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Problem Chosen :	B

2019APMCM summary sheet

Analysis of the Impact of Regional Economic Vitality Factors

Summary

Regional economic vitality is an important part of judging the comprehensive competitiveness of a region, and the size of economic vitality will be affected by both endogenous and exogenous variables. Moreover, due to the differences in resource endowment and human environment, policies are implemented in various regions. The effect is also different. In order to enhance regional economic vitality, we need to analyze the factors that influence economic vitality.

For the first question, this question needs to analyze and evaluate the influence of the factors on the economic vitality of a certain area from the factors of population and corporate vitality. Because Beijing is very representative and special in China, we chose Beijing as our research object. From the perspective of population, we start with three indicators: population number, natural population growth rate, and birth rate. From the perspective of corporate vitality, we start with three indicators: number of enterprises, growth of enterprises, and number of business cancellations. The data of various indicators in Beijing from 2009 to 2019 were collected, and a comprehensive evaluation model of principal components was constructed to obtain a model of the relationship between economic vitality and six indicators. It was finally concluded that the first effective method to increase economic vitality is to appropriately increase the number of urban population and the number of new enterprises each year, and the second effective method is to appropriately increase the birth rate of the population and the number of surviving enterprises.

For question two, we select Beijing as the research object, and consult the literature to select 2008 as the node of economic policy transition. The introduction of economic policies has different impacts on various industries in Beijing, thus affecting economic vitality. Therefore, we have found 18 exogenous economic indicators that affect economic vitality, including economic benefits, opening up, residents' quality of life, innovation ability, and education. Study the indicator system in 5 aspects, select 8 valid indicators through Spearman test, and use all data from 1990 to 2018 of these 8 indicators to predict the 8 indicators and economic vitality in the next 10 years with the vector autoregressive model. In the short term (within 3 years), the true value of the economic vitality score is always greater than the predicted value, and the difference is increasing year by year, indicating that the effect of policy implementation in 2008 is more obvious; in the long term (3-10 During the year), although the real value of the economic vitality score is always greater than the predicted value, the gap between the two tends to decrease first and then increase, especially in 2015, the distance between the real value and the predicted value is the smallest, which indicates that the effect of the policy over time Development is continuously decreasing, but there will

be a cycle of economic and policy cycles, so that the economic vitality always improves Good direction.

Regarding question three, in order to study and measure the impact of different areas on economic vitality, a model for evaluating economic vitality was established based on factor analysis. We collected 18 indicators from five aspects: economic efficiency, opening up, residents' quality of life, innovation ability, and education. KMO and Bartlett spherical tests were performed before factor analysis, and finally the per capita GDP, real GDP, the gross industrial product of industrial enterprises above designated size, the proportion of tertiary industry, the growth rate of social retail consumption, and the number of patents applied 6 For an effective indicator, the endogenous variable economic vitality score is used as the dependent variable, and the factor analysis is performed using the model of the first question. After reducing the dimension, it is transformed into industry and scientific research factor, consumption level factor, economic benefit factor, and service industry factor. See Table 15 for the scores obtained by the contribution of the variance of each factor. The dimensionality reduction effect of the model is obvious, and the evaluation results are more accurate.

Regarding the fourth question, through the first three questions to study the influence mechanism of endogenous and exogenous variables on Beijing's economic vitality, we analyze the development of Beijing's economic vitality both endogenously and exogenously, and Beijing can endogenously Properly increase the four indicators of the city's urban population, the number of new enterprises each year, the birth rate and the number of enterprises to enhance Beijing's economic vitality; exogenous aspects can be adjusted by optimizing the industrial structure, increasing the average social wage level, Investment in technology and education.

In the end, we evaluated the advantages and disadvantages of the established model, and discussed the generalization prospects of the model. At the same time, the model in this paper has great applicability in many fields.

Key words: Economic vitality; principal component evaluation model; Spearman test; vector autoregressive model; factor analysis

Contents

1 Problem Description

1.1 Background

China has entered a new period of socialism with Chinese characteristics. Under this new normal, China's economic growth has changed from high-speed growth to high-quality growth. Under the new normal of high-quality growth, we must not only keep the economic growth rate within a certain feasible range, but also constantly find the source of the fundamental driving force for economic growth under the new normal, so that the implementation of local policies can achieve the endogenous growth of economic growth Sufficient, exogenous economic growth factors facilitate the strategic development effect.

The Nineteenth National Congress pointed out that the main contradictions in our society have been transformed into: the contradiction between the people ’s increasing needs for a better life and imbalanced and inadequate development. The difference in external capabilities has led to differences in the direction, intensity, and effectiveness of policies implemented in various regions. Sustainable development ability and competitiveness are the key factors for judging the comprehensive strength of a region, and economic vitality is the key factor for the region to achieve sustainable development and maintain good competitiveness. Therefore, studying the influence factors of economic vitality is of great significance to regional development. .

In order to make the effect of research policy implementation more obvious, we must study not only the mechanism of endogenous factors affecting economic vitality, but also the impact of exogenous variables on economic vitality.

1.2 Restatement of the Problem

Increasing the regional economic vitality has a great impact on the improvement of regional comprehensive competitiveness. Therefore, various regions will introduce corresponding policies to stimulate economic vitality to enhance the economic vitality of the entire region or city, including financing support for SMEs and foreign talents. Giving preferential policies, improving the quality of the population while increasing the number of people imported, and increasing the degree of openness to the outside world will all enhance regional economic vitality and make the region more competitive and sustainable.

With the above prerequisites and background, we need to build a mathematical model and study the following issues:

Question 1: Select a region (city or province) as an example, analyze the various factors that affect regional economic vitality from the perspective of population and corporate vitality trends, and establish appropriate factors that affect economic vitality through the mechanism of factor influence After establishing the model, analyze the influence mechanism of the factors, and propose action plans to improve the regional economic vitality.

Question 2: Select a region (city or province) as an example to analyze the short-term and long-term effects of economic policy transition at a specific point in time on the future economic vitality of the region.

Question 3: By selecting a complex and appropriate indicator system, establish a general model of regional (city or province) economic vitality, including internal and external influences, and rank the economic vitality of cities in Annex 3.

Question 4: Based on the conclusions from questions 1-3, suppose the author is a decision maker

for regional economic development, and provide development suggestions for the region discussed in question 2, so that the region's economic vitality, sustainable development capacity, and regional competitiveness are enhanced.

2 Assumptions and Justifications

(1) Hypothesis 1 assumes that there are no major disasters and disease events before and after the urban policy transformation;
(2) Hypothesis 2 assumes that the influences of hot money outflow and outbound investment on the macro economy are not considered.
(3) Hypothesis 3 assumes that the economic impact of policy is much greater than the economic impact of other events on the region.

3 Notation

Symbols	Instructions
x_1	Population
x_2	Natural rate of population growth
x_3	The birth rate
x_4	Number of companies
x_5	Business growth
x_6	Number of business cancellations
A_1	GDP per capita
A_2	GDP growth rate per capita
A_3	Real GDP
A_4	GDP of Industrial Enterprises above Designated Size
A_5	Proportion of tertiary industry
A_6	Fiscal revenue as a percentage of GDP
A_7	Growth rate of fixed asset investment per capita
B_1	Cumulative number of tourists received throughout the year
B_2	Foreign trade import and export total index growth rate
C_1	Average monetary wage
C_2	Urban residents disposable income growth rate
C_3	Social retail consumption growth rate
C_4	unemployment rate
C_5	Urban green coverage
D_1	Number of patent applications
D_2	R & D expenditure as a percentage of GDP
E_1	Number of schools
E_2	Number of college students in total population

4 Model Establishment

4.1 Question 1

4.1.1 Problem Analysis

Regarding the first question, economic vitality refers to the capacity and potential of regional economic development, and it is a reflection of a region's comprehensive competitiveness composed

of many internal mechanisms. The internal factors that affect the economic vitality of a region (or city) are the two perspectives of population and corporate vitality, so this topic will discuss these two issues. Since Beijing is China's "four major centers" and is the front-end embodiment of China's economic vitality development, this topic selects Beijing's economic vitality as the research object.

From a population perspective, the adequacy of labor in a region directly affects the development of local economic vitality, so the number of population can directly reflect the labor situation in a region; at the same time, the natural population growth rate and birth rate reflect whether the region's economy is healthy Development, and whether it is an important indicator for attracting labor, so this question will choose three population indicators: population, natural population growth rate, and birth rate.

From the perspective of corporate vitality, enterprises are an important unit of urban economic development and a branch of the urban economy. The number of enterprises plays an important role in the overall vitality, upward and downward trends, and effectiveness of urban economic growth. Important status and role. The increase in number means the expansion of production scale, which accelerates the efficiency of input, production, output, and transformation, and enhances economic vitality. At the same time, the change in the number of enterprises each year can indirectly reflect the added value of corporate vitality. The number of business write-offs can indirectly reflect the decrease in business vitality; therefore, this question will select three business vitality indicators: the number of business, the number of business growth, and the number of business write-offs.

4.1.2 Principle of indicator selection

For the economic vitality evaluation index system, the following six basic principles should be followed when selecting specific indicators:

1. System comprehensiveness. The scientific evaluation index system requires that the selected indicators can be regarded as an organic whole, which should be able to comprehensively and accurately reflect, describe and evaluate the economic vitality of the selected city from all levels and angles.
2. Scientific. The selected index should be scientific, and only in this way can the selected index be scientifically, objectively, and truly measure and reflect the level of urban economic vitality.
3. Dynamic. The selected index should be able to reflect the dynamic development characteristics of this area, and should not be a static state, otherwise it will not have any reference meaning for the development of this area.
4. Operability. As the evaluation of economic vitality development is an intricate system, it is necessary to have strong measurability and comparability when selecting indicators. Attention should be paid to the availability of indicator data, and indicators that are simple and clear, easy to collect, representative, and easy to implement with measurement methods should be selected.
5. Typicality. It is necessary to ensure that the evaluation indicators have a certain typical representativeness, and reflect the level of economic vitality of the city as accurately as possible. The evaluation indicators should not be too much, too detailed, make the indicators too cumbersome and overlap each other, and the indicators should not be too small, too simple, to avoid omission of indicator information, errors and untrue phenomena.
6. Comparability. Since the indicator system is an organic whole, there must be a certain relationship between the indicator elements of each layer, which are comparable elements.

4.1.3 Definition of macro indicators

Economic Vitality:

Vitality refers to the vigorous vitality of a subject in terms of vitality, and economic vitality is a measure of whether a city's economy has "vigorous vitality." This question analyzes economic vitality from the two indicators of population and corporate vitality

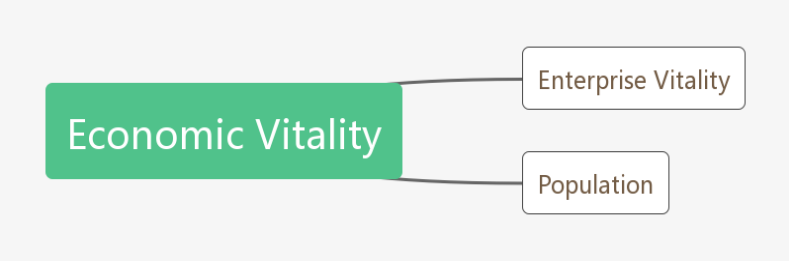

Figure 1 Economic Vitality

4.1.4 Definition of micro indicators

4.1.4.1 Population

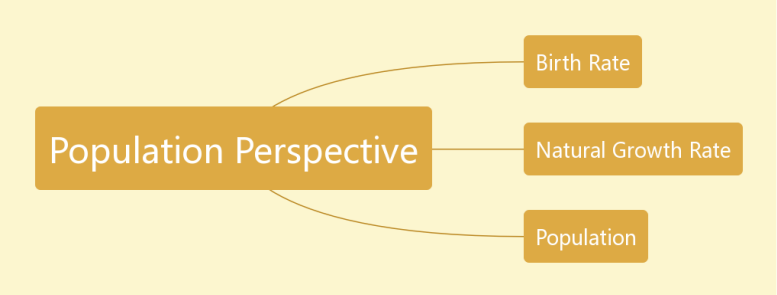

Figure 2 Population

1. The number of Population

The number of population This question selects the number of permanent residents in a region, and the larger the population in the region, the stronger the competitiveness of economic vitality, and the greater the economic vitality of the region.

2. Natural population growth

The natural population growth rate is the ratio of the natural population increase in a certain area to the average population in that period. It can reflect the population development speed of the area and important indicators for formulating a population plan. The larger the natural population growth rate, the greater the number of potential competitors in the region, and the economic vitality will further increase.

