Team Number:	98440

Problem Chosen:	B

2019APMCM summary sheet

Evaluation of regional economic vitality

Regional economic vitality is an important part of regional comprehensive competitiveness. How to grasp the key factors to improve the economic vitality of a city is a subject worthy of study.

For problem **I**, in order to improve the vitality of regional economy, we look up data from the China Yearbook. Using AHP to establish the model, and according to the data in the paper and the data obtained by our own survey, the factors that affect the regional economic vitality are divided into three first level indicators, eight second level indicators and 16 third level indicators for modeling. Then we find that the larger the ratio between the number of labor force and the number of the elderly is, the larger the number of enterprises to continue to exist is, the more registered capital of enterprises is, and the better the regional economic vitality is.

For problem **II**, we choose a Liaoning area, according to the data of our survey, we choose the "Two Child Policy" for analysis. We set up a population structure change model based on age structure, gender ratio, urban-rural structure, population density and natural growth rate. After that, we set up the population structure prediction based on Malthus theory to predict the population gender ratio and the urban-rural ratio. Finally, we calculated the total dependency ratio and the ratio of the old to the young before and after the implementation of the "Two Child Policy" and reflected the local economic vitality through the dependency ratio. We analyzed the short-term and long-term changes.

For problem **III**, we have established a comprehensive strength evaluation model for regional economic development. Based on the data in the Yearbook 2010-2016, we have established the entropy weight TOPSIS model to determine the weights of two secondary indicators and seven tertiary indicators. We have calculated and ranked the cities in Annex 3 according to our evaluation system. We have obtained that Beijing, Shanghai, Shenzhen are in the first place and Kunming, Shenyang is in the last place.

For problem **IV**, according to the conclusions for Problems 1-3, we provide a development proposal for Liaoning Province to enable the economic vitality in this region to present the benign sustainable development and the regional competitiveness is stronger.

Key words：Analytic hierarchy process; Entropy weight TOPSIS；MATLAB

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§ 1 Introduction

1.1 Restatement of the problem

The regional economic vitality is a vital part of regional comprehensive competitiveness. It is a worth study to figure out how to improve the regional economic vitality. In this problem, the APMCM expects us to develop a mathematical model to analyze and solve this question. There are three detailed questions. First, build a suitable relational model of influencing factors of economic vitality and analyze some concrete influence factors. Second, analyze the short-term and long-term effects of economic policies transformation on the economic vitality of a specific region. Third, select a suitable index system, establish the mathematical model which analyzes and measures the regional economic vitality. And finally, according to the models that we have established, provide a development proposal for the specific region mentioned in the Problem 2 to improve the economic vitality and the regional competitiveness.

1.2 Model-related concepts

1.2.1 Analytic Hierarchy Process

Analytic Hierarchy Process[1] (AHP) is a decision-making method that decomposes the elements that are always related to decision-making into objectives, criteria, schemes and other levels, on which can carry out qualitative and quantitative analysis.

AHP is a hierarchical weight decision-making analysis method. It is characterized by making use of less quantitative information to mathematicise the thinking process of decision-making on the basis of in-depth analysis of the nature, influencing factors and their internal relations of complex decision-making problems, so as to provide a simple decision-making method for complex decision-making problems with multi-objective, multi-criteria or no structural characteristics. It is especially suitable for situations where the decision results are difficult to measure directly and accurately.

1.2.2 TOPSIS

The full name of the **TOPSIS** is **Technique for Order Preference by Similarity to an Ideal Solution**[2]. It was first proposed by C. L. Hwang and K. Yoon in 1981. TOPSIS ranks a limited number of evaluation objects according to their proximity to idealized objectives. It is a relatively good or bad evaluation among existing objects.

§ 2 Assumptions of the model

★ As the impact of population migration on the population is small, we may as well ignore the population migration. This is reasonable for areas with a large population base.

★ It is assumed that there will be no special events (such as large-scale war, severe plague, large-scale natural disasters, etc.) with great impact on the population during the forecast period.

