

5.1.1 *Models Establishment*

(1) Factor Analysis Method

- Basic Idea of Factor Analysis Method
  The Factor Analysis Method mainly groups variables according to the magnitude of the correlation, so that the correlation of the variables in the same group is higher, and the correlation of different groups of variables is lower. Represent each variable of the original observation in order to explain the correlation between the original variables and reduce the dimensionality. At the same time, weights reflecting the amount of information contained in the factors and indicators are formed to calculate the comprehensive evaluation value. In this way, the influence of subjective factors is overcome in the selection of index weights, which helps to objectively reflect the actual relationship between samples[1].

- Basic Steps of Factor Analysis Method
  1)Standardize the raw data, that is $x_i^* = \frac{x_i - \bar{x}_i}{s_i}$, (where $\bar{x}_i$ is the sample mean and s_i is the sample standard deviation), to eliminate the impact of different dimensions;
  2)Calculate the correlation coefficient matrix R for dimensionless data;
  3)Find the eigenvalue, eigenvector, and contribution rate of R;
  4)Determine the number of principal components. Generally, principal components with eigenvalues greater than 1 are used as explanatory factors;
  5)Explain the economic significance of each major factor, and its significance is determined by the comprehensive significance of several indicators with the largest factor load;
  6)Calculate the scores and comprehensive scores of each factor, and then sort and compare and analyze the research objects. The calculation of the comprehensive score is based on the variance contribution rate of each factor, and the comprehensive evaluation index function is obtained from the linear combination of each factor:

$$\mathrm{F} = \frac{\gamma_1 F_1 + \gamma_2 F_2 + \cdots + \gamma_m F_m}{\gamma_1 + \gamma_2 + \cdots + \gamma_m} = \sum_{i=1}^{m} \omega_i F_i$$

  Where ω_i is the variance contribution rate of the factor before or after rotation.[2]

(2) Improved Neural Network Model

- Basic Idea of Neural Network Algorithm
  This paper uses a Neural Network Model based on Factor Analysis and BP Neu-

ral Network Algorithm to analyze the degree of influence of various factors on economic vitality. We first used a Factor Analysis Model to screen all the impact indicators, and finally got several key factors affecting economic vitality as input variables of the Neural Network. The basic idea of the BP Neural Network is that the learning process consists of two parts: forward signal propagation and backward feedback error. In forward propagation, input samples are passed in from the input layer, processed by each hidden layer in turn, and then transmitted to the output Layer, if the output layer output does not match the expectation, the error is returned back as the adjustment signal layer by layer, and the connection weight matrix between neurons is processed to reduce the error.

- Basic Steps of Neural Network algorithm
  The specific network structure of BP Neural Network is shown in Figure 1 below.

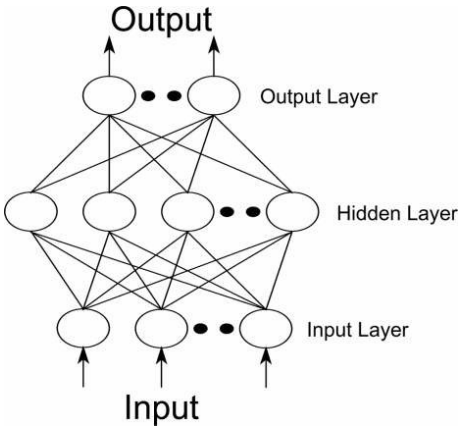


Figure 4 Multilayer feedforward network

1)Take a sample from the training set and enter the information into the network;
2)The actual output of the Neural Network is obtained after processing the connection between the nodes forward by layer;
3)Calculate the error between the actual output of the network and the expected output;
4)The error is transmitted back to the previous layers layer by layer, and the error signal is loaded on the connection weights according to certain principles, so that the connection weights of the entire Neural Network are transformed in the direction of decreasing errors;
5)Repeat the above steps for each input-output sample pair in the training set, until the error of the entire training sample set is reduced to meet the requirements.

5.1.2 *Models Solution*

(1) Key factors extraction by Factor Analysis

Principal component extraction was performed on the factors affecting population change, and Factor Analysis was performed using SPSS software, and the component

matrix was obtained as shown in Table 2 below.

Table 2 The component matrix

Component matrix a	Ingredients
Total population	0.999
Number of employees	0.997
Ageing	0.969
Natural population change	0.998
Education level	0.975
Permanent residents	0.997
Male to female ratio	0.947

From the perspective of the trend of population change, this article selects the total population, the number of employed persons, the degree of aging, the natural change of the population, the level of education, the permanent population, and the ratio of men and women as independent variables. Using correlation analysis, we know that some of the independent variables have a low degree of correlation, which leads to the redundancy of the variables, so we need to screen the variables. Analyzing the component matrix, it was found that the four indicators of total population, number of employed persons, natural population changes, and permanent population have a greater impact on economic vitality. Therefore, the above four indicators can be used as key factors affecting economic vitality[3].

Extract the principal components of the factors that affect the change of corporate vitality, and use SPSS software to perform factor analysis. The component matrix obtained is shown in Table 3 below.

Table 3 The component matrix

Component matrix a	Ingredients
Tertiary Industry Enterprise Output Value	0.999
Number of companies	0.997
Total catering retail	0.969
Output value of secondary industry enterprises	0.998
Deposit balance at the end of the financial year	0.945
Real estate investment	0.967
Construction value	0.986
Number of real estate companies	0.973
Construction companies	0.987
Industrial value-added	0.983

In the same way, from the perspective of the trend of population change, the output value of the tertiary industry enterprises, the output value of the secondary industry enterprises, the number of enterprises, and several typical industries that account for a

large proportion of the market are initially selected, including the balance of financial deposits at the end of the year, real estate investment factors, such as the amount of construction, the value of construction in the real estate industry, the number of real estate companies, the number of construction enterprises, and the total value-added retail of restaurants and catering, etc., are taken as independent variables, and the gross national product is the dependent variable. The factor matrix is used to obtain the component matrix. Finally, the output value of the tertiary industry enterprises, the output value of the secondary industry enterprises, and the number of enterprises are selected as the key factors affecting the regional economic vitality.

(2) Analysis of economic vitality changes based on Improved Neural Network Models

The key factors obtained in (1) above are used as input variables of the BP Neural Network. The degree of influence of these key factors on the regional economy is analyzed through the training results of the Neural Network Model.

In the case of neglecting slight changes in the network, after the principal component analysis, the total population, the number of employed persons, the natural population change, and the resident population were selected as input variables in the population change trend indicators, and the secondary and tertiary industries were selected in the enterprise vitality change trend indicators The output value and the number of enterprises are used as input variables, and GNP is selected as an output variable in the indicators that measure the change in regional economic vitality. Through the establishment of the Neural Network, we can obtain a structural analysis chart of the Neural Network. From the figure, we can know the training data. The relationship between the gradient and the mean square error validates the feasibility of this model. The following figures 5 and 6 are the results of inputting Neural Network Models into the key factors of population change and corporate vitality change, respectively.