3. Birth rate

The birth rate refers to the ratio of the number of births in a region in a year to the average population in that period, and it reflects the birth level of the population. The greater the birth rate, it will have an impact on the economic vitality of the region.

4.1.4.2 Enterprise Vitality

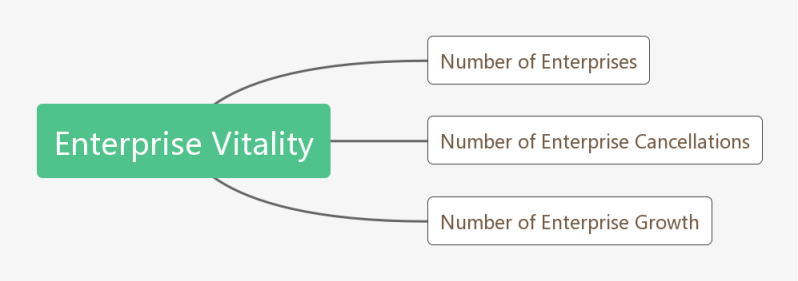

Figure 3 Enterprise Vitality

1. Number of companies

The number of companies refers to the number of companies that still have business operations in the region each year. It is the number of companies that still survive each year after the calculation of the number of start-up companies, increase of companies, and cancellation of companies. This number can be directly reflected The size of regional business vitality.

2. Growth of enterprises

The number of enterprises growth refers to the number of new enterprises in the region each year. This number is the number of newly registered and put into business each year. It becomes the net increase of enterprises each year and can directly reflect the increase in the number of enterprises in each year. This value The larger, the greater the economic vitality of the region.

3. Number of business cancellations

The number of business write-offs refers to the number of business write-offs in the region each year. This number can reflect the decrease in the annual vitality of the company. The larger the value, the lower the economic vitality of the region.

4.1.5 Model Establishment and Solution

4.1.5.1 Data Preparation

Since we need to study the impact of changes in Beijing's population and business vitality on the economic vitality of the region, we choose the annual population in Beijing from 2009 to 2018, the natural population growth rate, the birth rate, the number of businesses, the number of businesses, and the number of business cancellations Data, as shown in the following table:

Table 1 Selected six indicators

year	Population	Natural population growth rate	Birth rate	Number of Enterprises	Number of Enterprise Growth	Number of Enterprise Cancellations
2009	1860	3.33	7.66	136.64	9.11	2.89
2010	1961.9	2.98	7.27	142.36	5.72	3.39
2011	2018.6	4.02	8.29	144.22	11.7	3.86
2012	2069.3	4.74	9.05	142.53	10.2	13.39
2013	2114.8	4.41	8.93	147.6	11.64	5.13
2014	2151.6	4.83	9.75	165.81	18.21	-6.57
2015	2170.5	3.01	7.96	186.2	20.61	-2.18
2016	2172.9	4.12	9.32	199.25	22.43	7.56
2017	2170.7	3.76	9.06	210.04	19.48	11.64

2018	2154.2	2.66	8.24	215.11	18.35	14.41

Note: The above data are from the Beijing Statistical Yearbook 2009-2018

4.1.5.2 Principal Component Comprehensive Evaluation

1.Basic idea

The principal component analysis method uses the idea of dimensionality reduction to simplify a high-dimensional system containing multiple indicators, recombines the multiple indicators that were originally established, and converts them into a set of new comprehensive evaluation indicators that are not related to each other. A new set of uncorrelated comprehensive evaluation indicators replaces the original multiple evaluation indicators.

2. Basic principles

According to the principle of variance maximization, a new set of linearly independent and orthogonal vectors are used to represent the rows (or columns) of the original data matrix. This new set of vectors (principal components) is a linear combination of the original data vectors.

The original coordinate data (feature vector) is replaced by the original data's projection (dot product) by translation, scaling (reduction of mean and variance), and coordinate rotation (feature decomposition) of the original data. Vector of raw data.

3.The basic steps

a) Data standardization

In this economic vitality evaluation problem, because the units of each evaluation index are different, it has a dimensional impact. At this time, in order to eliminate the dimensional interference, it is necessary to perform dimensionless processing on the original indicator data:

From the original observations, the data is the following matrix:

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{16} \\ x_{21} & x_{22} & \cdots & x_{26} \\ & \vdots & & \\ x_{61} & x_{62} & \cdots & x_{66} \end{pmatrix}$$

Normalized processing. Normal normalization is equivalent to coordinate translation and scaling of the original data. The dimensionless data after the change is:

$$\tilde{x}_{ij} = \frac{x_{ij} - \bar{x}_j}{s_J} \quad (i = 1, 2, \ldots, 10; j = 1, 2, \ldots, 6.)$$

$\tilde{x}_{ij}$ for raw indicator datax_{ij};

$\bar{x}_j$is the sample mean of the j indicator variable;

s_j is the sample standard deviation of the j indicator variables.

b) Find the correlation coefficient matrix

Correlation coefficient matrix $R = (r_{ij})_{6\times 6}$

$$r_{ij} = \frac{\sum_{k=1}^{10} \tilde{x}_{ki} \cdot \tilde{x}_{kj}}{10 - 1}, i, j = 1, 2, \ldots, 6.$$

Where, $r_{ij} = r_{ji}, r_{ii} = 1, r_{ij}$ is the correlation coefficient between the i-th index and the j-th index

c) Calculate eigenvalues and Eigenvectors

Calculate the eigenvalues $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_6 \geq 0$ of the correlation coefficient matrix R. And

its corresponding normalized feature vectors $u_1, u_2, \dots, u_6$ where $u_j = [u_1, u_2, \dots, u_6]^T$, which consists of 3 new indicators composed of feature vectors:

$$y_1 = u_{11}\tilde{x}_1 + u_{21}\tilde{x}_2 + \cdots + u_{61}\tilde{x}_6,$$
$$y_2 = u_{12}\tilde{x}_1 + u_{22}\tilde{x}_2 + \cdots + u_{62}\tilde{x}_6,$$
$$y_3 = u_{13}\tilde{x}_1 + u_{23}\tilde{x}_2 + \cdots + u_{63}\tilde{x}_6,$$

Where y_i is the i-th principal component.

d) Calculate cumulative contribution rate

$$b_j = \frac{\lambda_j}{\sum_{k=1}^{6}\lambda_k}, \quad j = 1,2,3$$

$$\alpha_p = \frac{\sum_{k=1}^{p}\lambda_k}{\sum_{k=1}^{6}\lambda_k}$$

Among them, λ_k is the eigenvalue of the correlation coefficient matrix $(\mathrm{k} = 1,2, \dots,6)$, , b_j is the information contribution rate of y_j, α_p is the cumulative contribution rate of main components $y_1, y_2, \dots, y_p$, when α_p approaches 1 , The first p index variables are selected as the main component, and p is the number of main components.

e) Calculate composite score Z

$$Z = \sum_{j=1}^{P} b_j\, y_j$$

Where, b_j is the information contribution rate of y_j.

4.1.5.3 Model solving

Use Matlab to find the table of the first five characteristic roots, contribution rates, and cumulative contribution rates of the correlation coefficient matrix.

Table 2 Principal Component Analysis Results

Serial number	Eigenvalues	Contribution rate	Cumulative contribution rate
1	3.0721	51.2019	51.2019
2	1.7671	29.4511	80.653
3	0.9677	16.1279	96.7809
4	0.1465	2.4412	99.2221
5	0.0420	0.7004	99.9225
6	0.0046	0.0775	100

As can be seen from the above table, the cumulative contribution rate of the first three characteristic roots has reached 96.78%, and the principal component effect is very good, so the comprehensive evaluation of the first three principal components.

Table 3 Feature vectors corresponding to the first 3 principal components

	x_1	x_2	x_3	x_4	x_5	x_6
1	0.5392	0.1401	0.4281	0.4706	0.5254	0.0944
2	-0.0168	0.7120	0.4717	-0.4110	-0.1371	-0.2874
3	-0.0637	0.2031	0.1625	-0.0124	-0.2760	0.9230

Get three principal components as:

$$y_1 = 0.5392x_1 + 0.1401x_2 + 0.4281x_3 + 0.4706x_4 + 0.5254x_5 + 0.0944x_6,$$
$$y_2 = -0.0168x_1 + 0.7120x_2 + 0.4717x_3 - 0.4110x_4 - 0.1371x_5 - 0.2874x_6,$$
$$y_3 = -0.0637x_1 + 0.2031x_2 + 0.1625x_3 - 0.0124x_4 - 0.2760x_5 + 0.9230x_6.$$

Use the contribution ratios of the three principal components as weights to construct a model of the relationship between economic vitality and other principal components

$$Z = 0.5120y_1 + 0.2945y_2 + 0.1935y_3$$

Finally, I got the comprehensive score and ranking of the economic vitality of Beijing in each year from 2009 to 2018, as shown in the figure below:

Table 4 Ranking and Score

Years	2009	2010	2011	2012	2013
score	1.126	1.0723	0.8616	0.4835	0.3275
Ranking	8	6	9	4	5
Years	2014	2015	2016	2017	2018
Score	0.0015	-0.2684	-0.4104	-1.5151	-1.6785
Ranking	10	7	3	1	2

4.1.6 Relational Model of Influencing Factors of Economic Vitality

According to the relationship model of economic vitality, the degree of dependence of economic vitality scores on the three principal components is 0.5120, 0.2945, and 0.1935, respectively. Therefore, to improve the overall economic vitality score, the first principal component should be increased, It can be known from the influence ratio of each principal component index that the most effective solution to increase the first principal component is to appropriately increase x_1, x_5, that is, to appropriately increase the number of urban populations, and to increase the number of new enterprises can increase urban vitality; the second is effective The plan is to appropriately increase x_3, x_4, that is, to appropriately increase the birth rate and the number of enterprises to increase the vitality of the enterprise.

To sum up, in order to improve Beijing's economic vitality, the first effective method is to appropriately increase the number of urban populations in the city and the number of new enterprises each year, and the second effective method is to appropriately increase the birth rate and number of enterprises. Both programs can effectively boost Beijing's economic vitality.

4.2 Question 2

4.2.1 Problem Analysis

For the second question, explore the short-term and long-term impact of policies at a certain point in time on the future economic vitality of the region. We still chose Beijing as the subject of this question, and through the reading of the literature, we chose 2008 as the policy node. Because the introduction of economic policy has different effects on various industries in Beijing, in order to reflect the strength of the influence of policy on economic vitality from the change of the argument, we set up the evaluation model of the influence of the exogenous variable of economic vitality (later referred to as the exogenous variable evaluation model), and obtained the evaluation score of the exogenous variable son influencing the economic vitality (later referred to as the exogenous variable score), Quantifying the effect of exogenous variables on economic vitality, the method of modeling models follows the comprehensive evaluation of the main components of the first question, and obtains the real exogenous variable score from 2008 to 2019.

In order to ensure the reliability of the model, we first predicted the economic indicators for

2007-2009 with vector self-regression model based on the data from 1990-2006, and found that the error was within control. As time goes on, beijing's economy in 2008 by the economic crisis brought about by the negative effects and the Beijing Olympic Games brought about by the promotion of the negative impact of the economic crisis is gradually weakened over time, the Beijing Olympic Games to Beijing's economy has brought the lag effect is also smaller, Therefore, the above-mentioned can be based on this model forecast 2008-2019 economic indicators. However, spearman test of all selected indicators is carried out before the vector self-regression is carried out to select the indicators with strong correlation and exclude the indicators with poor correlation.

Then we forecast the economic vitality indicators for the ten years from 2009 to 2018 according to the data from 1990-2008, and bring the forecast value into the exogenous variable evaluation model to get the predicted exogenous variable score. Comparing the two scores over a short period of 3 years and 10 years in the long term, we can draw a score on the extent to which the economic restructuring will affect Beijing's economic vitality.

4.2.2 Background on Policy Reform

Through reading the literature, in the reform of the larger economic system introduced by Beijing in the past ten years, we found that Beijing began to issue more documents in 2008 to improve economic vitality, among which, the reform of the economic property rights system changed from expanding the pilot to speeding up the overall; To implement a number of key projects to enhance the capacity of resources and energy security, to liberalize the outpatient clinics of 800,000 urban "old and small" residents and flexible employees, to reduce personal health insurance expenditure by 300 million yuan, to encourage enterprises and residents to purchase housing through group purchases, and to increase policy housing construction to support the development of the building economy and productive services. So we consider 2008 as the starting year for policy reform, and analyze the impact of this reform on Beijing's economy after 2008.