★ The two child policy only affects the birth rate.

★ It is assumed that the data used in this model are all true and effective, and have statistical analysis value.

★ All models are based on the premise of long-term stability of population policy.

★ Experience vitality is determined only by the indicators involved[3].

§ 3 Symbol description

The main symbols and their meanings in this paper are shown in **Table 1**.

Table 1:Symbols and significance of the main variables

Symbol	Unit	Symbol description
$\bar{x}$	1	Average value
C	1	Survival rate
A_i	1	Age index
B_i	1	Sex ratio
D_i	1	Population density
E_i	1	Natural growth rate
X_i	1	Population proportion

§ 4 Model establishment and solution

4.1 Problem I: Build a model to describe the economic vitality

The economic vitality determines the ability and the potential of a region's sustained economic growth[4]. From the macroscopic point of view, this kind of ability and potential show the ability of self-accumulation, self-transformation and self-development of economic entities; from the microscopic point of view, they show the ability of competition, market adaptability and attraction to the economic elements of economic entities. The analysis and evaluation of the economic vitality of a region can accurately indicate the current situation of its economic vitality and has important guiding significance for further stimulating the economic vitality.

In our paper, the modeling of factors affecting economic vitality will mainly focus on element attraction, economic sustainable development and residents' living quality as the first level index[5].

4.1.1 Factors of The Economic Vitality

There are four factors of the economic vitality[6]: the economic development, the element attraction, the residents' living quality and the technical progress.

★ The economic development

The economic development refers to the potential and power of economic growth, focusing on the ability of sustainable growth. The economic development includes economic aggregate and its growth rate. Economic aggregate is the foundation of future economic development, the foundation of economic vitality, and the economic growth rate is the most direct embodiment of the release of economic vitality. In the process of economic development, the scale economy based on the economic aggregate can spontaneously guide the agglomeration of economic elements, improve the efficiency of economic output, and then support the sustainable economic growth.

★ The element attraction

The element attraction is embodied in the attraction of capital, labor force, enterprises and other factors of production as well as the use efficiency of these factors. Labor determines the endogenous power of economy and is the basis of economic vitality. The size of economic vitality of a region is closely related to the flow and composition of talents. Capital is the driving force to promote economic development. It is an important issue for an economic entity to solve in the process of development whether it can raise sufficient funds for economic development. Enterprises are the unit cells of economic vitality, and also the basis of expanding investment, expanding production scale and improving production level. The quantity and quality of enterprises directly determine the economic strength of a region and play a very important role in economic growth.

★ The residents' living quality

The residents' living quality is the embodiment of the overall development of economy and culture in a region, which is mainly composed of residents' income and consumption. To a certain extent, the income of residents reflects the quality of regional labor force, and the increase of residents' income is the basis of expanding market demand and realizing a virtuous economic cycle. The consumption of residents is the basic guarantee to improve their living quality. The economic vitality of a region is closely related to the consumption of residents.

★ The technological progress

The technological progress is an important source of economic growth, including the diffusion of new products, industries and technologies. According to the neoclassical economic growth theory, technological progress can improve the position of the growth curve by changing

the production function without increasing the input of factors, so as to achieve long-term growth. On the one hand, technological progress promotes sustained economic growth by improving factor production efficiency; on the other hand, it accelerates economic growth by optimizing economic structure.

4.1.2 The Establishment of Economic Vitality Evaluation System

★ The Establishment Principles

▲ Scientific nature

In the economic vitality evaluation system, the indexes involved should have the functions of description, evaluation and interpretation, which can fully reflect and indicate the connotation of economic vitality. It is necessary to systematically and accurately understand and grasp the essence of economic vitality from a scientific point of view. In the selection of specific indicators, we should emphasize the comprehensiveness of indicators, avoid using fuzzy indicators and try to use quantitative analysis indicators.

▲ Feasibility

The feasibility principle refers to the fact that the indexes listed have certain reality and the evaluation method has certain operability.

▲ Integrality

Index system can comprehensively reflect the phenomenon studied.