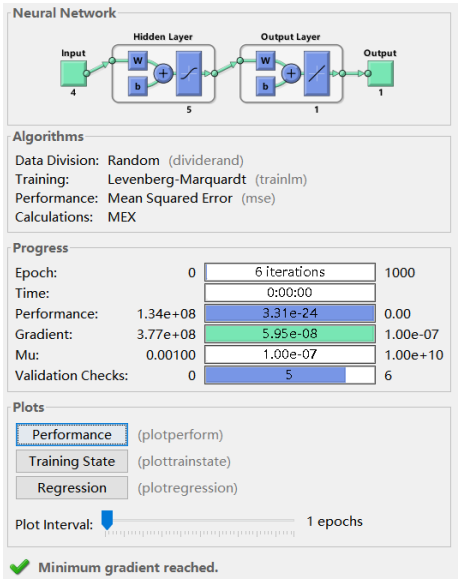


Figure 5 Demographic change results

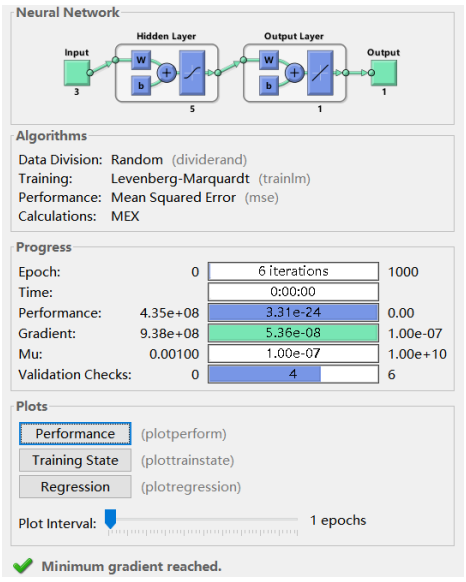


Figure 6 Corporate vitality change results

By analyzing the following figures 7 and 8, we can obtain the degree of influence of different key factors on regional economic vitality. Observing the results of regression analysis, the correlation can reach 0.99, and the correlation is high. Therefore, the analysis of regional economic vitality changes can use the total population, the number of employees, natural population changes, the permanent population, the output value of the secondary and tertiary industries and the number of enterprises Key factors affecting regional economic vitality.

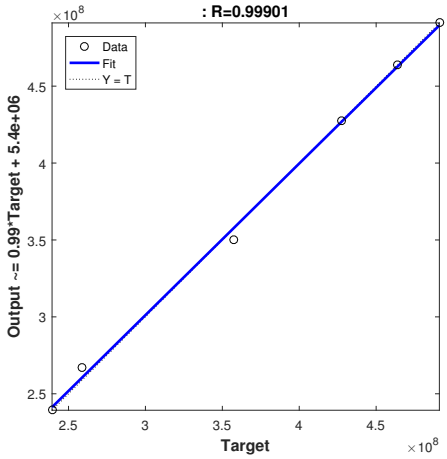


Figure 7 Correlation analysis of population factors

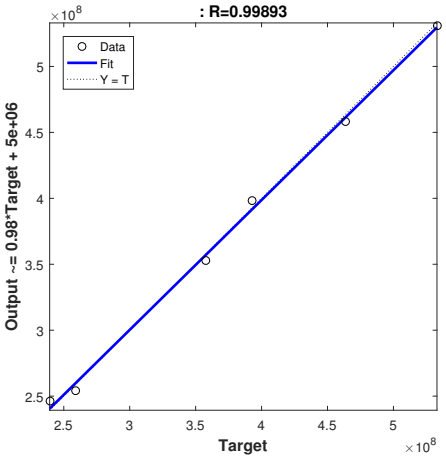


Figure 8 Correlation analysis of enterprise vitality factors

Next, we use SPSS software to perform regression analysis on key factors and regional economic vitality, so as to obtain the specific degree of each factor's impact on regional economic vitality. Figure 9 shows the impact of population changes on regional economic vitality.

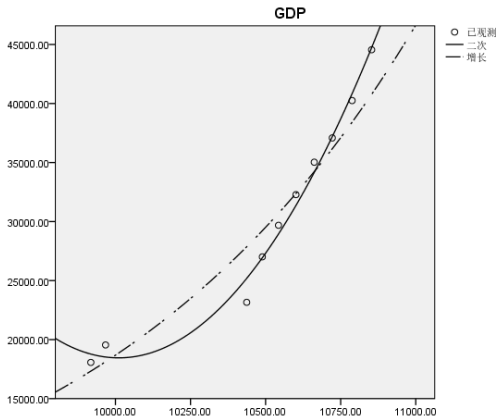


Figure 9 Total population regression analysis chart

The impact of population changes on regional economic vitality:

$$Y = -26.905X_1 + 27.839X_1^2$$

Among them, Y is the GDP that the dependent variable represents the regional economic vitality, and X_1 is the total population that the independent variable represents the trend of population change.

As shown in Figure 10, it shows the impact of enterprise output value on regional economic vitality.

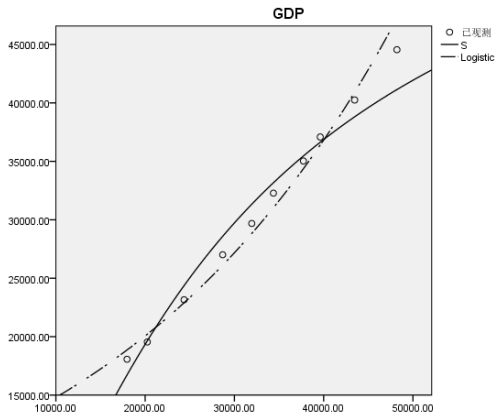


Figure 10 Enterprise output value regression analysis chart

The impact of enterprise output value on regional economic vitality:

$$\ln(Y) = X_2 + 9.15 \times 10^{-5}$$

Among them, Y is the GDP of which the dependent variable represents the regional economic vitality, and $X_2$is the output value of the enterprise whose independent variable represents the trend of corporate vitality.

As shown in Figure 11, it shows the impact of the number of enterprises on regional economic vitality.

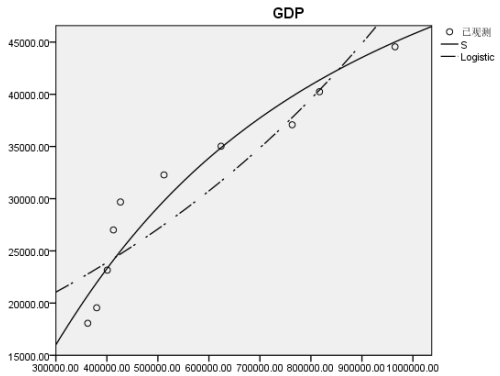


Figure 11 Regression analysis chart of the number of enterprises

The impact of the number of enterprises on regional economic vitality:

$$\mathrm{In(Y)} = -450123.339/\mathrm{X_3} + 11.181$$

Among them, Y is the GDP whose dependent variable represents the regional economic vitality, and X_2 is the number of enterprises whose independent variable represents the trend of corporate vitality.

To sum up, the larger the regional population, the higher the gross national product. In the short term, the gross domestic product will grow exponentially with the population, and then the gross domestic product will change within a certain range. The more the number of enterprises, the higher the output value of the enterprise. The higher the GDP, the higher its overall exponential growth. Based on the analysis of the above results, we have formulated a plan to improve the vitality of the regional economy. In terms of enterprises, we can increase the number of enterprises by introducing policies such as foreign-funded enterprises, lowering the threshold for corporate registration, reducing the registered capital of enterprises, and reducing tax collection of low-turnover enterprises. And output value. In terms of population, it is possible to formulate preferential policies to attract talents, rationally improve the age structure of the population in the current region, and increase the proportion of employed people in order to increase the population in the region[4].

5.2 Question Two

5.2.1 *Models Establishment*

This paper considers using the Gray Prediction model GM (1,1) to analyze the short-term and long-term effects on regional economic vitality after economic policy transition. Gray Prediction is a prediction made for the gray system. The model requires less modeling information, is convenient to operate, and has high modeling accuracy. It has a wide range of applications in various prediction fields and is an effective tool for dealing with small sample prediction problems.