4.2.3 Definition of indicator

In order to study the mechanism of the internal factors that determine the economic vitality, we need to systematically study the exogenous variables that affect economic vitality, and this paper selects five aspects to study the index system, including the sub-index system of economic benefits, the sub-index system of opening up to the outside world, the sub-index system of residents' quality of life, the sub-index system of innovation ability, Education sub-indicator system, each sub-indicator system contains individual indicators.

1. Economic benefits A

The economic development of the region is the obvious indicator of economic vitality in the region, and the display of economic effect can be presented in many aspects, such as per capita indicators, aggregate indicators, rate indicators, structural indicators and so on, so this paper selects economic-related indicators including PER capita GDP, GDP growth per capita, real GDP, real GDP, The gross domestic product of industrial enterprises above the scale, the proportion of tertiary industry, the proportion of fiscal revenue to GDP, and the growth rate of per capita fixed asset investment are seven indicators.

(1) Gross domestic product per capita A_1

Gross domestic product per capita is the ratio of a country's gross domestic product (GDP) to that country's resident population over a period of time (usually one year), a measure of the standard of living standards in different regions. GDP per capita is an effective tool for people to understand and

grasp the macroeconomic health of a country or region, that is, "GDP per capita", which is often used as an indicator to measure economic development in development economics, is one of the most important macroeconomic indicators.

(2) GDP growth per capita A_2

First, in the vast majority of industrialized countries other than resource countries, GDP per capita more objectively reflects the level of development and development of a certain country's society; Although GDP per capita cannot be directly equal to the per capita income and living standard of the residents, it constitutes the main material basis of per capita income and living standard of the inhabitants of a country, and is an important reference index to improve the per capita income level and living standard of the residents. According to Huntington's analysis, at a certain stage, per capita GDP growth is directly proportional to social stability and social harmony. The reforest can also be used as one of the indicators of economic development effectiveness.

(3) Real GDP A_3

Real GDP is the ratio of nominal GDP to consumer price index in a region. As nominal GDP can not objectively reflect the local economic development, it is necessary to deal with the CPI, the real GDP can be excluded from the price impact of the general price level, the real objective reflection of the total economic development in this period of time.

(4) Gross domestic product of industrial enterprises above the scale A_4

Industries above the scale refer to all state-owned and non-state-owned industrial legal enterprises with annual main business income of 5 million yuan and above. Gross industrial production refers to the final results of industrial production activities in the form of monetary expressions by industrial enterprises during the reporting period, which can reflect the influence of industry. This indicator can reflect the contribution of large and medium-sized enterprises to society, and can also affect the economic vitality of the region.

(5) The proportion of the tertiary industry is A_5

The proportion of tertiary industry is the percentage of GDP added by the tertiary industry, which is equivalent to the contribution rate of the tertiary industry, and the significance of accelerating the development of the tertiary industry is mainly: it is conducive to the establishment and improvement of the socialist market economy system; To ease the pressure on employment in China, to improve people's living standards and achieve well-off. So we chose the proportion of the tertiary industry as an indicator of the economic vitality of the city.

(6) Fiscal revenue as a percentage of GDP A_6

Fiscal revenue is an important index to measure the government's financial resources, the scope and quantity of public goods and services provided by the government in social and economic activities, to a large extent, is determined by the abundant fiscal revenue, so we choose fiscal revenue can reflect the city government's urban infrastructure construction, urban welfare.

(7) Per capita fixed asset investment growth rate A_7

Fixed asset investment is the amount of work that an enterprise does to build and acquire fixed assets in a certain period of time and the changes in costs associated with it. Including real estate, buildings, machinery, machinery, means of transport, as well as enterprises for capital construction, renovation, major repairs and other fixed asset investment growth rate can reflect the scale of investment, speed and proportion of fixed assets.

2. Opening to the outside world B

"Opening to the outside world" is a great progress for China to enter a new historical stage,

which will also promote the economic and social development of the region. The redeveloped economy of the region also needs to be connected to the outside world for trade, and to promote the development of economic vitality and competitiveness through opening up to the outside world. Therefore, this paper selects the cumulative number of visitors and the index growth rate of total foreign trade import and export to evaluate the degree of regional opening up.

(1) Cumulative number of visitors throughout the year B_1

The cumulative number of visitors throughout the year is the number of tourists in a year, this indicator can reflect the scale of tourism development in various places, is the basic core indicator of tourism economic benefits, this indicator is used to measure the degree of economic activity of tourism in a region, mainly used to reflect the region's economic dependence on tourism, And can eliminate the economic and population size differences brought about by the incomparable factors.

(2) The growth rate of the index of total foreign trade imports and exports B_2

The growth rate of the index of total foreign trade imports and exports is the growth rate of the total foreign trade import and export index of the previous year, which can reflect the city's degree of opening up, the speed of economic development and the degree of external dependence, which can be influenced by trading on economic vitality.

3. Quality of life of the population C

The social accumulation of the region will eventually be enjoyed by the residents, so the quality of life of the residents of the region can affect the development of the economic vitality of the region. The improvement of the quality of life of the residents will stimulate the vitality of social and economic development, which in turn will affect the competitiveness of the region. This paper evaluates the five aspects of average monetary wage, urban residents' disposable income growth rate, social retail consumption growth rate, unemployment rate and urban greening coverage.

(1) Average monetary wage s. C_1

It shows the level of wage income of workers in this region in a certain period of time, which is the main index that reflects the wage level of workers, which can reflect how much social wealth is occupied by workers.

(2) Growth rate of disposable income of urban residents C_2

The disposable income of the residents is the income at the disposable expense of the residents, i.e. the income that must be deducted from the total income of the household that must be paid to the state, the social insurance (such as medical insurance, old-age insurance, unemployment insurance, etc.). The disposable income of the resident is an important measure of the living standard of the people, because it marks the immediate consumption capacity of the residents.

(3) Growth rate of social retail consumption C_3

The total retail sales of consumer goods refers to the amount of goods sold by enterprises (units) to individuals and social groups, non-production and non-operational goods, and the amount of income obtained by providing catering services. Total retail sales of consumer goods include online retail sales of physical goods, but excluding online retail sales of non-physical goods. This indicator can see the improvement of people's material and cultural standard of living in a certain period of time, reflecting the degree of realization of the purchasing power of social goods, as well as the size of the retail market.

(4) Unemployment rate C_4

The unemployment rate refers to the proportion of the unemployed workers who meet all the conditions of employment in a certain period of time, which is designed to measure the labor capacity

in idle ness, and is the main indicator to reflect the unemployment situation of a country or region, and the change of unemployment data can properly reflect economic development. The unemployment rate has a reverse change between the rate of economic growth.

(5) Urban greening coverage C_5

Greening coverage is an important index to reflect the ecological environment protection of a country or region, and also an important index for the model city of environmental protection and the creation of civilized city assessment in China. It is the ratio of all green cover area in the city to the total area of the area. Greening coverage area refers to the vertical projection area of all vegetation such as trees, shrubs and lawns in the city, including public green space, residential green space, unit-affiliated green space, protective green space, production green space, road green space, green planting area of scenic forest land, green cover area of roof and scattered trees.

4. Innovation D

Combined with the trend of China's economic development, innovation is the driving force of urban development, cities in the continuous innovation will appear new technologies, industries, and even industries, to stimulate the spirit of individual and collective innovation, and then into the promotion of urban economic development, so this paper chooses to apply for patents and R.D. Expenditure as a proportion of GDP to evaluate the city's innovation ability.

(1) Number of patent applications D_1

Under the background of China's market economy, only by constantly producing products and services to meet market demand and increasing independent research and development technology and industry can we improve the economic benefits of the city, thus promoting the economic growth of the region and stimulating the development of industry.

(2) The proportion of R-D funding to GDP D_2

Increasing the investment of science and technology and scientific research personnel is the basis and premise for vigorously developing high-tech industries and enhancing technological innovation ability. The greater the investment in scientific research, the more high-tech talents can be attracted, and the establishment of talent introduction mechanism, personnel training mechanism and talent utilization mechanism, so as to improve competitiveness, so as to sustain the economic benefits of enterprises throughout the region

Education E

"One hundred-year plan, education first", a country, a city's development and education investment in a certain proportion of positive correlation; Education has a catalytic effect on the economy. Therefore, this paper selects the number of schools and the total number of college students to the total number of students to evaluate the city's innovation ability.

(1) Number of schools E_1

The number of schools in the region is a prerequisite for the vigorous development of education in this area, and the establishment of schools is a direct reflection of the investment in education.

(2) The number of college students accounted for E_2 of the total population

College students are the higher intellectuals of regional education, the overall quality is guaranteed, and the quality of population education is a reflection of a city's educational level, the proportion of college students can indirectly reflect the intensity of investment in education.

4.2.4 Model establishment and solution

4.2.4.1 Spearman Inspection

1. Definition of The Spearman Level Correlation Factor

This coefficient is an indicator that describes whether there is the same or opposite convergence between two sets of variables. The test does not require the distribution of the original variable, i.e. there is no need to assume that the population obeys the normal distribution, nor does it need to limit the size of the sample size, and only needs to determine the level of the variable at each period. Therefore, in the absence of duplicate observations in both sets of data, the Formula for The Spearman Level Correlation Coefficient is:

$$r_{sp} = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

Among them, r_{sp} represent spearman grade correlation coefficients, d_i represents the grade difference between the two sets of data, n represents the sample size.

2. Testing of Spearman grade correlation coefficients

In the process of inferring the population with a sample, because the sample is random, it is a misjudgment of the correlation between variables, so the correlation results need to be tested, so the steps of the hypothesis test are as follows:

The original assumption H_0: the overall correlation between the study, i.e. the study is not relevant, i.e. $\rho \neq 0$

Alternative hypothesis H_1:the overall correlation between the studies, i.e. $\rho = 0$

In the case of small samples, the sample estimate is the Spearman grade correlation coefficient, usually the critical value r can be obtained directly from the table, but in the case of large samples, it can be converted to:

$$t = r_{sp}\sqrt{\frac{n-2}{1-r_{sp}^2}}$$

Among them, the variable obeys the t distribution of $t_{(n-2)}$ and uses the two-sided t test.

4.2.4.2 Vector Self-Regression

1. The theoretical basis for vector self-regression

Vector self-regression model is not based on strict economic theory, but is based on the statistical nature of data, driven by the data itself model dynamic structure model. The VAR model is a function that constructs the model as a lag value for all endogenous variables in the system, thus studying the relationship between variables.

The mathematical expression of the VAR (p) model is:

$$y_t = A_0 + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + Bx_t + \varepsilon_t \quad (t = 1,2,\ldots,T)$$

Among them, the y_t is the k-dimensional endogenous variable column vector, p is the lag order, x_t is the exogenous variable column vector, T is the number of samples, the matrix $A_1, A_2, \ldots, A_p$ and matrix B is the coefficient matrix, and the ε_t is the k-dimensional disturbance movement, the perturbation variable can be correlated between the contemporaneous, but not related to the variables on the right side of the hysterile and equation.

2. Vector self-regression model

(1) Smoothness test

A smooth random sequence is described as wide and smooth. If the expectation of the random

process, the variance (Var), and the covariance (Cov) do not change over time, i.e. $\mathrm{E}(y_t) = \mu$, $\mathrm{Var}(y_t) = \sigma^2$ and, $\mathrm{Cov}(y_t, y_s) = \gamma$, the level is called wide and stable.

The test method of the stability of the general time series is the unit root test, the core of which is the ADF test.

The original assumption H_0: $\gamma = 0$: the time series has at least one unit root, and the time series is non-stable time series;

The alternative assumption H_1: $\gamma < 0$, the time series does not have a unit root, is a smooth time series.

(2) Co-integration inspection

Cointegration is a description of the long-term stable relationship between non-stable variables, that is, although each variable is not stable, but the linear combination between variables is stable, it can be said that there is a cointegration relationship between variables. Cointegration testing is generally based on Johansen test: feature root test, maximum feature root test.

① Feature root test

The original assumption H_0: y_t have r cointegration relationship

Alternative assumptions H_1: y_t have an $\mathrm{r}+1$ co-integration relationship

The construction of the inspection statistics:

$$\eta_r = -\mathrm{n}\sum_{i=r+1}^{k} \ln(1-\lambda_i) \quad (r = 0,1,\ldots,k-1)$$

Where n is the sample capacity, the λ_i is the i-th characteristic value arranged by size, and r is the number of covariates variables.