▲ Practicality

The evaluation of economic activities is a changing process with different characteristics in different stages.

★ Index Selection

Combined with the previous analysis, this paper selects indicators from the aspects of element attractiveness, sustainable economic growth and residents' life.

▲ Sustainability of economic growth

It mainly reflects the potential and development potential of economic growth, which can be divided into economic benefit index and financial guarantee index. Economic benefit mainly refers to the quality of regional economic growth. Achieving quality growth is an important basis for maintaining sustainable economic growth; financial guarantee is used to measure the ability of local governments to obtain financial resources and develop local economy, which reflects economic reserve for regional development.

▲ Element attraction

It mainly reflects the attraction of regions to capital, labor and enterprises. An economy with economic vitality should be attractive to the factors of production with strong liquidity.

▲ Residents' life

It mainly reflects the quality of life of residents, including income and consumption. A region with economic vitality should enable residents to maintain a long-term stable quality of life.

★ Weight Determination

In this paper, the weight selection of economic vitality evaluation index is mainly determined by *The Entropy Method*[7], and the weight of the first level index is obtained by summing up the weights of similar indexes. The principle and steps of *The Entropy Method* are as follows:

If there are n observations and P indexes, then X_{ij} is the j th index of the i th observation ($i = 1, 2, 3, 4 \ldots \mathrm{n}; \mathrm{j} = 1, 2, 3, 4 \ldots \mathrm{P}$), for a given j, the greater the difference between X_{ij}, the greater the comparative effect of this index on the system, that is, the more information this index contains and transmits. The increase of information means the decrease of entropy, which can be used to measure the amount of information. The steps of using *The Entropy Method* to determine the weight selection of economic vitality are as follows[8]:

Step 1: Calculate the characteristic specific weight of the i th observation value under the j th index.

$$\mathrm{P}_{ij} = \mathrm{X}_{ij} / \sum_{i=1}^{n} \mathrm{X}_{ij}$$

where

P_{ij} ------ the characteristic specific weight of X_{ij}

X_{ij} ------the initial value

Step 2: Calculate the information entropy of index j.

$$\mathrm{e}_j = -\mathrm{K} \sum_{i=1}^{n} \mathrm{X}_{ij} \ln \mathrm{X}_{ij}$$

$$\mathrm{K} = 1 / \ln \mathrm{n}$$

Step 3: Calculate the difference coefficient of index X_{ij}.

$$\mathrm{d}_j = 1 - \mathrm{e}_j$$

The information utility value of an index depends on the difference coefficient of that index. Its value directly affects the weight. The larger the information utility value is, the more important it is to the evaluation and the greater the weight is.

Step 4: Calculate the weight of index X_{ij}.

$$w_j = d_j / \sum_{i=1}^{n} d_j$$

★ **Evaluation method**

The evaluation of economic vitality is expressed by economic vitality index. In the process of index calculation, the value of each index will be calculated, and the comprehensive index of economic vitality will be synthesized by the weight of each index. The value of each index indicates the change degree of the indicator. In addition, the inverse indexes such as consumption of ten thousand-yuan GDP, Engel coefficient and average value of regional environmental noise are dealt with by the reciprocal method.

4.1.3 The Analytic Hierarchy Process Model

There are four steps to build the AHP model:

Step 1: Build hierarchical structure model;

Step 2: Construct all judgment matrices in each level;

Step 3: Hierarchical single ordering and consistency test;

Step 4: Overall arrangement and consistency test.

The following describes the implementation process of these four steps:

★ **Top Level**

There is only one element in this layer, generally it is the predetermined goal or ideal result of analyzing the problem, so it is also called the goal level.

★ **Middle Level**

This level includes the intermediate links involved in the realization of goals. It can be composed of several levels, including the criteria and sub criteria to be considered, so it is also called the criteria level.

★ **Bottom Level**

This level includes a variety of measures and decision-making plans that can be selected to achieve the goal, so it is also called measure level or plan level.