(1) Basic Principles

Gray Prediction identifies the degree of disparity in development trends between system factors, that is, performs correlation analysis, and generates and processes the original data to find the rules of system changes, generates data sequences with strong regularity, and then establishes corresponding differential equations model to predict the future development of things. It constructs a Gray Prediction Model with a series of quantitative values of the characteristics of the prediction object observed at equal time intervals, and predicts the feature quantity at a certain time in the future, or the time to reach a certain feature quantity[5].

(2) Specific Steps of Gray Prediction Model-GM (1,1)

1)Grey system theory is based on the relational space. Concepts such as smooth discrete functions define gray derivatives and gray differential equations, and then use discrete data columns to build dynamic models in the form of differential equations.

2)Set negative raw sequence: $\boldsymbol{x}^{(0)} = \left\{\boldsymbol{x}^{(0)}(\mathbf{1}), \boldsymbol{x}^{(0)}(2), \cdots, \boldsymbol{x}^{(0)}(\boldsymbol{n})\right\}$.

3)Accumulate it once to get the generated sequence:

$$x^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n)\right\}$$

among them, $\boldsymbol{x}^{(1)}(\boldsymbol{k}) = \sum_{i=0}^{k} x(i)$

4)Define the gray derivative of $\boldsymbol{x}^{(1)}$ as $dx^{(1)}(k) = x^{(0)}(k) = x^{(1)}(k) - x^{(1)}(k-1)$ make

$$z^{(1)}(k) = \frac{1}{2}\left(x^{(1)}(k) + x^{(1)}(k-1)\right) \quad k = 2, 3, \ldots, n$$

Then define the gray differential equation model of GM (1,1) as:

$$x^{(0)}(k) + az^{(1)}(k) = u$$

.

Among them, $x^{(0)}(k)$ is called the gray derivative, a is the development coefficient, $z^{(1)}(k)$ is the whitening background value, and u is the amount of gray effect.

5)Move the gray differential equation and expand it:

$$\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} = \begin{bmatrix} -\frac{1}{2}\left(x^{(1)}(1) + x^{(1)}(2)\right) & 1 \\ -\frac{1}{2}\left(x^{(1)}(2) + x^{(1)}(3)\right) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}\left(x^{(1)}(n-1) + x^{(1)}(n)\right) & 1 \end{bmatrix}$$

Let the left side of the equation be equal to Y and the right side be equal to B, $\Phi = \begin{bmatrix} a & u \end{bmatrix}^T$ as the parameter vector to be identified, the gray differential equation can be written as $Y = B\Phi$.

6)The parameter vector $\hat{\boldsymbol{\Phi}} = [\hat{a}, \hat{u}]^T = \left(B^T B\right)^{-1} B^T Y$ can be obtained by the method of least squares, which is brought into the equation, and the discrete solution is: $\hat{x}^{(1)}(k+1) = \left[x^{(1)}(1) - \frac{\hat{u}}{\hat{a}}\right] e^{-\hat{a}k} + \frac{\hat{u}}{\hat{a}}$, restore to the original data is :

$$\hat{\boldsymbol{x}}^{(0)}(\boldsymbol{k}+\mathbf{1}) = \hat{\boldsymbol{x}}^{(1)}(\boldsymbol{k}+\mathbf{1}) - \hat{\boldsymbol{x}}^{(1)}(\boldsymbol{k}) = \left(\mathbf{1} - \boldsymbol{e}^{\hat{a}}\right)\left[\boldsymbol{x}^{(1)}(\mathbf{1}) - \frac{\hat{\boldsymbol{u}}}{\hat{\boldsymbol{a}}}\right] e^{-\hat{a}\boldsymbol{k}}$$

The above formula becomes a time response function model of the GM (1,1) model, and is a specific calculation formula of the GM (1,1) Gray Prediction.

5.2.2 *Models Solution*

According to the establishment of the above model, we use MATLAB software to predict the analysis of factors that reflect economic vitality in turn using the gray forecast method based on data before 2008. Due to too many factors selected, we only show GDP and total fixed asset investment in the entire society The forecast and analysis results of four factors, total retail sales of social consumer goods and household consumption level, and relevant conclusions are given. As shown in Figure 12-15, the forecast results of the above four factors are shown, and the impact of economic policy changes on each factor after 2008 in practice.

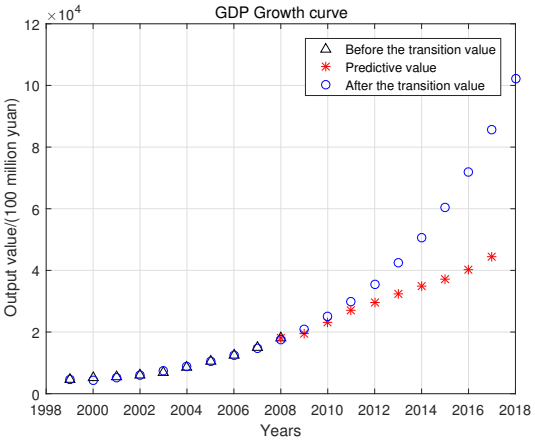


Figure 12 GDP Forecast Results

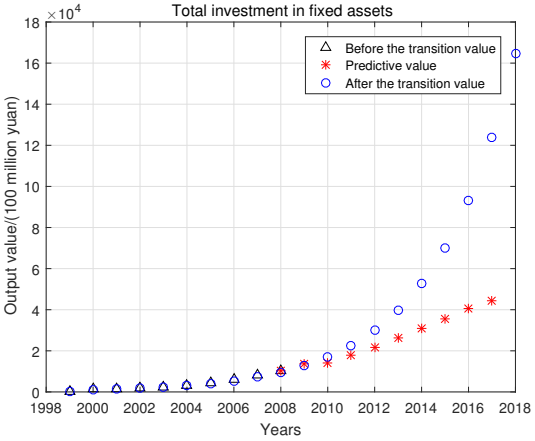


Figure 13 Forecast Results of Total Fixed Asset Investment

Analyzing the above forecast results, we find that after the implementation of economic policy changes (after 2008), the two factors of GDP and total fixed asset investment in the region have not changed much in the short term, and the values after the implementation of the policy are not significantly different. The long-term time change, the value difference after the implementation of the policy gradually increases, and the value after the economic policy change is generally larger than the predicted

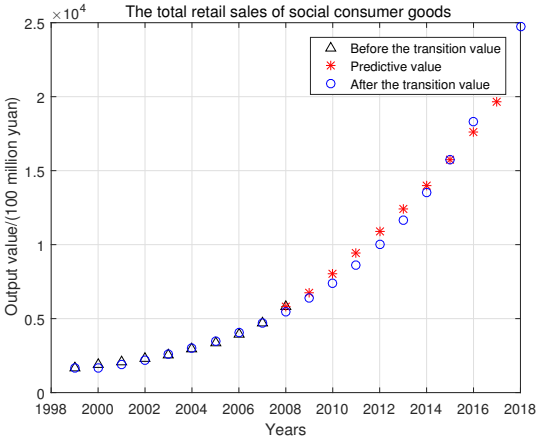


Figure 14 Forecast Results of Total Retail Sales of Consumer Goods

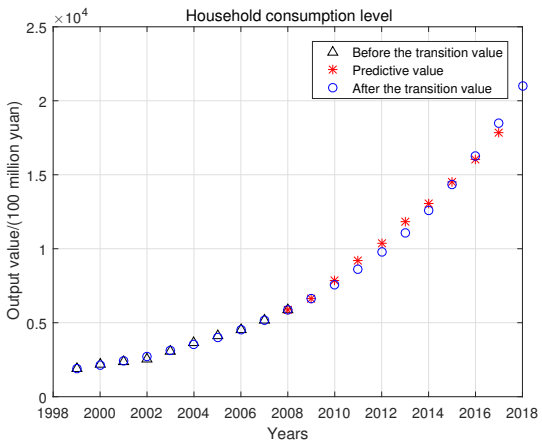


Figure 15 Forecast Results of Household Consumption Level

value; obviously, the two factors of the economic policy change on the total retail sales of consumer goods and the level of household consumption in the short and long term The impact is consistent, and there are no significant differences before and after economic policy changes[6].