When the η_1 <critical value of the H_{10} is accepted, the y_t has 1 cointegration relationship;

when η_1 >the critical value, the rejection of H_{10}, y_t has at least 2 cointegration relationships;

When the H_{r0} is accepted ,the η_r >critical value, y_t only r cointegration relationship.

② Maximum feature value test

The original and alternative assumptions of this hypothesis are the same as the characteristic root test, and the number of test statistics constructed is:

$$\delta_r = -\mathrm{n}\ln(1-\lambda_{r+1})$$

Where λ_{r+1} is the maximum characteristic value of the related pair matrix $(\sum_{i=1}^{p} A_i - \mathrm{E})$.

(3) Determining the optimal lag order

The key to building the VAR model is the value of the lag order p, which we often use as a lag order and BIC information criteria:

$$\mathrm{AIC} = \ln|\widehat{sum}| - \frac{2r}{T} \qquad \mathrm{BIC} = \ln|\widehat{sum}| - \frac{lnT}{T}\mathrm{r}$$

Among them, $|\widehat{sum}|$ is the determinant of the variance covariance matrix that estimates the residuals of the VAR model, r is the number of parameters to be evaluated by the model, which should contain constant entries, and T is the sample capacity.

(4) Parameter Estimation

The parameter estimation of the VAR model can be carried out by means of the estimation method sparing the minimum two-way estimate and the maximum like-for-like estimation. The sum of the residual squares between the fitted and true values of the model is generally minimal.

(5) Stability test

For a smooth VAR model, the impact of a random interference on the system decreases and fades over time, otherwise it is unstable. Therefore, the stable condition of the VAR model is that all the roots of $|\varphi(\mathrm{L}) - \lambda\mathrm{E}|$=0 fall in the unit circle, and $\varphi(\mathrm{L}) = A_1\mathrm{L} + A_2L^2 + \cdots + A_pL^p$。

6) Granger causality test

An important role of the VAR model is to analyze the causal relationship between time variables, which is designed to test whether x is helpful in y's prediction, i.e. "y can be caused by x Granger".

The original assumption H_0: the coefficients for x_t lag items in y_t expressions are 0

Alternative assumptions H_1: the coefficient for x_t lag items in y_t expressions is not all 0

Therefore, construct the F statistic for testing:

When the F < threshold, the H_0 is accepted, indicating that there is a Granger causal relationship between the x_t and the y_t

When the F > threshold is, the refusal H_0 indicates that there is no Granger causation x_t y_t.

4.2.5 Presentation of The Conclusions

1. Spearman level correlation coefficients filter the indicator

According to the above operating results, the above 18 indicators of the Spearman test, only 8 indicators passed the test, namely: per capita GDP A_1, real GDP A_3, industrial enterprises above the scale of GDP A_4, the tertiary industry accounted for A_5, the cumulative number of visitors B_1, Average monetary wages C_1, urban greening coverage C_5, patent applicationsD_1, as detailed in the figure below.

Table 5 Spearman Test Result

	A_1	A_3	A_4	A_5	B_1	D_1	C_1	C_5
Correlation factor	1	1	0.99	0.99	0.99	1	0.99	0.98
P	0	0	0	0	0	0	0	0
Correlation factor		1	0.99	0.99	0.99	1	0.99	0.98
P		0	0	0	0	0	0	0
Correlation factor			1	0.99	0.99	0.99	0.99	0.98
P			0	0	0	0	0	0
Correlation factor				1	0.98	0.99	0.99	0.97
P				0	0	0	0	0
Correlation factor					1	0.99	0.99	0.97
P					0	0	0	0
Correlation factor						1	0.99	0.98
P						0	0	0
Correlation factor							1	0.98
P							0	0
Correlation factor								1
P								0

2. Vector self-regression for predictive analysis

After screening the indicator through the Spearman test, it is necessary to test the prediction ability of the vector self-regression model, and according to the data from 1990-2006, the economic indicators for 2007-2009 are predicted with vector self-regression model, and the error is within control (the result ingressometric error is about 7%) Therefore, the eight indicators for 2010-2018 are forecasted based on the data for 1990-2008, and the results are shown in the figure below.

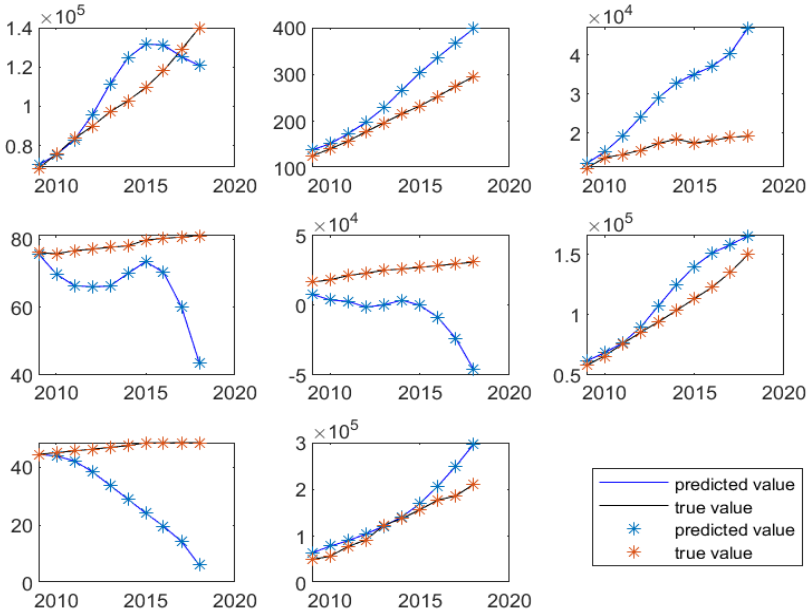

Figure 4 Comparison of the indicator forecasts with the original values

From the figure above, there is a difference between the actual value and forecast of 8 indicators, such as Beijing's GDP per capita from 2009 to 2018, real GDP, gross domestic product of industrial enterprises above the scale, proportion of the tertiary industry, cumulative number of visitors for the whole year, number of patents filed, average monetary wages, urban greening coverage, etc.

Through the deepening of the policy in 2008, there is not much difference between Beijing's GDP per capita in the short term (within 3 years), real GDP, GROSS product of industrial enterprises above the scale, number of patents filed, the true value of urban greening coverage and the forecast value; The real value of average monetary wages is significantly larger than forecast, indicating that Beijing's situation is getting better because of the implementation of the policy.

Through the deepening of the policy in 2008, the proportion of Beijing's tertiary industry in the long term (within 3-10 years), the cumulative number of visitors to the whole year, the average monetary wage swelled significantly, far greater than the forecast of the downward trend, the remaining indicators of the real value is less than the forecast value.

3. Scoring analysis of economic vitality

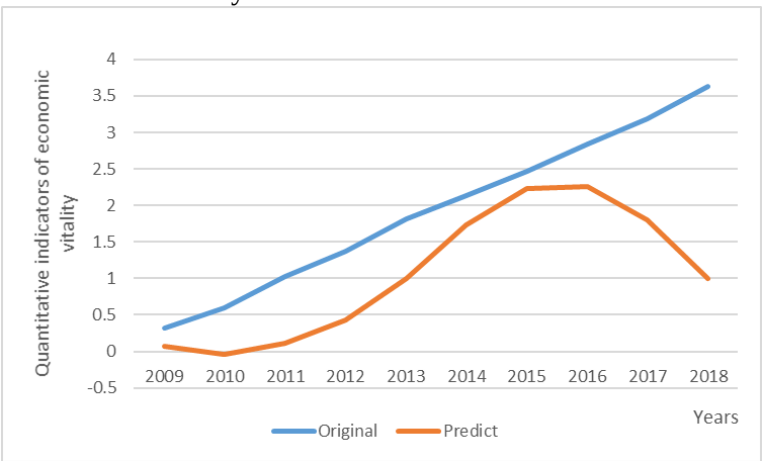

Figure 5 Comparison of actual and predicted values 2009-2018

In the short term (within 3 years), the true value of the economic vitality score is always greater than the predicted value, and the difference is increasing year by year, indicating that the effect of policy implementation in 2008 has become more obvious; in the long term (within 3-10 years), the true value of the economic vitality score It is always larger than the predicted value, but the gap between the two tends to decrease first and then increase, especially in 2015, the distance between the real value and the predicted value is the smallest, which indicates that the long-term impact of the

policy is continuously decreasing, and there is an economy and policy The cyclical cycle makes the economic vitality always develop in a good direction.

4.2.6 Model Inspection

4.2.6.1 Rationality Analysis

In order to ensure the reliability of the model, we first predicted the economic indicators for 2007-2009 with vector self-regression model based on the data from 1990-2006, and found that the error was within control. As time goes on, Beijing's economy in 2008 by the economic crisis brought about by the negative effects and the Beijing Olympic Games brought about by the promotion of the negative impact of the economic crisis is gradually weakened over time, the Beijing Olympic Games to Beijing's economy has brought the lag effect is also smaller, Therefore, the above-mentioned can be based on this model forecast 2008-2019 economic indicators. However, spearman test of all selected indicators is carried out before the vector self-regression is carried out to select the indicators with strong correlation and exclude the indicators with poor correlation.

4.3 Question 3

4.3.1 Problem analysis

For the third question, it is necessary to establish a complex mathematical model of economic vitality and rank the economic vitality of the cities in Annex 3. Since the first question has been the analysis of the endogenous factors of economic vitality, this question needs to study the exogenous variables of economic vitality, the question follows the indicators in the second question, through these indicators of the impact of exogenous variables on economic vitality, and finally get the ranking, so based on the above analysis to find the indicators affecting economic vitality, The evaluation score of the endogenous variable obtained by the first question is used as a dependent variable, and the dimension reduction is carried out by factor analysis, which is summarized into four categories of variables, and the score is obtained according to the variance interpretation rate, and the ranking is finally made.

4.3.2 Model establishment and solution

4.3.2.1 Factor Analysis

1. Basic ideas

Factor analysis is a widely used multivariate analysis method, the main purpose of which is to group variables according to the correlation of variables, so that the variables between the same groups are more correlated, different groups of variables are less relevant, each group of variables represents a basic structure, this basic structure is called public factor.

A sample usually has many variables to describe, and there is often some kind of connection between these variables, the purpose of factor analysis is to find this connection, with fewer variables, it can help us to analyze and explain complex economic problems, from the data to find the hidden relationship of the variables we do not notice, Convenient for our understanding of multidimensional data.

2.KMO and Bartlett Inspection

Due to the number of indicators in this paper, in factor analysis, because the number of indicators in this paper is too many, some indicators of low correlation may make the KMO value too low, the data in advance KMO and Bartlett test. We used SPSS to carry out KMO and Bartlett spherical testing of 20 indicators, 14 indicators failed the test screening, and finally only 6 indicators passed the test, the final result is:

Table 6 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.729
Bartlett's Test of Sphericity	Approx. Chi-Square	55.302
	df	15

	Sig.	.000

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy item is greater than 0.7, and the Bartlett spherical test is less than 0.05, indicating that factor analysis can be performed.

Reflecting the same as the KMO test shows that variables are suitable for factor analysis by reflecting the matrix, the results are as follows:

Table 7 Anti-image Matrices

		Gross domestic product per capita	Real GDP (GDP/Total Consumer Price Index) (RMB 100 million)	Gross domestic product of industrial enterprises above the scale (RMB 100 million)	Percentage of tertiary industry	Number of patents filed	Growth rate of social retail consumption
Anti-image Covariance	Gross domestic product per capita	.612	.059	-.045	.007	-.133	-.154
	Real GDP (GDP/Total Consumer Price Index) (RMB 100 million)	.059	.210	-.117	-.121	-.072	-.011
	Gross domestic product of industrial enterprises above the scale (RMB 100 million)	-.045	-.117	.241	.147	-.083	-.073
	Percentage of tertiary industry	.007	-.121	.147	.529	-.091	.095
	Number of patents filed	-.133	-.072	-.083	-.091	.183	.118
	Growth rate of social retail consumption	-.154	-.011	-.073	.095	.118	.749
Anti-image Correlation	Gross domestic product per capita	.758[a]	.165	-.116	.012[a]	-.397	-.227
	Real GDP (GDP/Total Consumer Price Index) (RMB 100 million)	.165	.765[a]	-.520	-.362	-.366[a]	-.027
	Gross domestic product of industrial enterprises above the scale (RMB 100 million)	-.116	-.520	.708[a]	.413	-.395	-.172[a]
	Percentage of tertiary Industry	.012	-.362	.413	.661	-.291	.151
	Number of patents filed	-.397	-.366	-.395	-.291	.760	.320
	Growth rate of social retail consumption	-.227	-.027	-.172	.151	.320	.602

The value of the Anti-image Correlation item in the table shows that the variable is suitable for factor analysis

The final indicator sifts for: GDP per capita, real GDP, gross domestic product of industrial enterprises above the scale, proportion of tertiary industry, growth rate of consumption of social retail goods, number of patents filed, etc.