This is the schematic diagram of the AHP model we have established:

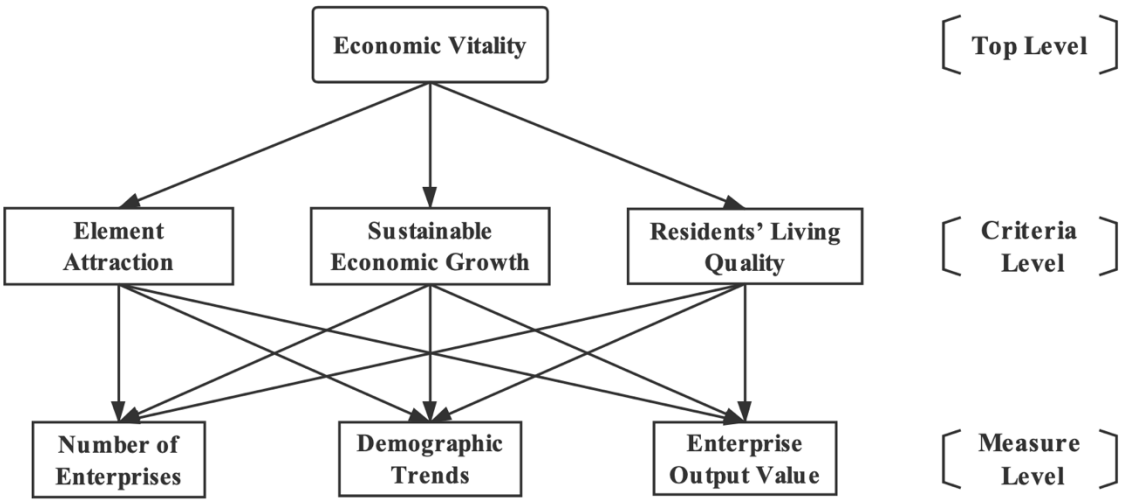

Figure 1: Schematic diagram of the AHP model

When comparing the importance of the element i and element j with that of the first element in the upper layer, we use a_{ij} to describe the quantitative relative weight. If there are n elements involved in comparison, we call "$A = (a_{ij})_{n*n}$" pairwise comparison matrix.

The value of a_{ij} in pairwise comparison matrix can be assigned according to the following scales according to Satty's proposal. (T.L. Saaty- American Operations Research Scholar in the mid-1970s) a_{ij} takes the value between 1-9 and its reciprocal.

▲$a_{ij} = 1$, element i and element j are of the same importance to the factors at the upper level;

▲$a_{ij} = 3$, element i is slightly more important than element j;

▲$a_{ij} = 5$, element i is more important than element j;

▲$a_{ij} = 7$, element i is much more important than element j;

▲$a_{ij} = 9$, element i is extremely more important than element j;

▲$a_{ij} = 2n$, n=1,2,3,4 the importance of elements i and j lies between $a_{ij} = 2n - 1$ and $a_{ij} = 2n + 1$;

▲$a_{ji} = \frac{1}{a_{ij}}$, if and only if the ratio of the importance of elements i and j is a_{ij}.

Table 2: Judgment matrix of criteria level

A	B_1	B_2	B_3	B_4	B_5	B_6
B_1	1	1	1	4	1	1/2
B_2	1	1	2	4	1	1/2
B_3	1	1/2	1	5	3	1/2
B_4	1/4	1/4	1/5	1	1/3	1/3
B_5	1	1	1/3	3	1	1
B_6	2	2	2	3	3	1

Table 3: Judgment matrix of measure level

B_1	C_1	C_2	C_3	B_2	C_1	C_2	C_3	B_3	C_1	C_2	C_3
C_1	1	1/4	1/2	C_1	1	1/4	1/5	C_1	1	3	1/3
C_2	4	1	3	C_2	4	1	1/2	C_2	1/3	1	1/7
C_3	2	1/3	1	C_3	5	2	1	C_3	3	1	1
B_4	C_1	C_2	C_3	B_5	C_1	C_2	C_3	B_6	C_1	C_2	C_3
C_1	1	1/3	5	C_1	1	1	7	C_1	1	7	9
C_2	3	1	7	C_2	1	1	7	C_2	1/7	1	1
C_3	1/5	1/7	1	C_3	1/7	1/7	1	C_3	1/9	1	1