Therefore, it can be concluded that, in the short term, the change in regional economic policies will have a minor effect on regional GDP, total output value of enterprises, and total investment in fixed assets. The factors have no obvious influence; in the long run, the change of regional economic policy has a very obvious driving effect on the main factors for measuring economic vitality, which can fully improve the local economic vitality.

5.2.3 *Models Test*

(1) We use the posterior error test method to check the accuracy of the model.

Let the $\hat{\boldsymbol{X}}^{(0)}$ and residuals that have been obtained according to the GM (1,1) modeling method, and the variances of the original sequence $\boldsymbol{X}^{(0)}$ and the residual sequence E are S_1^2 and S_2^2 respectively, then:

$$S_1^2 = \frac{1}{n}\sum_{k=1}^{n}\left[x^{(0)}(k) - \bar{x}\right]^2$$
$$S_2^2 = \frac{1}{n}\sum_{k=1}^{n}[e(k) - \bar{e}]^2$$

Among them, $\bar{x} = \frac{1}{n}\sum_{k=1}^{n} x^{(0)}(k), \bar{e} = \frac{1}{n}\sum_{k=1}^{n} e(k)$.

Table 4 Reference Table for Accuracy Inspection Level

Model accuracy level	Mean square error ratio C	Small error probability p
Level 1 (good)	$C <= 0.35$	$0.95 <= p$
Level 2 (qualified)	$0.35 < C <= 0.5$	$0.80 <= p < 0.95$
Level 3 (reluctantly)	$0.5 < C <= 0.65$	$0.70 <= p < 0.80$
Level 4 (Disqualified)	$0.65 < C$	$p < 0.70$

Calculate the posterior error ratio $C = S_2/S_1$, and calculate the small error probability $p = P\{|e(k) - \bar{e}| < 0.6745S_1\}$. The smaller the index C is, the better the p is. Generally, the accuracy level of the model is divided into four levels, as shown in Table 4.

(2) The test results obtained by running with MATLAB are shown in Table 5.

Table 5 Reference Table for Accuracy Inspection Level

Inspection standards	GDP	Total investment in fixed assets	The total retail sales of social consumer goods	Household consumption level
Variance ratio C	0.074	0.1044	0.1134	0.0614
Small error probability P	1	1	1	1

The model built from the data in the above table against the accuracy test level reference table conforms to the model accuracy level 1 level, which proves that the gray prediction model we built is very reasonable.

5.3 Question Three

5.3.1 *Models Establishment*

(1) Basic principles of Cluster Analysis

The principle of Cluster Analysis is to solve the ranking problem in multi-index system evaluation. In order to avoid the variance contribution rate of the first principal component is not high enough, only the first principal component score brings the one-sidedness of the sample ranking evaluation. Cluster Analysis is a combination of these two methods, using the "Principal Component Cluster Analysis" method. Cluster Analysis is a multivariate statistical analysis method that can reasonably classify samples or indicators according to their characteristics. Although Cluster Analysis can classify multi-indicator data, it cannot obtain the evaluation results of various pros and cons.

(2) Specific steps of Cluster Analysis

- Data pre-processing.
  Select the number, type, and scale of features (based on feature selection and extraction). Feature selection selects important features. Feature extraction converts the input feature into a new salient feature. Avoid "dimensional disaster" clustering and move outliers out of the data (outliers are data that do not depend on general data behaviors or models).
- Define a distance function to measure the similarity between data points.
  Since similarity is the basis for defining a class, the measurement of the similarity between different data in the same feature space is important for the clustering step.

Due to the diversity of feature types and feature scales, distance measures must be cautious. It often depends on the application. For example, the dissimilarity of different objects is usually evaluated by defining a distance metric in the feature space. Many distances are applied in some different fields. A simple distance metric, such as Euclidean distance, is often used as a reflection The dissimilarity between different data, some similarity measures, such as PMC and SMC, can be used to characterize the conceptual similarity of different data. In image clustering, the error correction of the subgraph image can be used to measure the two Similarity of two figures.

- Clustering or grouping.
  The data objects are classified into different classes. The division method and the hierarchical method are the two main methods of Cluster Analysis. In addition, there are density-based clustering, model-based clustering, and grid-based clustering.

(3) Comprehensive index evaluation model based on Factor Cluster Analysis

- Principles for the establishment of a comprehensive indicator system. Comprehensively reflect the vitality of the city's economy; select composite dimensional indicators as much as possible; selection of evaluation indicators should be as simple and independent as possible; selected indicators can reflect annual changes to a certain extent[7].
- Select indicators according to the principle of the indicator system, and use Factor Analysis to calculate the components of each indicator when it affects the dependent variable.
- Based on the selected main indicators, Cluster Analysis is used to classify the cities, and then, for similar cities at the same economic level, the urban economic vitality index is calculated to rank the cities.

5.3.2 *Models Solution*

In order to comprehensively analyze and measure the vitality of the regional economy, this article selects some representative economic influencing factors, including the total economic volume, economic growth, the number of enterprises, the average annual income of the enterprise, the registered capital of the enterprise, the income and expenditure of residents, and the fiscal And social security, foreign investment, education level, geographical factors,etc. According to the conclusion of Question 1, it can be known that the trend of population change and the trend of corporate vitality have a strong positive correlation with regional economic vitality. Therefore, the correlation analysis and component extraction of each index can be performed here to reduce the complexity of the evaluation index[8-9].

According to the Factors Correlation Analysis in Table 6, it can be known that the

Table 6 Factors Comorrelation Matrix

Relevance	Economic Increment	Enterprises Number	Residents Income	Foreign Capital	Educational Level	Population
Economic Increment	1	0.995	0.696	0.469	0.597	0.91
Enterprises Number	0.995	1	0.245	0.459	0.402	0.895
Residents Income	0.696	0.245	1	0.121	0.674	0.423
Foreign Capital	0.469	0.459	0.121	1	0.2	0.413
Educational Level	0.597	0.402	0.674	0.2	1	0.746
Population	0.91	0.895	0.423	0.413	0.746	1

above-mentioned indicators are close to 1 with the number of enterprises, the annual average income of the enterprise, and the registered capital of the enterprise, so they can be replaced by linear expressions or direct variables.

According to the attached information, the number of enterprises is an important indicator of regional economic vitality. The number of enterprises can directly affect the existing employment opportunities. It greatly promotes the circulation of resources and determines the economic benefits of enterprises. In order to reduce the complexity of the model solution, different cities can be classified according to the number of new and cancelled enterprises in the past ten years, so as to establish a comprehensive evaluation model of Factor Cluster Analysis[10].