3. Filtered data

Table 8 Filtered data

2018year	A_1	A_3	A_4	A_5	C_3	D_1
Beijing	140211	295.8049	19212.91	81	2.7	211212
Shanghai	135000	321.6523	34841.84	69.9	7.9	150233
Shenzhen	185942.5	235.6224	33174.49	58.8	7.6	200476
Guangzhou	155491	223.2358	31399.47	71.75	6.4	173124
Chongqing	65933	199.6391	21173.21	52.3	10.8	64648
Chengdu	93954.5	101.4	5692.17	61.3	10	35926
Nanjing	152886	125.1992	3091.8	61.03	8.4	40652
Hangzhou	140180	138.1979	14016.41	71.29	8.951496	98396
Suzhou	173480	181.2865	33100	50.8	7.4	135862
Tianjin	120605.5	184.3137	8464.338	58.6	1.7	99000
Qingdao	128459	117.5465	4800.6	56.4	10	26267
Dongguan	98939	80.76673	5620	51.1	8.1	97030
Zhengzhou	101349	99.05566	3191.3	54.67	9.7	70128
Wuhan	135136	145.7017	13696	54.6	10.5	60511
Xian	165706	81.94171	6396.28	61.8	9.6	56408
Ningbo	132603	96.68035	15850.89	45.2	10.4	62104
Changsha	131207	107.8766	11756.29	29.8	10.5	41034
Shenyang	69754	56.54676	5272.7	57.75	0.09	20879
Kunming	76387	51.19862	4552.25	56.6	10	23921

4. Basic steps

(1) Select analysis variables

The filtered data is standardized in the following ways:

$$\tilde{x}_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j} \quad (i = 1,2,\dots,19; j = 1,2,\dots,6.)$$

Where $\tilde{x}_{ij}$ is the corresponding amount-free indicator data corresponding to the original indicator data x_{ij}, $\bar{x}_j$ is the sample mean of the j indicator variable, and s_j is the sample standard deviation of the j indicator variable.

(2) Calculate the correlation coefficient matrix of the selected original variable

Correlation coefficient matrix $R = (r_{ij})_{6\times6}$ is:

$$r_{ij} = \frac{\sum_{k=1}^{10} \tilde{x}_{ki} \cdot \tilde{x}_{kj}}{19-1}, i,j = 1,2,\dots,6.$$

Where $r_{ij} = r_{ji}$, $r_{ii} = 1$,$r_{ij}$the correlation coefficient of the i-st and j indicators.

3) Calculating the primary load matrix

The characteristic value $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_9 \geq 0$ of the correlation coefficient matrix R is calculated and its corresponding standardized feature vector $u_1, u_2, \dots, u_6$, where in $u_j = [u_1, u_2, \dots, u_6]^T$ is composed of 6 new indicators:

$$\Delta_1 = \left[\sqrt{\lambda_1}u_1, \sqrt{\lambda_2}u_2, \sqrt{\lambda_3}u_3, \sqrt{\lambda_4}u_4, \sqrt{\lambda_5}u_5, \sqrt{\lambda_6}u_6\right]$$

Table 9 Common factor variance table

	Initial	Extraction
Gross domestic product per capita	1.000	.603

Real GDP (GDP/Total Consumer Price Index) (RMB 100 million)	1.000	.834
Gross domestic product of industrial enterprises above the scale (RMB 100 million)	1.000	.816
Percentage of tertiary industry	1.000	.653
Number of patents filed	1.000	.899
Growth rate of social retail consumption	1.000	.744

The greater the variance of the common factor extracted between variables, the greater the ability to be interpreted by the common factor, while the variable factor sits presented by the extracted common factor variance is mostly interpreted to a degree of more than 70%, so the extraction effect is better and the information of the original data loss is less. In general, for a variance contribution rate of no less than 75%, the factor extraction component interpretation information accounts for 75% of the total information. For factors with a feature root greater than 1, data analysis is based on SPSS software, resulting in four factors, as shown in the following table:

Table 10 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	3.324	55.397	55.397	3.324	55.397
2	1.227	20.443	75.840	1.227	20.443
3	.594	9.896	85.736		
4	.584	9.737	95.472		
5	.137	2.284	97.757		
6	.135	2.243	100.000		

Total Variance Explained

Component	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings		
	Cumulative %	Total	% of Variance	Cumulative %
1	55.397	2.875	47.922	47.922
2	75.840	1.675	27.918	75.840

As can be seen from Table 12, the cumulative variance contribution rate reaches 95%, indicating that the first four factors contain 95% of all indicator information, and the amount of information extracted is relatively large, so it can be shown that the effectiveness of factor analysis to extract the original variable information is higher.

(4) 4 main factors proposed

The contribution rate of the common factor. And the extraction of the factor load matrix rotation, to obtain matrix $\Delta_2 = \Delta_1^{(2)} T$.Get factor model:

$$\begin{cases} \tilde{x}_1 = \alpha_{11} F_1 + \cdots + \alpha_{14} F_4 \\ \vdots \\ \tilde{x}_6 = \alpha_{61} F_1 + \cdots + \alpha_{64} F_4 \end{cases}$$

Where

$$\Delta_2=\begin{pmatrix}\alpha_{11} & \cdots & \alpha_{14}\\ \vdots & \ddots & \vdots\\ \alpha_{61} & \cdots & \alpha_{64}\end{pmatrix}$$

Table 11 Rotated Component Matrix

	Component			
	1	2	3	4
Gross domestic product per capita	.3034	-.0.0487	.9458	.069
Nominal GDP (RMB 100 million)	.8787	-.1093	.12	.3438
Gross domestic product of industrial enterprises above the scale (RMB 100 million)	.9363	.0209	.2357	-.0154
Percentage of tertiary industry	.2192	-.2095	.0706	.9440
Number of patents filed	.7886	-.2473	.3547	.3102
Growth rate of social retail consumption	-.0977	.9738	.0386	-.1913

It can be seen that after the revision of GDP, above the scale of industrial output value, the number of patent applications mainly constitute factor 1, the revised GDP index reflects the economy, the gross domestic product of industrial enterprises above the scale reflects the production capacity, the number of patent applications reflects the level of scientific research, therefore, factor 1 can be named industrial and scientific research factors; The growth rate of social retail consumption mainly constitutes factor 2, the growth rate of social retail consumption reflects the consumption level, so factor 2 is named the consumption level factor, the per capita GDP is mainly constituted factor 3, the per capita GDP reflects the economic benefits, therefore, factor 3 can be named the economic benefit factor. The proportion of tertiary industry and the number of patent applications after the revision of GDP composition factor 4, the tertiary industry reflects the level of service industry, so factor 4 can be named service factor.

Table 12 Contribution Rate Data Table

Factor	Contribution	Contribution rate	Cumulative contribution rate
1	2.4202	0.4034	0.4034
2	1.0682	0.178	0.5814
3	1.0968	0.1828	0.7642
4	1.1472	0.1912	0.9554

(5) Calculate the factor score.

Using regression method to find a single factor score function is as follows

$$\hat{F}_j = \beta_{j1}\tilde{x}_1 + \beta_{j2}\tilde{x}_2 + \cdots + \beta_{j6}\tilde{x}_6, j = 1,2,\ldots,4$$

The calculated score function of each factor is

$$F_j = X\beta$$

The composition score coefficient matrix. To obtain the expression of the factor, the component matrix of the factor load matrix is extracted: β

Table 13 Factor Score Factor Beta

	β_{j1}	β_{j2}	β_{j3}	β_{j4}	β_{j5}	β_{j6}
F_1	-0.2858	0.4548	0.568	-0.2068	0.0756	0.2638

F_2	-0.0455	0.1093	0.0756	0.2195	1.0555	-0.1242
F_3	1.1037	-0.2895	-0.1708	-0.0236	-0.0639	0.0993
F_4	-0.0273	0.1068	-0.3258	1.0637	0.2528	0.0141

(6) Comprehensive score formula:

$$F = \frac{40.34F_1 + 17.80F_2 + 18.28F_3 + 19.12F_4}{95.54}$$

4.3.3 Presentation of The Conclusions

Table 14 Summary Presentation

Variable	Main ingredient F1 score	Main ingredient F2 score	Main ingredient F3 score	Main ingredient F4 score	Comprehensive score	Ranking
shanghai	2.0264	0.4622	-0.6019	0.786	0.9838	1
Shenzhen	1.4344	-0.1641	1.4942	-0.4078	0.7793	2
Guangzhou	1.1324	-0.2415	0.5415	0.7968	0.6962	3
Beijing	0.9754	-1.3377	0.0833	1.8668	0.5521	4
Suzhou	1.0746	-0.3172	1.2129	-1.2737	0.3717	5
Hangzhou	-0.3806	0.5437	0.4585	1.3393	0.2964	6
Chongqing	1.2124	1.0898	-2.3166	-0.4152	0.1886	7
Wuhan	-0.1275	0.8251	0.2147	-0.131	0.1148	8
Xian	-1.3013	0.4949	1.542	0.5896	-0.0442	9
Ningbo	-0.1052	0.5497	0.3092	-1.1736	-0.1177	10
Nanjing	-1.1912	0.1654	1.0186	0.5811	-0.1609	11
Qingdao	-0.8849	0.6732	0.1908	0.219	-0.1678	12
Chengdu	-0.6974	0.7796	-0.8641	0.6731	-0.1798	13
Zhengzhou	-0.6313	0.4459	-0.5029	0.0811	-0.2634	14
Changsha	-0.0366	0.3106	0.2807	-2.5201	-0.4082	15
Dongguan	-0.449	-0.2243	-0.4638	-0.4793	-0.416	16
Kunming	-0.8695	0.6555	-1.2323	0.1946	-0.4418	17
Tianjin	-0.1612	-2.0904	-0.0825	-0.2267	-0.5187	18
Shenyang	-1.0198	-2.6204	-1.2823	-0.5	-1.2643	19

According to economic vitality, the cities on the table can be divided into three echelons, the first echelon is Shanghai, Shenzhen, Guangzhou, Beijing, the second echelon is: Suzhou, Hangzhou, Chongqing, Wuhan, the third echelon is: Xi'an, Ningbo, Nanjing, Qingdao, Chengdu, Zhengzhou, Changsha, Dongguan, Kunming, Tianjin, Shenyang.

The following features can be summarized:

The industrial and scientific research factors of the first echelon are generally higher, indicating that Beijing, Shenzhen, Guangzhou and Shanghai attach more importance to industrial output and scientific and technological innovation.

Main component F2: Consumption level factor has little effect on overall ranking, indicating that consumption level has less impact on economic vitality

Main component F3: Compared to F1 secondary impact on the final ranking, including Beijing, Hangzhou, Guangzhou, Shanghai higher ratings.

The main component F4: The service factor has less impact on the overall ranking, with Beijing,

Shanghai, Guangzhou and Chengdu at the forefront.

For the accuracy of the ranking: macro-point, the top cities, the reality of economic strength and growth rate is generally higher, in line with economic common sense. From a microcosmic point of view, we query from the major economic websites to the economic vitality ranking, and the ranking is similar, so from the side to support the accuracy of the model.

4.4 Question 4

4.4.1 Analysis of the problem

According to the research on the endogenous driving force of Beijing's economic vitality, the internal driving can be carried out in two aspects:

1.In terms of population.

According to the analysis of the first question, the population can be analyzed from three perspectives: population, natural population growth rate, and birth rate. The most effective solution to increase the first principal component is to appropriately increase x_1, that is, to increase the number of urban populations can increase the number of cities. Vitality; the second most effective solution is to appropriately increase x_3, that is, to appropriately increase the birth rate to increase corporate vitality.

2. Enterprise vitality

According to the analysis of the first question, the population can be analyzed from three aspects: the number of enterprises, the number of enterprises, and the number of business cancellations. The most effective solution to increase the first principal component is to appropriately increase x_4, that is, to appropriately increase the number of new enterprises. Increase the vitality of the city; the second effective plan is to appropriately increase x_5, that is, to appropriately increase the number of enterprises to increase the vitality of the enterprise.