Table 4: Index and weight

First Level Index	Second Level Index	Third Level Index	Weight
The Element attraction (49%)	Assets	Total Fixed Assets	
		Proportion of Fixed Assets	
	Labor	Number of the Unemployed	
		Average Wage of the Employed	
	Enterprises	Number of New Enterprises	
		Number of Surviving Enterprises	
	Upgrading of Industrial Institutions	Product	
		GDP of Characteristic Industries	
Sustainable Economic Growth (37%)	Economic Performance	Per Capita GDP Growth Rate	
		Consumption of 10000 Yuan GDP	
	Financial Guarantee	Public Budget Expenditure	
		Public Budget Revenue	
The Residents' Living Quality (14%)	Household Income	Per Capita Disposable Income	
		Per Capita GDP	
	Household Consumption	Engel Coefficient	
		Annual Per-Capita Consumption	

4.2 Problem II: Economic policies on the economic vitality

This problem requires us to analyze the effects of economic policies transformation on the economic virality of specific region. We take the economic policy "Two-child Policy" on the Liaoning Province as an example to build a model to explain this question: whether to implement the "Two-child Policy" may have different effect on the population structure of the Liaoning Province, and the transformation of population structure may have different effect on the economic vitality. So, we just need to build a model to analyze the effect of this policy on the population structure. After that, we can bring the results into the AHP model (Problem 1) and finally get the impact of economic policy on the economic vitality.

There are four steps to do:

Step 1: Establish the index system of sustainable development of population structure, the

relevant indexes should be scientific, representative and comprehensive;

Step 2: Establish the Population Prediction Model.

Step 3: Assume that the "Two-child Policy" is not implemented in Liaoning Province, predict the trend of population structure change in the next 20 years;

Step 4: Under the "Two-child Policy" in Liaoning Province, predict the trend of population structure change in the next 20 years.

4.2.1 The Establishment of Population Structure Evaluation System

Population structure, also known as population composition, refers to the result of dividing population by different standards. It reflects the proportion relations of different regulations within the population of a certain region, time and place. According to the natural, social and regional characteristics of the population itself, it divides the population into the proportion of each component.

There are five criteria that can be included in the indicator system of sustainable development: age structure, gender structure, urban & rural structure, population density and natural growth rate.

★ Age structure

From the perspective of economic development, the higher the proportion of the population in the 15-64 age group, the better. But from the perspective of sustainable development, the age structure most conducive to sustainable development is stable. In other words, the closer the age structure is to the stable type, the better. Here we can use the Picard son correlation coefficient to express. But the range of the correlation coefficient of Picard son is: - 1 ~ 1, where - 1 is the negative correlation, so we need to improve the model. The improved correlation coefficient of Picard son is expressed as:

$$r_{xy} = \frac{\sum(x-\bar{x})(y-\bar{y})}{(\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2})(\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2})}$$

$$A_i = \frac{r_{xy}+1}{2}$$

★ Gender structure

In order to improve the fertility efficiency and make the society develop harmoniously and stably, the closer the male to female ratio is, the better. In order to represent the gender ratio in the sustainable development of population structure, we construct the following functions:

$$B_i = 1 - \frac{s_i - 1}{\max(s_i) - 1}$$

★ **Urban & rural population structure**

Reasonable urbanization can improve the environment and promote economic development. In the current situation, the higher the level of urbanization, the better the sustainable development of population structure. Therefore, we can simply express this indicator as the proportion of urban population C_i.

★ **Population density**

Population density has a great influence on the sustainable development of population structure, but due to the difference of regional environment, it is difficult to have a reasonable standard of population density, so we need to deal with this standard as follows: $D_i = 0$.