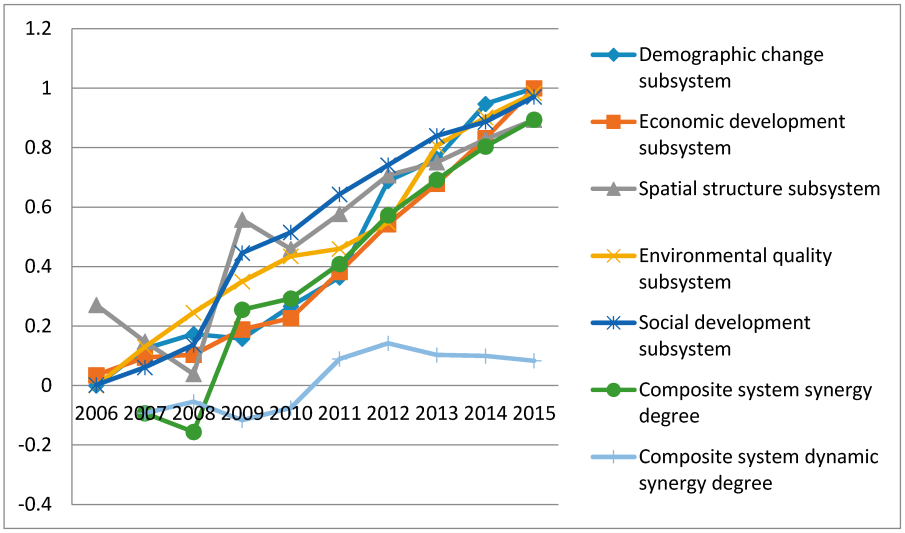


Figure 16 Systematic analysis of various economic indicators in recent years

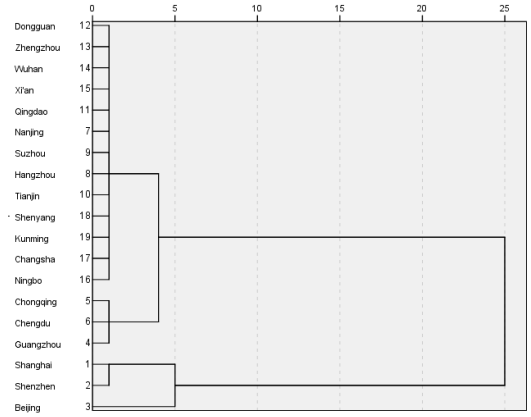


Figure 17 Clustering Treemap for Each City

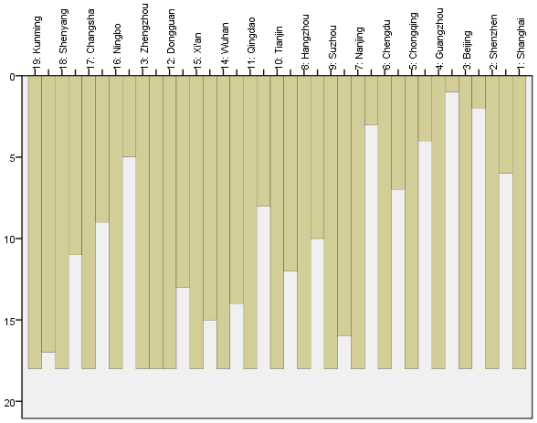


Figure 18 Clustered Icicles for Each City

As can be seen from Figure 17-18, if the cities in the annex are divided into two categories, Beijing, Shenzhen, and Shanghai are classified into one category, and the remaining cities are classified into one category, which roughly conforms to the classification of first-tier cities and second-tier cities. If divided into four categories, Beijing is classified as one category, Shanghai and Shenzhen are classified as one category, Chongqing, Chengdu and Guangzhou are classified as one category, and the remaining other cities are classified as one category. Further solution analysis is underway.

First, an index set matrix of each independent variable is established according to the comprehensive index system, and the matrix data is standardized. Then, the evaluation indexes of each index and index set are calculated separately, and finally, the urban economic vitality evaluation index is calculated.

Table 7 Eigenvalue and Main Factor Contribution Rate

Principal factor	Characteristic value	Contribution rate	Cumulative contribution rate
1	6.456	27.47608185	27.47608185
2	6.357	27.05474788	54.53082973
3	5.877	25.01191652	79.54274625
4	2.215	9.426815566	88.96956181
5	1.318	5.609274454	94.57883627
6	0.607	2.583330496	97.16216676
7	0.309	1.315072691	98.47723945
8	0.170	0.723502775	99.20074223
9	0.125	0.531987334	99.73272956
10	0.049	0.208539035	99.9412686
11	0.0138	0.058731402	100

Table 7 shows the eigenvalues of each component, the variance contribution rate and the cumulative variance contribution rate of each principal factor. The inverse compact transformation is solved to obtain the corresponding feature vector. It is further

possible to determine the principal component and calculate the factor load in the case of the relative importance of the principal factor.

Calculation formula as follows:

$$L_{ij} = \sqrt{\lambda_i} l_{ij}$$

$$H_{ij} = L_{ij} P_j$$

Among them, λ is the eigenvalue, I is the eigenvector, P is the main factor, and L is the factor load.

Finally, the city's economic vitality index table obtained based on the model. The city's economic vitality ranking in Annex 3 is : Shenzhen, Shanghai, Guangzhou, Dongguan, Suzhou, Beijing, Ningbo, Hangzhou, Tianjin, Qingdao, Nanjing, Shenyang, Kunming, Wuhan , Changsha, Chengdu, Zhengzhou, Xi'an, Chongqing.

5.3.3 *Extension of Model*

Existing studies have shown that the brightness value of night lights can represent socio-economic conditions, so the DN value of night light data can be used to analyze and measure regional economic vitality. Vibrant cities are constantly developing and changing. The night light data is not only used to measure the speed of regional economic development, as an important indicator for evaluating economic development, but also an important indicator of urban vitality. In addition, night light data can monitor the urbanization process, can be used in the study of the evolution of urban agglomerations, and can be used as an important indicator of regional economic vitality.

This chapter is mainly based on the DMSP / OLS stable night light data, the light DN value is reclassified as vitality, and the national-scale urban vitality status analysis and spatial-temporal change analysis are performed using spatial analysis, quantitative analysis and other methods.

As shown in Figure 19, on the national scale, we evaluated the economic development level and economic development speed of each region based on the lighting data of the cities in Annex 3 over the years and combined with various economic data in the statistical yearbook. Among them, the evaluation of the development level mainly uses a qualitative analysis method, and the observation and comparison of lighting images of cities in the past years draw conclusions; the evaluation of the development speed mainly uses a quantitative analysis method, and the growth rate of the total DN value is used to indicate the speed of urban development. The growth rate of total DN over the years and comparative analysis.

We measure the regional economic vitality based on the night light data, and use spatial analysis and quantitative analysis to evaluate the economic vitality of the cities in Annex 3. The economic vitality ranking of each city is shown in Table 8.