According to the study of the impact of changes in exogenous variables of Beijing's economic vitality, external drivers can be carried out from five aspects:

1. Economic benefits

Regional economic growth refers to the potential for economic growth. Economic growth is the main component of urban economic vitality and an important manifestation of economic vitality. Economic growth can be evaluated by GDP per capita, GDP per capita growth rate, real GDP, GDP of industrial enterprises above designated size, tertiary industry ratio, fiscal revenue GDP ratio, and per capita fixed asset investment growth rate. GDP mainly reflects It is the foundation of regional economic capacity and future sustainable development. According to empirical results, it can be known that under other conditions, the higher the economic growth, the stronger the city's economic vitality.

According to the analysis in the second and third questions, it can be obtained that the per capita GDP, actual GDP, the gross domestic product of industrial enterprises above designated size, and the proportion of the tertiary industry in the economic benefit indicators are effective indicators. The economically favorable policy of Beijing policy should Tend to these four indicators.

2. Residents' quality of life

The income of residents has a driving role in the vitality of the city's economy. Within a certain range, the higher the income of local residents, it can not only reduce the loss of local labor, but also attract foreign labor, so that the local labor continues to grow steadily, so that the scale of production

gradually expands, and the urban economy grows rapidly. The increase forces the demand for labor quality to rise, which promotes the improvement of the overall quality of residents and the further development of the urban economy.

According to the analysis in the second and third questions, it can be obtained that the average currency wages, the growth rate of social retail consumption, and the urban green coverage in the residents' quality of life indicators are effective indicators. Therefore, in order to improve the social sustainable urban development and competitiveness, The average wage and working environment of the working people must be guaranteed.

3. Terms of opening up

Foreign trade is a reflection of the regional economy's ability to compete externally, especially foreign trade imports and exports is one of the factors that reflect the sustainable development of the economy. As in the above studies, foreign trade has no obvious impact on the enhancement of economic vitality, so opening up can be a basic indicator of the region's enhanced economic development capacity.

4. In terms of innovation

Innovation is the source of urban economic vitality, the driving force for economic development and productivity growth, and the driving force for national prosperity and social progress. Through the above studies, the number of patent applications in terms of innovation capacity has become the driving force of innovation to drive economic vitality. Therefore, in order to enhance economic vitality, scientific and technological development can be promoted, scientific research and patents can be encouraged.

5. Technology education

Modern science and technology have become the decisive factor affecting economic growth, and the contribution of scientific and technological progress to economic growth has been ahead of labor and capital. High-tech and its industries are the locomotive of contemporary economic development. The development of high-tech and its industries has become a general worldwide trend. The level of high-tech development has become a major factor in a country's overall national strength and an important indicator of whether a country is developed or not. The social function of education is to train talents for the development of the country and serve its political and economic development. Therefore, it is urgent to improve science and technology and education.

4.4.2 Provide development suggestions

1. Improve economic efficiency

(1) Improve the efficiency of economic output

In order to increase the per capita GDP of the region, it is necessary to start from improving the regional GDP. Therefore, in the development of various industries, large and medium-sized enterprises should continue to play a leading role in the market economy and use science and technology to enhance production Ability; small businesses should get preferential treatment from the market and increase the market share of SMEs, thereby forming a multi-level market structure.

(2) Actively and vigorously develop the tertiary industry

The tertiary industry is an important symbol of a country's economic development. Compared with the primary and secondary industries, the tertiary industry has the characteristics of less investment, shorter cycles, quicker results, and higher wages for employees. Moreover, the increase in the proportion of the tertiary industry will increase the level of productivity and efficiency of the entire society.

(3) Strengthen the primary and secondary industries

The primary industry and the secondary industry are the basis for the development of the tertiary industry. Therefore, while adjusting the economic structure and improving the competitiveness of the industry, it is also necessary to strengthen the primary industry and expand the scale of the secondary industry.

2. Improve residents' quality of life

(1) Increase social security and social average wage

Beijing needs to expand demand, increase the total social production, and promote the income of employed people, thereby improving the living standards of residents, forming a virtuous circle, which can reduce the income gap between cities and promote economic development.

(2) Implementation of related policies and financial subsidies

Actively encourage insurance companies to launch preferential and practical products to satisfy families with poor economic conditions, to ensure that more residents enjoy benefits and enhance the happiness of residents, so as to enhance the vitality and influence of the city and lay a good foundation for the sustainable development of the city's economy basis.

(3) Improve green forest coverage

In order to enhance the region's sustainable development capabilities, coordinated economic, social, environmental, and resource development must be achieved. Therefore, while developing the economy, it is necessary to intervene in the external environment of the city, improve the quality of life of the people, and indirectly improve the city Competitiveness.

3. Increase investment

(1) Improve innovation ability

Regions should vigorously introduce advanced technology and experience to enhance their own technological innovation capabilities. Not only that, we should actively use Beijing's abundant resource endowments to become a technological spillover area and a limited innovation area from the perspective of manpower and material resources.

(2) Increase investment in education and research

Only by increasing investment in scientific research and actively carrying out technological innovation activities can we attract high-tech talents. At the same time, we must establish a talent introduction mechanism, a talent training mechanism, and a talent use mechanism, and establish an economic zone test zone preparation and adjustment system to solve the uneven distribution of high-tech talents. And improve competitiveness, so that the economic benefits of enterprises throughout the region continue to grow.

Finally, the government needs to continuously adjust and optimize the industrial structure, improve the overall happiness of the society, increase the average wage level of the society, increase investment in science and technology and education, improve the economic benefits of industrial enterprises above designated size, and strengthen the opening-up of cities. In order to increase the economic vitality of Beijing and promote the rapid development of Beijing's economy, aspects such as degree of employment, expansion of employment, and increase of income of employed persons will be shown to the city's good capacity for sustainable development and strong competitiveness.

5 Evaluation and promotion of models

5.1 Advantages of the model

1. Use the idea of dimensionality reduction to extract useful information from multi-dimensional data

and reduce complexity.

2. Finding artifact variables from multi-dimensional data and scientifically evaluating objective phenomena.

3. Vector autoregression does not need to specify which variables are endogenous or exogenous, and VAR allows the value of a variable to depend on its own lag and the lag of other variables. Therefore, the model provides a rich structure to capture more data features. And VAR-generated predictions are usually better than traditional structural models.

5.2 Model Disadvantages

1. The interpretation of the components is generally somewhat vague, not as clear and precise as the meaning of the original variables. This is the price that has to be paid in the process of reducing the dimension of the variables.

2. When the sign of the factor load of the principal component is positive or negative, the comprehensive evaluation function is not very clear.

5.3 Generalization of the model

1. The evaluation model can be used in evaluation models such as comprehensive national strength and urban competitiveness.

2. The vector autoregressive prediction model can be used in the prediction model of the impact of large events on various industries in the region.

6 References

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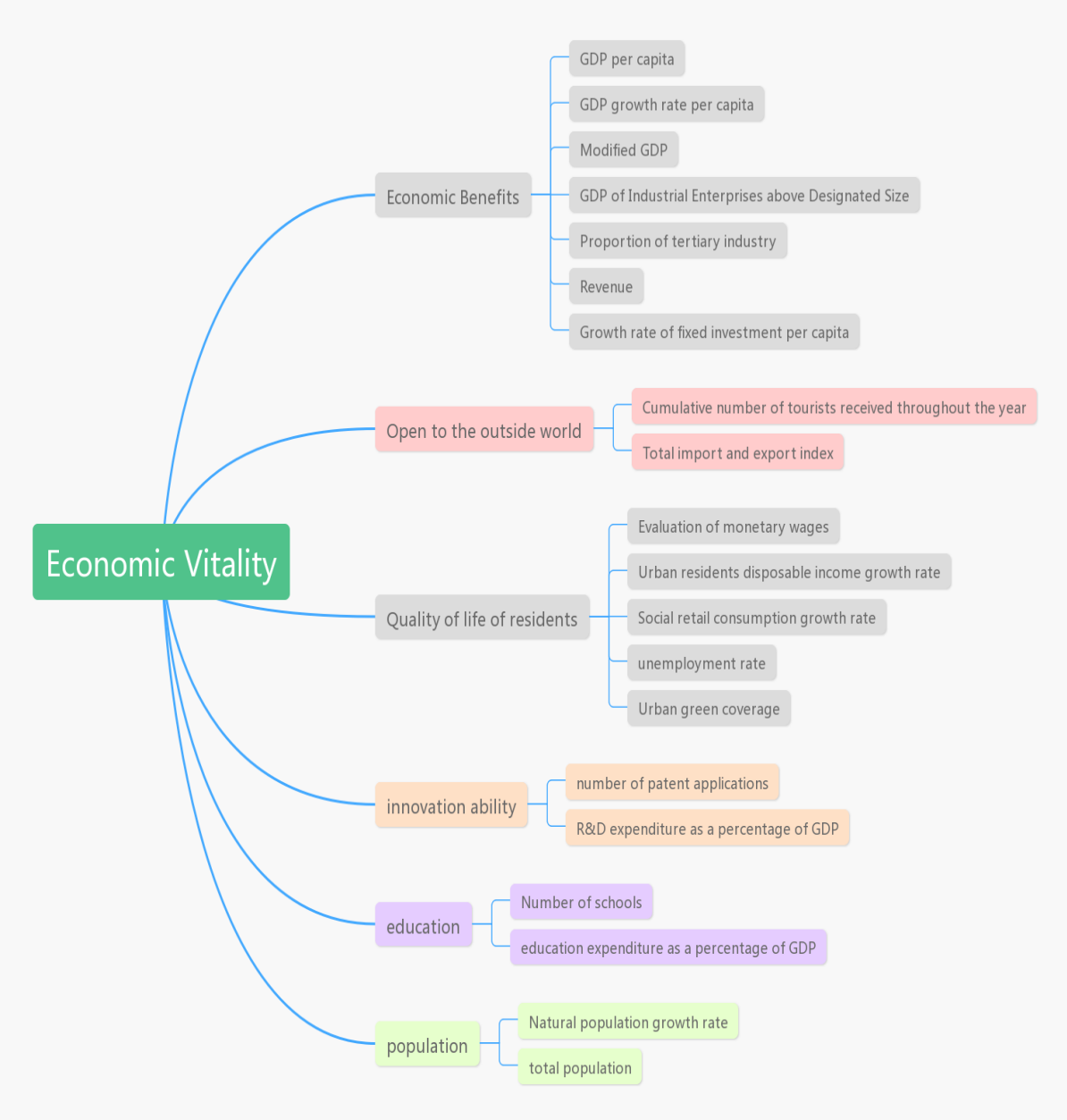
7 Appendix

7.1 Map of Economic Vitality Indicators



7.2 Matlab code

QUESTION 1:

```
clc,clear
gj=xlsread('first.xlsx','B2:G11');
gj=zscore(gj);
r=corrcoef(gj);
[x,y,z]=pcacov(r)
f=repmat(sign(sum(x)),size(x,1),1);
x=x.*f
num=3;
df=gj*x(:,[1:num]);
tf=df*z(1:num)/100;
[stf,ind]=sort(tf,'descend');
stf=stf', ind=ind'
```

QUESTION 2

Data

	Map of economic vitality indicators	GDP growth rate per capita	Modified GDP	GDP of Industrial Enterprises above Designated Size	Proportion of tertiary industry	Revenue
1990	4635	5.2	4.751423	625.9	58.22614	18.81589
1991	5494	9.9	5.3521	730.2	59.07873	16.79412
1992	6458	11.3	6.452229	860	59.93132	18.81589
1993	8006	12.3	7.447059	1166.6	60.78391	16.79412
1994	10240	13.7	9.169736	1576.6	61.6365	18.81589
1995	12690	12	12.85337	1493.3	62.48909	16.79412
1996	14380	9.8	16.17384	1590.6	63.34169	18.81589
1997	16778	10.2	19.91263	1819.7	64.19428	16.79412
1998	19361	9.6	23.49805	1947	65.04687	18.81589
1999	21684	11	26.97316	2183.5	65.89946	16.79412
2000	24518	12	31.04155	2842	65.14319	18.81589
2001	27430	11.8	36.56547	3270.1	67.41727	16.79412
2002	31307	11.8	44.76578	3620.2	69.47573	18.81589
2003	35450	11.1	50.93912	4410.8	69.0059	16.79412
2004	41809	14.3	61.03861	5733.3	68.31951	18.81589
2005	47127	12.3	70.35862	6946.2	70.13902	16.79412
2006	52964	12.8	82.38454	8209.997	72.27207	18.81589
2007	61470	14.4	98.3584	9648.4	73.85297	16.79412