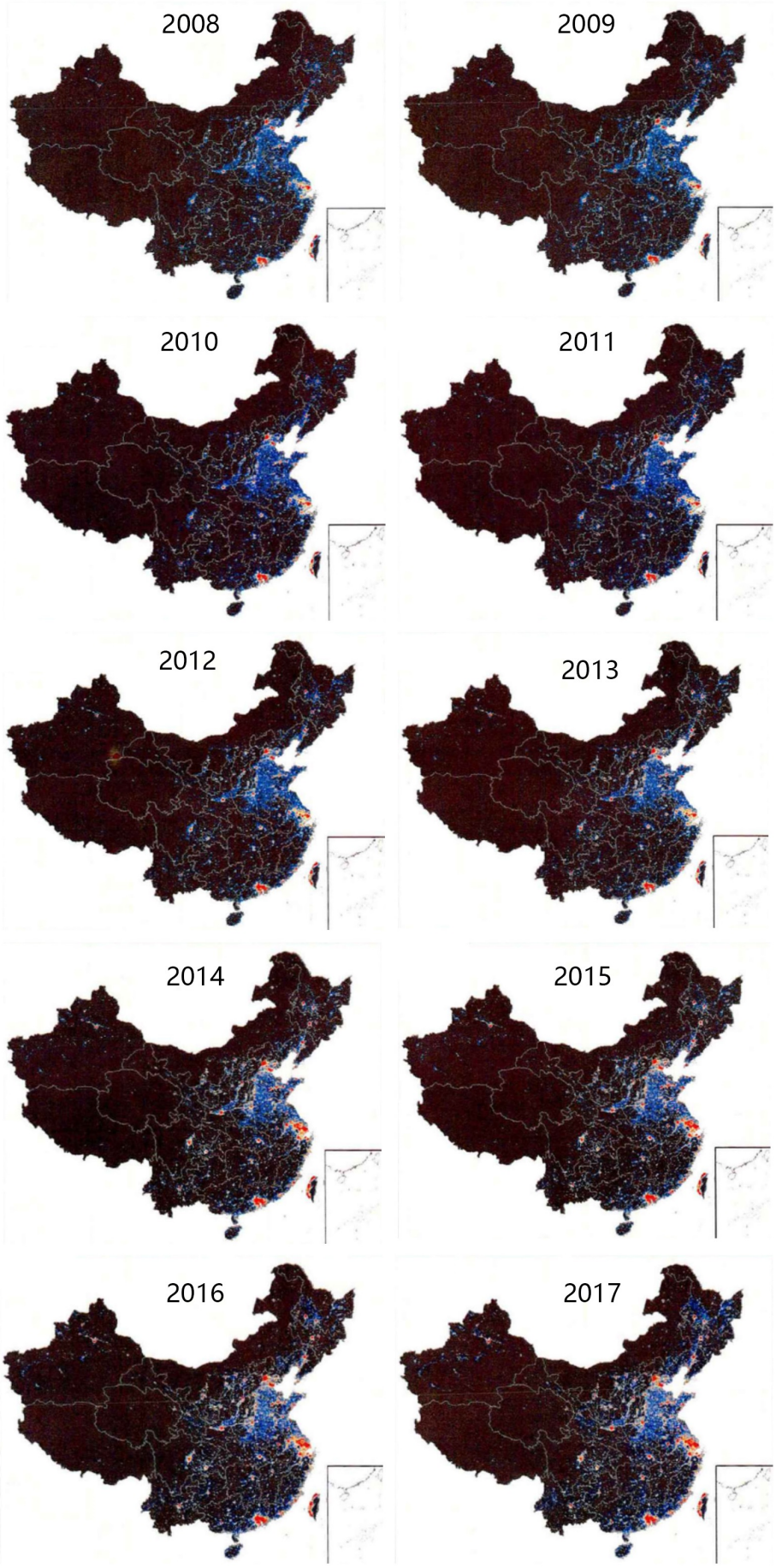


Figure 19 Night light data in various regions of the country

Table 8 Eigenvalue and Main Factor Contribution Rate

Ranking	City	City Revenue Score	Overall ratings	Vitality index difference
1	Shenzhen	239.2412	254.3275	60.5072
2	Shanghai	206.3317	193.8741	60.4534
3	Guangzhou	135.3358	133.5072	60.3669
4	Dongguan	126.4613	132.8615	0.6457
5	Suzhou	96.50997	101.4244	3.8928
6	Beijing	96.50997	93.42414	0.53117
7	Ningbo	89.85411	88.59692	3.77157
8	Hangzhou	84.30756	84.76472	3.8322
9	Tianjin	81.3494	78.72073	3.54968
10	Qingdao	74.69354	76.40789	0.40336
11	Nanjing	68.03768	66.89478	2.29918
12	Shenyang	49.17941	51.35092	1.67407
13	Kunming	44.74217	44.74217	1.86223
14	Wuhan	38.82585	38.48298	0.01338
15	Changsha	35.49792	36.41224	0.60504
16	Chengdu	35.49792	34.92647	148577
17	Zhengzhou	27.36298	30.33452	2.01025
18	Xi'an	20.70712	19.67851	3.57658
19	Chongqing	14.42103	14.19245	3.51609

5.4 Question Four

High-quality development is based on the scientific judgment of the party 's central committee on the new direction of China 's economic history based on Comrade Xi Jinping 's core. It is also a basic feature of China 's economic development in the new era. Based on the conclusions of Questions 1-3 and the strategic deployment of "two high-quality developments", we put forward countermeasures and suggestions for promoting the high-quality economic development of Henan Province in combination with the actual situation in Henan, focusing on solving the problem of imbalanced and insufficient development and accelerating the quality The pace of change, efficiency change, and power change in order to enhance the regional competitiveness of Henan Province and maintain sustainable economic development in Henan.

5.4.1 *Accelerating Industrial transformation and upgrading*

The first is to accelerate the adjustment of production capacity structure. orderly promote the withdrawal of excess production capacity in thermal power, cement and other industries, and accelerate the development of strategic emerging industries such as new-generation information technology, high-end equipment and new energy.

The second is to accelerate the adjustment of the industrial structure. promote the optimization and upgrading of leading industries such as equipment manufacturing and food manufacturing, optimize the industrial structure, and continuously enhance the adaptability of the supply structure and market demand.

The third is to accelerate the adjustment of product structure. in-depth implementation of the strategy of strengthening the province of quality, vigorously promote innovative manufacturing, boutique manufacturing, brand manufacturing, and continuously increase the flexibility of supplying products and market demand.

Figure 20 Economic vitality of Henan Province

5.4.2 *Promoting Talent-saving strategy*

The first is to strengthen the training of talents. Issue policies and focus resources to support the "double first-class" construction of Zhengzhou University and Henan University, promote the construction of characteristic backbone universities and universities of applied technology, and strengthen the cultivation of high-skilled talents.

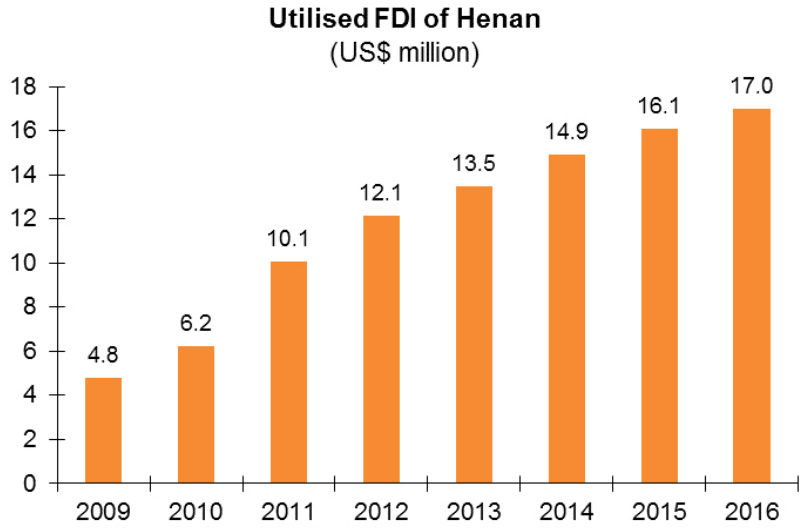
The second is to actively introduce the "four batches". Fully implement the "four batches" project of cultivating and introducing innovation-leading enterprises, platforms, institutions, and talents, and accelerate the full coverage of provincial R & D institutions of large and medium-sized industrial enterprises.

The third is to deepen the reform of the innovation system and mechanism. Focusing on the relevant policies and measures of national scientific research project management and talent evaluation, we took the lead in implementing the incentive mechanism oriented to increasing the value of knowledge.