2008	66098	9	108.392	10413.1	75.83243	18.81589
2009	68406	10	126.0812	11039.13	76.05588	16.79412
2010	75573	10.4	141.0313	13699.8	75.69035	18.81589
2011	83547	8.1	157.4612	14513.6	76.61923	16.79412
2012	89778	8	177.6389	15596.21	77.06624	18.81589
2013	97178	7.7	196.8064	17370.88	77.60646	16.79412
2014	102869	7.4	215.9852	18452.9	78.0233	18.81589
2015	109603	6.9	232.669	17449.6	79.73045	16.79412
2016	118198	6.8	253.1469	18087.27	80.23217	18.81589
2017	128994	6.7	274.9254	18901.07	80.6	16.79412
2018	140211	6.6	295.8049	19212.91	81	18.81589

Growth rate of fixed investment per capita	Cumulative number of tourists received throughout the year	Total import and export index	Natural population growth rate	total population	Evaluation of monetary wages	Urban residents disposable income growth rate
28.45878	3967.818	-17.369	7.23	1086	2653	13
7.142857	4599.45	2.523223	2.21	1094	2877	2
38.54167	5231.082	3.056914	3.11	1102	3402	7.2
54.28571	5862.714	11.74662	3.19	1112	4780	16.6
58.08967	6913	3.452349	3.2	1125	6540	14.8
29.70099	6527	28.23448	2.8	1251.1	8144	4.5
4.206774	7901.9	-20.8364	2.68	1259.4	9579	5.4
9.613411	8450.8	3.650228	1.89	1240	11019	1.2
20.22472	8951.5	0.38686	0.7	1245.6	12285	6.7
1.298027	9512.4	12.63168	0.9	1257.2	13778	8.5
10.83205	10468.1	43.77506	0.9	1363.6	15726	9.8
17.9667	11292.8	4.24628	0.8	1385.1	19155	9.3
18.54296	11810.4	1.955804	0.87	1423.2	21852	10.5
18.89434	8885.1	30.46337	-0.09	1456.4	25312	12
17.20829	12265.5	38.06641	0.74	1492.7	29674	12.4
11.82217	12862.9	32.70469	1.09	1538	34191	12.1
19.25226	13590.3	25.91915	1.28	1601	40117	13.1
17.6	14715.5	22.12344	3.33	1676	46507	8.3
-3	14560	40.78353	3.3	1771	54913	7.8
26.24139	16669.5	-20.9435	3.33	1860	58140	10.7
13.0722	18390.1	40.44408	2.98	1961.9	65683	7
13.3	21404.4	29.14588	4.02	2018.6	75834	7.2
9.3	23134.6	4.8	4.74	2069.3	85307	7.3
8.8	25189	5.4	4.41	2114.8	93997	7.1
7.5	26149.7	-3.4	4.83	2151.6	103400	7.2

5.7	27279	-23.1	3.01	2170.5	113073	7
5.9	28531.5	-11.6	4.12	2172.9	122749	6.9
5.7	29746.2	14.6	3.76	2170.7	134994	7
-9.9	31093.58	27.4	2.66	2154.2	149843	6.2

Social retail consumption growth rate	unemployment rate	Urban green coverage	number of patent applications	R&D expenditure as a percentage of GDP	Number of schools	education expenditure as a percentage of GDP
17.06242	0.3	28	4284	1.0032	8807	1.285875
18.31353	0.4	28.43	4624	1.222523	8496	1.251737
23.19373	0.36	30.33	6316	1.441846	8052	1.270218
21.51093	0.41	31.33	6972	1.661169	7789	1.429011
25.42539	0.41	32.39	6852	1.880492	7574	1.55736
23.976	0.46	32.68	6362	2.099815	7158	1.456103
11.70034	0.58	33.24	6595	2.319138	7121	1.508282
13.8376	0.73	34.22	6313	2.538461	6858	1.579371
13.66156	0.66	35.6	6321	3.57889	6456	1.709891
9.87915	0.62	36.3	7723	3.458413	5807	1.861542
9.898629	0.76	36.5	10344	4.84623	5458	2.072345
10.41177	1.18	38.78	12174	4.540452	4873	2.456747
9.490008	1.35	40.57	13842	4.994078	4447	2.800541
14.54718	1.43	40.87	17003	5.020508	4158	3.150906
14.35413	1.3	41.91	18402	5.14047	3971	3.351276
10.5	2.11	42	22572	5.314744	3782	3.489753
12.8	1.98	42.5	26555	5.208794	3751	3.464722
16	1.84	43	31680	5.232971	3593	3.388276
20.8	1.82	43.5	43508	5.443297	3508	3.250361
15.7	1.44	44.4	50236	5.383952	3425	3.102978
17.3	1.37	45	57296	5.690655	3330	2.945247
10.8	1.39	45.6	77955	5.632953	3367	2.866506
11.6	1.27	46.2	92305	5.794864	3314	2.811791
8.7	1.21	46.8	123336	5.829038	3439	2.78624
8.6	1.31	47.4	138111	5.781953	3437	2.76359
7.3	1.39	48.4	156312	5.843291	3454	2.734153
6.5	1.41	48.4	177497	5.783508	3524	2.707851
5.2	1.43	48.42	185928	5.64	3556	2.675003
2.7	1.4	48.44	211212	6.17	3585	2.697674

Matlab Code

```
clc,clear
data=[4635 5.2 4.75142315 625.9 58.22613642 0.188158946 28.5 3967.8
    -17.4 7.23 1086.0 2653 13.0 17.1 0.30 28.0 4284 1.00
    8807 0.012858748
5494 9.9 5.352100089 730.2 59.07872806 0.167941226 7.1 4599.5 2.5
    2.21 1094.0 2877 2.0 18.3 0.40 28.4 4624 1.22 8496
    0.012517367
6458 11.36.452229299 860.0 59.93131969 0.155887745 38.5 5231.1
    3.1 3.111102.0 3402 7.2 23.2 0.36 30.3 6316 1.44 8052
    0.012702178
8006 12.3 7.447058824 1166.6 60.783911330.167219589 54.3 5862.7
    11.73.19 1112.0 4780 16.6 21.5 0.41 31.3 6972 1.66 7789
    0.014290108
10240 13.7 9.169735789 1576.6 61.63650297 0.105238802 58.1
    6913.0 3.5 3.20 1125.0 6540 14.8 25.4 0.41 32.4 6852 1.88
    7574 0.0155736
12690 12.0 12.85336743 1493.3 62.4890946 0.108376998 29.7 6527.0
    28.2 2.80 1251.1 8144 4.5 24.0 0.46 32.7 6362 2.10 7158
    0.014561026
14380 9.8 16.17383513 1590.6 63.34168624 0.1115346264.2 7901.9 -20.8
    2.68 1259.4 9579 5.4 11.70.58 33.2 6595 2.32 7121
    0.015082817
16778 10.2 19.91263058 1819.7 64.19427787 0.086951545 9.6 8450.8
    3.7 1.89 1240.0 11019 1.2 13.8 0.73 34.2 6313 2.54 6858
    0.01579371
19361 9.6 23.49804688 1947.0 65.04686951 0.095357826 20.2 8951.5
    0.4 0.70 1245.6 12285 6.7 13.7 0.66 35.6 6321 3.58 6456
    0.017098908
21684 11.026.97316103 2183.5 65.899461150.103692648 1.3 9512.4 12.6
    0.90 1257.2 13778 8.5 9.9 0.62 36.3 7723 3.46 5807
    0.018615415
24518 12.0 31.04154589 2842.0 65.1 0.107382968 10.8 10468.1 43.8
    0.90 1363.6 15726 9.8 9.9 0.76 36.5 10344 4.85 5458
    0.020723453
27430 11.836.56547042 3270.1 67.41726527 0.120472692 17.96670264
    11292.8 4.246279844 0.8 1385.1 19155 9.3 10.411768251.18 38.78 12174
    4.540451951 4873 0.024567468
31307 11.844.765784113620.2 69.47572913 0.121471793 18.54295982
    11810.4 1.955804237 0.87 1423.2 21852 10.5 9.490007644 1.35
    40.57 13842 4.994077584 4447 0.02800541
35450 11.150.93912176 4410.8 69.00589722 0.11609098618.89433941
    8885.1 30.46337417 -0.09 1456.4 25312 12 14.54717734 1.43 40.87
    17003 5.020508219 4158 0.031509063
```

41809 14.3 61.03861386 5733.3 68.31951052 0.120762705 17.20828891 12265.5 38.06640959 0.74 1492.7 29674 12.4 14.35412948 1.3 41.91 18402 5.140469559 3971 0.033512762
47127 12.3 70.35862069 6946.2 70.139021140.128715658 11.822173 12862.9 32.70469295 1.09 1538 34191 12.1 10.5 2.1142 22572 5.31474397 3782 0.034897529
52964 12.8 82.38453915 8209.99684 72.27207274 0.134392368 19.25226372 13590.3 25.91915304 1.28 1601 40117 13.1 12.8 1.98 42.5 26555 5.208794329 3751 0.03464722
61470 14.4 98.35839844 9648.4 73.85297099 0.148198453 17.6 14715.5 22.1234367 3.33 1676 46507 8.3 16 1.84 43 31680 5.23297117 3593 0.033882757
66098 9 108.3920076 10413.1 75.83242919 0.161281601 -3 14560 40.78352666 3.3 1771 54913 7.8 20.8 1.82 43.5 43508 5.443297466 3508 0.032503614
68406 10 126.0812183 11039.1290676.05587872 0.163202351 26.24139275 16669.5 -20.94345133 3.33 1860 58140 10.7 15.7 1.44 44.4 50236 5.383951578 3425 0.031029785
75573 10.4 141.03125 13699.8 75.69034797 0.162996482 13.07220484 18390.1 40.4440829 2.98 1961.9 65683 7 17.3 1.37 45 57296 5.690655418 3330 0.02945247
83547 8.1 157.461174214513.6 76.61923245 0.180797335 13.3 21404.4 29.14588325 4.02 2018.6 75834 7.2 10.8 1.39 45.6 77955 5.632952729 3367 0.028665065
89778 8 177.6389158 15596.21 77.06624102 0.180649152 9.3 23134.6 4.8 4.74 2069.3 85307 7.3 11.61.27 46.2 92305 5.794864445 3314 0.028117914
97178 7.7 196.8063892 17370.88 77.60646058 0.180083226 8.8 25189 5.4 4.41 2114.8 93997 7.1 8.7 1.21 46.8 123336 5.829037888 3439 0.027862398
102869 7.4 215.9852362 18452.9 78.02330107 0.183519032 7.5 26149.7 -3.4 4.83 2151.6 103400 7.2 8.6 1.31 47.4 138111 5.781953294 3437 0.027635899
109603 6.9 232.6689587 17449.6 79.73045317 0.199439324 5.7 27279 -23.1 3.01 2170.5 113073 7 7.3 1.39 48.4 156312 5.843290545 3454 0.027341534
118198 6.8 253.1469428 18087.272 80.23216993 0.197952382 5.9 28531.5 -11.6 4.12 2172.9 122749 6.9 6.5 1.41 48.4 177497 5.783508167 3524 0.027078513
128994 6.7 274.9254171 18901.0708 80.6 0.193853628 5.7 29746.2 14.6 3.76 2170.7 134994 7 5.2 1.43 48.42 185928 5.64 3556 0.026750035
140211 6.6 295.804878 19212.90785 81 0.190828417 -9.9 31093.58084 27.4 2.66 2154.2 149843 6.2 2.7 1.4 48.44 211212 6.17 3585 0.026976743

```
];
num=15;
data(:,[2,9,10,13])=[];
data(:,[5,6,8,10,11,14,15,16])=[];

data=[(1990:2018)',data];
%%
[row,col]=size(data);
coeff=zeros(col-1,col-1);
p=zeros(col-1,col-1);
for i=1:col-1
    for j=1:col-1
    [coeff(i,j),p(i,j)] = corr(data(:,1+i) , data(:,1+j) , 'type' , 'Spearman');
    end
end
%%
YF=xlzhg(data(1:18,:),3);
error=zeros(3,8);
for i=1:3
for j =1:8
    error(i,j)=(YF(i,j)-data(17+i,j+1))/data(17+i,j+1);
end
end
error_avg=zeros(1,3);
for i=1:3
    error_avg(i)=sum(error(i,:))/num;
end
```

```
clc,clear
%%
gj=xlsread('2t.xlsx','B3:I31');
% gj=zscore(gj);
load YF.mat
xy1=zscore([gj;YF]);
gj=xy1([1:29],:);
r=corrcoef(xy1(1:29,:));
[x,y,z]=pcacov(r)
f=repmat(sign(sum(x)),size(x,1),1);
x=x.*f
num=2;
df=gj*x(:,[1:num]);
tf=df*z(1:num)/100;
[stf,ind]=sort(tf,'descend');
stf=stf', ind=ind'
%%
```

```
xishu=x(:,[1,2]);
pf=zeros(1,10);
for k=1:10
    pf1=0;
    pf2=0;
    for j=1:8
        pf1=pf1+xishu(j,1)*xy1(k+29,j);
        pf2=pf2+xishu(j,2)*xy1(k+29,j);
    end
    pf(k)=(0.955642*pf1+0.037229*pf2)/(0.955642+0.037229);
end
pf=pf'
scatter(2009:2018,df(20:29));
hold on;
scatter(2009:2018,pf);
hold on;
plot(2009:2018,df(20:29));
hold on;
plot(2009:2018,pf);
```

```
function [YF,changshu,xishu]=xlzhg(data,yc_num)
date=data(:,1);
data1=data(:,2:end);
ld=data1; %
[n,p]=size(ld);

x=zeros(n,p);
h=zeros(p,1);
pValue=zeros(p,1);
stat=zeros(p,1);
cValue=zeros(p,1);
for i=1:p
    x(:,i)=ld(:,i);
end

for i=1:p
    [h(i,:),pValue(i,:),stat(i,:),cValue(i,:)] = adftest(x(:,i),'model','ARD','lags',2);
end
fprintf('\n');
fprintf('-------------------------ADF TEST-------------------------\n');
fprintf('%4s%12s%15s%15s','h','TJL','LJZ','p ');
fprintf('\n');
for i = 1:p
    fprintf('%.4f%13.4f%17.4f%17.4f\n',h(i,:),stat(i,:),cValue(i,:),pValue(i,:));
end
```

```
[h,pValuet,statt,cValue] = jcitest(ld,'model','H1','test','trace');
[h,pValuem,statm,cValue] = jcitest(ld,'model','H1','test','maxeig');
%%建立模型
ld1=ld; %
Md0 = varm(p,0);
EstMd0 = estimate(Md0,ld1);
summarize(EstMd0);
Mdl = varm(p,1);
EstMdl = estimate(Mdl,ld1);
summarize(EstMdl);
isStable1 = isstable(EstMdl)
YF = forecast(EstMdl,yc_num,ld(n,:));
%%
fprintf('\n------------------------------------------------------------FORECAST-------------------------------
----------------------------\n');

fprintf('%3s%10s','TYPE','YEAR');
for i =1:p
    fprintf('%10s',strcat('y',num2str(i)));
end
fprintf('\n');
%------------------------------------------------------------
fprintf('%3s%14.0f','TRUE-VALUE',date(n));
for i =1:p
    fprintf('%11.4f',ld(n,i));
end
fprintf('\n');
for i=1:yc_num
    fprintf('%3s%14.0f','PREDICT-VALUE',date(n)+(i-1)*(data(2,1)-data(1,1)));
    for j =1:p
        fprintf('%11.4f',YF(i,j));
    end
    fprintf('\n');
end

changshu = EstMdl.Constant
xishu = EstMdl.AR{1, 1}
end
```

```
clc,clear
data=[4635  5.2  4.75142315  625.9   58.22613642    0.188158946    28.5    3967.8
    -17.4   7.23    1086.0  2653    13.0    17.1    0.30    28.0    4284    1.00
    8807    0.012858748
     5494   9.9  5.352100089    730.2   59.07872806    0.167941226    7.1  4599.5
    2.5  2.21    1094.0  2877    2.0  18.3    0.40    28.4    4624    1.22    8496
```

0.012517367
6458 11.36.452229299 860.0 59.93131969 0.155887745 38.5
5231.1 3.1 3.111102.0 3402 7.2 23.2 0.36 30.3 6316 1.44 8052
0.012702178
8006 12.3 7.447058824 1166.6 60.783911330.167219589 54.3
5862.7 11.73.19 1112.0 4780 16.6 21.5 0.41 31.3 6972 1.66
7789 0.014290108
10240 13.7 9.169735789 1576.6 61.63650297 0.105238802 58.1
6913.0 3.5 3.20 1125.0 6540 14.8 25.4 0.41 32.4 6852 1.88
7574 0.0155736
12690 12.0 12.85336743 1493.3 62.4890946 0.108376998 29.7
6527.0 28.2 2.80 1251.1 8144 4.5 24.0 0.46 32.7 6362 2.10
7158 0.014561026
14380 9.8 16.17383513 1590.6 63.34168624 0.1115346264.2 7901.9 -20.8
2.68 1259.4 9579 5.4 11.70.58 33.2 6595 2.32 7121
0.015082817
16778 10.2 19.91263058 1819.7 64.19427787 0.086951545 9.6
8450.8 3.7 1.89 1240.0 11019 1.2 13.8 0.73 34.2 6313 2.54
6858 0.01579371
19361 9.6 23.49804688 1947.0 65.04686951 0.095357826 20.2
8951.5 0.4 0.70 1245.6 12285 6.7 13.7 0.66 35.6 6321 3.58
6456 0.017098908
21684 11.026.97316103 2183.5 65.899461150.103692648 1.3 9512.4 12.6
0.90 1257.2 13778 8.5 9.9 0.62 36.3 7723 3.46 5807
0.018615415
24518 12.0 31.04154589 2842.0 65.1 0.107382968 10.8 10468.1
43.8 0.90 1363.6 15726 9.8 9.9 0.76 36.5 10344 4.85 5458
0.020723453
27430 11.836.56547042 3270.1 67.41726527 0.120472692 17.96670264
11292.8 4.246279844 0.8 1385.1 19155 9.3 10.411768251.18 38.78 12174
4.540451951 4873 0.024567468
31307 11.844.765784113620.2 69.47572913 0.121471793 18.54295982
11810.4 1.955804237 0.87 1423.2 21852 10.5 9.490007644 1.35
40.57 13842 4.994077584 4447 0.02800541
35450 11.150.93912176 4410.8 69.00589722 0.1160909818.89433941
8885.1 30.46337417 -0.09 1456.4 25312 12 14.54717734 1.43 40.87
17003 5.020508219 4158 0.031509063
41809 14.3 61.03861386 5733.3 68.31951052 0.120762705
17.20828891 12265.5 38.06640959 0.74 1492.7 29674 12.4
14.35412948 1.3 41.91 18402 5.140469559 3971 0.033512762
47127 12.3 70.35862069 6946.2 70.139021140.128715658 11.822173
12862.9 32.70469295 1.09 1538 34191 12.1 10.5 2.1142 22572
5.31474397 3782 0.034897529
52964 12.8 82.38453915 8209.99684 72.27207274 0.134392368

```
19.25226372 13590.3 25.91915304 1.28 1601 40117 13.1 12.8
1.98 42.5 26555 5.208794329 3751 0.03464722
61470 14.4 98.35839844 9648.4 73.85297099 0.148198453 17.6
14715.5 22.1234367 3.33 1676 46507 8.3 16 1.84 43 31680
5.23297117 3593 0.033882757
66098 9 108.3920076 10413.1 75.83242919 0.161281601 -3 14560
40.78352666 3.3 1771 54913 7.8 20.8 1.82 43.5 43508
5.443297466 3508 0.032503614
68406 10 126.0812183 11039.1290676.05587872 0.163202351
26.24139275 16669.5 -20.94345133 3.33 1860 58140 10.7 15.7
1.44 44.4 50236 5.383951578 3425 0.031029785
75573 10.4 141.03125 13699.8 75.69034797 0.162996482 13.07220484
18390.1 40.4440829 2.98 1961.9 65683 7 17.3 1.37 45 57296
5.690655418 3330 0.02945247
83547 8.1 157.461174214513.6 76.61923245 0.180797335 13.3 21404.4
29.14588325 4.02 2018.6 75834 7.2 10.8 1.39 45.6 77955
5.632952729 3367 0.028665065
89778 8 177.6389158 15596.21 77.06624102 0.180649152 9.3
23134.6 4.8 4.74 2069.3 85307 7.3 11.61.27 46.2 92305 5.794864445
3314 0.028117914
97178 7.7 196.8063892 17370.88 77.60646058 0.180083226 8.8 25189
5.4 4.41 2114.8 93997 7.1 8.7 1.21 46.8 123336 5.829037888 3439
0.027862398
102869 7.4 215.9852362 18452.9 78.02330107 0.183519032 7.5 26149.7
-3.4 4.83 2151.6 103400 7.2 8.6 1.31 47.4 138111 5.781953294 3437
0.027635899
109603 6.9 232.6689587 17449.6 79.73045317 0.199439324 5.7 27279
-23.1 3.01 2170.5 113073 7 7.3 1.39 48.4 156312 5.843290545
3454 0.027341534
118198 6.8 253.1469428 18087.272 80.23216993 0.197952382 5.9
28531.5 -11.6 4.12 2172.9 122749 6.9 6.5 1.41 48.4 177497
5.783508167 3524 0.027078513
128994 6.7 274.9254171 18901.0708 80.6 0.193853628 5.7 29746.2 14.6
3.76 2170.7 134994 7 5.2 1.43 48.42 185928 5.64 3556
0.026750035
140211 6.6 295.804878 19212.90785 81 0.190828417 -9.9 31093.58084
27.4 2.66 2154.2 149843 6.2 2.7 1.4 48.44 211212 6.17 3585
0.026976743
];
data(:,[2,9,10,13])=[];
data(:,[5,6,8,10,11,14,15,16])=[];
data=[(1990:2018)',data];
YF=xlzhg(data(1:20,:),10);
%%
```

```
for i=1:8
    figure(i)
    plot(2009:2018,YF(:,i))
    hold on;
    plot(2009:2018,data(20:29,i+1));
    hold on;
    scatter(2009:2018,YF(:,i));%yuce
    hold on;
    scatter(2009:2018,data(20:29,i+1));
    legend('P-V','T-V','P-V','T-V');
end
```

QUESTION 3

```
clc,clear
gj=xlsread('first.xlsx','B2:G11');
A=xlsread('附件 3.xlsx','B2:G20');
gj=zscore(gj);
r=corrcoef(gj);
[x,y,z]=pcacov(r)
f=repmat(sign(sum(x)),size(x,1),1);
x=x.*f
num=3;
df=A*x(:,[1:num]);
tf=df*z(1:num)/100;
[stf,ind]=sort(tf,'descend');
stf=stf', ind=ind'
xlswrite('attachment3.xlsx',tf,'H2:H20')
```

```
clc,clear
[data,text]=xlsread('Q3FINAL.xlsx','Sheet5');
m=size(data,1);
x=zscore(data(:,1:end-1));
n=size(x,2);
y=data(:,end);          %
r=corrcoef(x);     %
[vec1,val,con1]=pcacov(r);
con1
num=input('number of factors：');
a=vec1*diag(sqrt(val));
am=a(:,1:num);
[bm,t]=rotatefactors(am,'method','varimax');

bt=[bm,a(:,num+1:end)];
con2=sum(bt.^2);
```

```
rate=con2(1:num)/sum(con2);
res1=cell(num+1,3);
res1(2:end,1)=num2cell(con2(1:num)');
res1(2:end,2:3)=num2cell([rate',cumsum(rate')]);
disp('res1=');disp(res1)

varname=text(1,2:end-1)';
res2=cell(n+1,num+1);
str2='factorF';
% res2{1,1}='标准化指标';
for i=1:num
    res2{1,i+1}=strcat(str2,num2str(i));
end
res2(2:end,1)=varname;
res2(2:end,2:end)=num2cell(bm);
disp('res2=');disp(res2)

coef=inv(r)*bm;
res3=cell(num+1,n+1);
res3(1,2:end)=varname;
str3='factorF';

for i=1:num
    res3(i+1,1)=cellstr(strcat(str3,num2str(i)));
end
res3(2:end,2:end)=num2cell(coef');
disp('res3=');disp(res3)

score=x*coef;    %
weight=rate/sum(rate);
Fscore=score*weight';
[st,id]=sortrows([Fscore,score],-1);
res4=cell(m+1,3+num);
str41='facorF';
str42='grade';

for i=1:num
    res4{1,i+1}=strcat(strcat(str41,num2str(i)),str42);
end
res4{1,num+2}='score';
res4{1,num+3}='ranking';
companyname=text(2:end,1);   %
res4(2:end,1)=companyname(id);
res4(2:end,2:end)=num2cell([st(:,2:2+(num-1)),st(:,1),sort(id)]);
```

```
disp('res4=');disp(res4)
```