5.4.3 *Deepening Reform and opening up*

The first is to promote deeper reforms. Reduce the market entry threshold, fully implement the negative list system for market access; establish and improve the social credit system, and build a new supervision mechanism with credit as the core of ”pre-credit commitments, classified supervision during events, and joint rewards and punishments afterwards”; deepen the factor price market Reforms in power, medical care, transportation, natural gas, agricultural water, etc; use capital as a link to promote

reform of mixed ownership by state-owned enterprises; and continue to deepen reforms in key areas such as technology, education, and culture.



Source: Henan Statistical Yearbook, 2017

Figure 21 Foreign Investment in Henan Province after the Policy Transition

The second is to implement a higher level of openness. Coordinate the overall development of open platforms such as the Henan Pilot Free Trade Zone, Zhengzhou Airport Port Area, and port function platforms, build sea, land, and air networks to a high standard, and open up the four ”Silk Roads” in three dimensions, and implement the five major areas of government, supervision, finance, law, and multimodal transport Special service plan, focusing on creating special zones for internationalization of investment and trade, rule of law, and facilitation, and applying for free trade ports in due course.

5.4.4 *Promoting new urbanization*

The first is to accelerate the integration process of the Central Plains urban agglomeration. Highlight the five key projects of Zhengzhou National Central Urban Transportation and Logistics Hub Construction, Industrial Transformation and Upgrade, Open Innovation, Ecological Construction, Cultural Construction, and accelerate the construction of important regional central cities.

The second is to implement intensively the construction and upgrading projects of Baicheng. Adhere to the "hardware" and "software", and take the old urban areas and county-level cities of provincial cities as the main body, do a good job of urban planning, improve urban functions, strengthen urban management, promote the construction of eight municipal infrastructure projects, and promote the sponge city as a whole. , Smart cities, humanistic cities, ecological garden cities, and forest cities.

The third is to accelerate the civicization of the agricultural migration population. In accordance with "One Basic, Two Implications and Three Guarantees", we will actively develop social undertakings such as medical care, education, and old-age care, accelerate

the civicization of the agricultural transfer population, and achieve full coverage of the permanent population of basic public services in cities and towns.

5.4.5 *Adhere to ecological civilization*

The first is to increase the protection and restoration of ecosystems. Implement a new round of ecological province construction, speed up the construction of five major ecosystems of forests, wetlands, watersheds, farmland, and cities, and make overall plans to promote the restoration and restoration of mining environment, land consolidation and pollution restoration, and water environment protection of river basins.

The second is to improve the economic system of green and low-carbon development. Expand the scale of the energy-saving and environmental protection, clean production and clean energy industries, start the implementation of the three-year action plan for the construction of the vein industrial park, and build a market-oriented green low-carbon circular development economic system.

The third is to improve the ecological civilization system. Improve the assessment mechanism for the construction of ecological civilization, establish a market-oriented and diversified ecological compensation mechanism, complete the negative list system for industrial access to key national ecological function zones, improve the environmental governance and ecological restoration system, and establish a market-oriented and diversified ecological compensation mechanism.

5.4.6 *Improving supporting policy system*

The first is to build a scientific and reasonable indicator system. Improving the total factor productivity, scientific and technological innovation capabilities, human resources quality, financial system efficiency, and market resource mechanism assessment framework in a timely manner, and adding corresponding specific indicators representing dynamic change, quality change, efficiency change, and people's livelihood development, and building a high Quality development index system, statistical system, policy system, standard system, performance evaluation, and performance evaluation[11].

The second is to strengthen competition and cooperation between regions. Relying on the enclave economic model, the sharing ratio of economic and social development results is cleverly set to achieve regional traffic connectivity, free flow of production factors in the region, and cooperation in ecological and environmental protection.

The third is to create a good environment for the development of the real economy. Explore the implementation of the öne seal management approvalsystem, continuously improve the market competition rules, implement the state's preferential tax policies such as reducing the manufacturing value-added tax burden, and implement corporate growth promotion actions and financial return to root causes.

VI. Model Adaptability Test

Improved neural network model for sensitivity analysis

6.1 Analysis of residual normality test

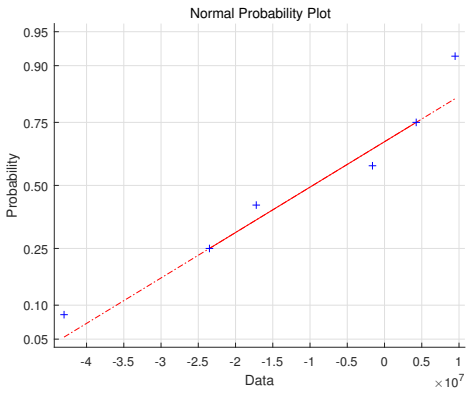


Figure 22 Population Normal Probability

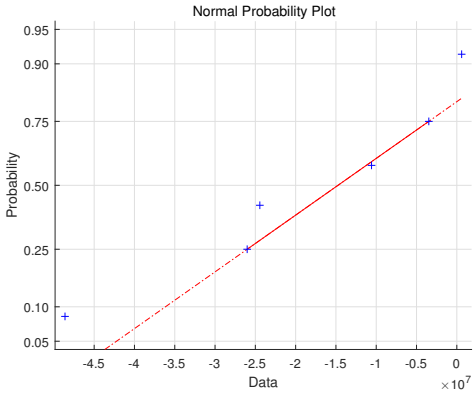


Figure 23 Enterprise vitality Normal Probability

As shown in Figure 22-23, analysis of the residual normality test chart of the population change trend and corporate vitality change trend shows that the residual error roughly conforms to the normal distribution, and the data structure and model assumptions are reasonable, so an improved neural network model is established. An analysis of the impact of changes in regional economic activity will result in smaller errors and more accurate results.

6.2 Analysis of error results

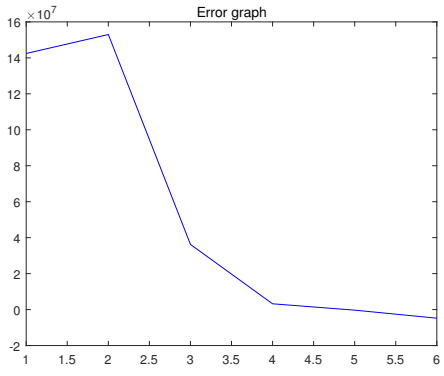


Figure 24 The Error Graph of Population

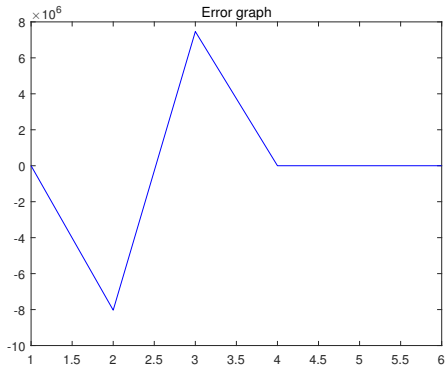


Figure 25 Enterprise vitality Error Graph

As shown in Figure 24-25, analysis of the error graph shows that the improved neural network model can effectively adjust the number of hidden nodes and learning rate of the neural network, accelerate convergence, eliminate oscillations, and make the error smaller.

6.3 Autocorrelation of Error test

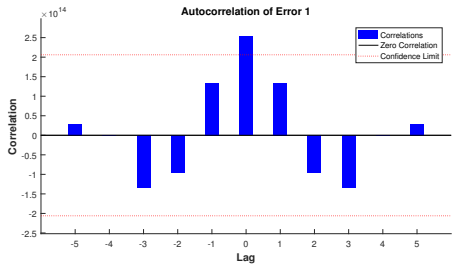


Figure 26 Population Autocorrelation

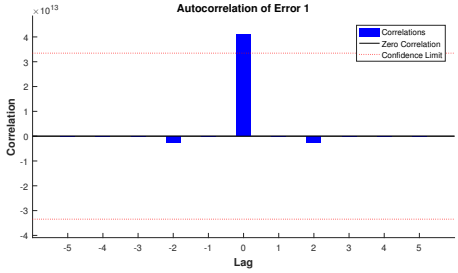


Figure 27 Enterprise vitality Autocorrelation

As shown in Figure 26-27, we can see that the demographic and corporate vitality factors have a high degree of autocorrelation with regional economic vitality, indicating that these indicators selected from them can well characterize regional economic vitality.

VII. The Evaluation of Model

7.1 Strength

Strength1: Using MATLAB for solving and curve fitting of the relationship between variables, the model idea is clear.

Strength2: The improved neural network algorithm is used to simplify the evaluation index and the calculation result is accurate.

Strength3: Considering the long-term impact of policy on the economy based on the difference between predicted and actual values, the conclusion is more convincing.

Strength4: Using factor clustering analysis, the classification is first solved, the model is clear, the accuracy of the solution is improved, and the calculation error is reduced.

Strength5: Regarding the suggestions for regional economic development, combining the conclusions and actual data of problem one two three, the specific situation is analyzed specifically, and clear solutions are given in different situations.

7.2 Weakness

Weakness1: The simplification of the model may cause additional error effects, making the economic policy adjustment biased.

Weakness2: Only the influence of various factors on the economy is considered, the reaction of the economy to it is not considered, and there is no closed-loop feedback, which is not good for the long-term forecast of the economy.

VIII. References

[1] Haimiao Lou, Qiubi Sun. Research on the evaluation of economic vitality of provinces in China based on factor analysis [J]. Journal of Fuzhou University, 2015,3:32-35.

[2] Haiming Lin, Wenlin Zhang. Similarities and differences between principal component analysis and factor analysis and SPSS software – Discussion with Yumei Liu, Wendai Lu and other comrades [J]. Statistical research, 2005,3:65-69.

[3] National Bureau of statistics. Henan statistical yearbook-2018 [Z]. Beijing: Statistics Press. 2018.Study.

[4] Zhongya Wang. Empirical Study on the comprehensive evaluation of urban development level in Central Plains Economic Zone [J]. Journal of Henan University of Technology: Social Science Edition, 2012,2:34-39.

[5] Shengpeng Wang, Peng Zeng, Yonglong Sun. Study on the grey comprehensive evaluation and unbalanced difference of the comprehensive development level of ten major urban agglomerations in China [J]. Journal of Northwest University for Nationalities: Philosophy and Social Sciences, 2008,2:41-48.

[6] Xiaoxi Li, Ming Yu. Transmission mechanism of monetary policy and national economic vitality [J]. Financial research, 2000,7:1-9.

[7] Tao Chen, Zhiqiang Zhao, Shuyan Li. Empirical Study on the economic vitality of Anshan City [J]. Liaoning Economic Statistics, 2014,6:12-14.

[8] Hongdong Zhang, Zhenyan Qin. Analysis of the composition of urban economic vitality [J]. Heilongjiang Science and technology information, 2011, 21:155-155.

[9] Yuanmin Zhou, Jianmei Luo, Zhihua Jiang. Research on economic and social development in Western China: a comprehensive evaluation of 12 western provinces based on factor and cluster analysis [J]. Journal of Chengdu Institute of information engineering, 2007, z1:182-184.

[10] Xiaoli Lu, Wanshan Guo. Comprehensive evaluation index system of urban economic vitality [J]. Statistics and decision making, 2007,11:77-78.

[11] National Bureau of statistics. 2018 China Urban Statistical Yearbook [Z]. Beijing: Statistics Press. 2018.Study

IX. Appendix

Listing 1: The matlab Source code of Improved Neural Network Algorithm

```
clc;clear all;close all
load p.txt; save p.mat; p=p';
t=[18068.47 19547.60 23157.64 27007.46 29681.79 32278.04 35026.99
    37084.20 40249.23 44552.83];
[p1,ps]=mapminmax(p);[t1,ts]=mapminmax(t);
[trainsample.p,valsample.p,testsample.p] =dividerand(p,0.6,0.2,0.2);
[trainsample.t,valsample.t,testsample.t] =dividerand(t,0.6,0.2,0.2);
TF1='tansig';TF2='purelin';
net=newff(p,t,5,{TF1 TF2},'traingdm');
net.trainParam.epochs=10000;
net.trainParam.goal=1e-7;
net.trainParam.lr=0.01;
net.trainParam.mc=0.9;
net.trainParam.show=25;
net.trainFcn='trainlm';
[net,tr]=train(net,trainsample.p,trainsample.t);
[normtrainoutput,trainPerf]=sim(net,trainsample.p,[],[],trainsample.t);
[normvalidateoutput,validatePerf]=sim(net,valsample.p,[],[],valsample.t);
[normtestoutput,testPerf]=sim(net,testsample.p,[],[],testsample.t);
trainoutput=mapminmax('reverse',normtrainoutput,ts);
validateoutput=mapminmax('reverse',normvalidateoutput,ts);
testoutput=mapminmax('reverse',normtestoutput,ts);
trainvalue=mapminmax('reverse',trainsample.t,ts);
validatevalue=mapminmax('reverse',valsample.t,ts);
testvalue=mapminmax('reverse',testsample.t,ts);
errors=trainvalue-trainoutput;
figure,plotregression(trainvalue,trainoutput)
figure,plot(1:length(errors),errors,'-b');title('Error graph')
figure,hist(errors);figure,normplot(errors);
[muhat,sigmahat,muci,sigmaci]=normfit(errors);
[h1,sig,ci]= ttest(errors,muhat);
figure, ploterrcorr(errors);figure, parcorr(errors);
```

Listing 2: The matlab Source code of Grey Prediction Algorithm

```
 clc;clear all;close all;
syms a b; c = [a b]';
A =[15064.73 18068.47 19547.60 23157.64 27007.46 29681.79 32278.04
    35026.99 37084.20 40249.23];
n = length(A); B = cumsum(A);
for i = 2:n
    C(i) = (B(i) + B(i - 1))/2;
end
C(1) = []; B = [-C;ones(1,n-1)]; Y = A; Y(1) = []; Y = Y';
c = inv(B*B')*B*Y; c = c'; a = c(1); b = c(2);
F = []; F(1) = A(1);
for i = 2:(n+10)
    F(i) = (A(1)-b/a)/exp(a*(i-1))+ b/a;
end
G = []; G(1) = A(1);
for i = 2:(n+10)
    G(i) = F(i) - F(i-1);
end
disp('The forecast data is:'); G
H = G(1:10);epsilon = A - H;
delta = abs(epsilon./A); disp('Relative residual Q test:')
Q = mean(delta); disp('Variance ratio C test:')
C = std(epsilon, 1)/std(A, 1);S1 = std(A, 1);
tmp = find(abs(epsilon - mean(epsilon))< 0.6745 * S1);
disp('Small error probability P test:')
P = length(tmp)/n
t1 = 2007:2016;t2 = 2007:2026;
plot(t1, A,'ro'); hold on;plot(t2, G, 'g-');
xlabel('Years'); ylabel('Output value/(100 million yuan)');
legend('Actual value','Predictive value');
title('GDP Growth curve');
grid on;
```