★ **Natural growth rate**

For the serious situation of aging population in China, although the population problem is already a problem that cannot be ignored, it is unreasonable to blindly reduce the population, so improving the population structure on the basis of controlling the population is the best choice to realize the sustainable development of population structure. Therefore, the closer the natural growth rate is to 0, the better it is. So it can be simply expressed as:

$$E_i = 1 - |gr_i|$$

4.2.1.1 Gender Structure Prediction

Based on the Malthus model to predict the trend of population gender ratio, the founder of the model initially used it to predict the trend of population development. After years of verification, the data predicted by Malthus model will be more reliable.

Suppose that the change rate of population sex ratio in unit time is directly proportional to the current population sex ratio, namely:

$$\frac{dX}{dt} = RX$$

$$X(t) = X_0$$

Where R is the growth rate, $X(t)$ is the sex ratio of the population at the time of t, easy to obtain:

$$X(t) = X_0 e^{Rt}$$

Based on the population sex ratio from 2010 to 2016, using MATLAB to solve the above formula, $R = -0.0018$, where $X(t) = 106.81$, is the population sex ratio in 2010. So, we can get the population forecast of 2010-2025.

Table 5: Prediction results of population sex ratio in 2010-2029 based on Malthus theory

Year	2010	2011	2012	2013	2014	2015	2016	2017
Sex ratio	106.41	106.65	106.48	106.32	106.18	106.01	105.68	105.37
Year	2018	2019	2020	2021	2022	2023	2024	2025
Sex ratio	105.5	105.34	105.18	105.02	104.69	104.69	104.21	103.89

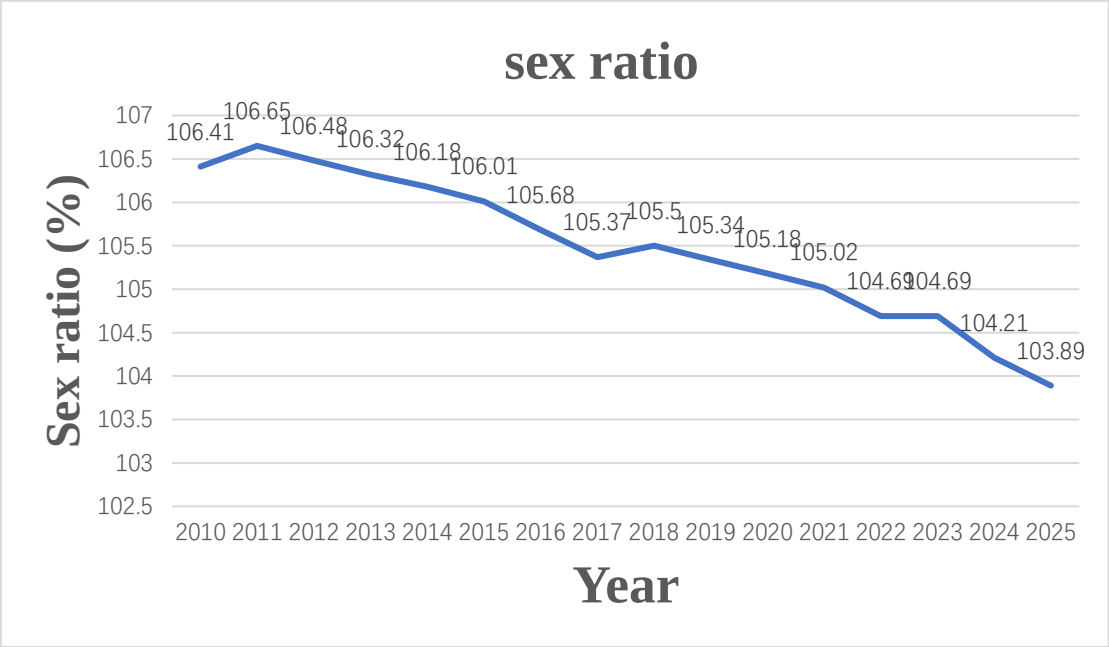

Figure 2: Trends of population gender change from 2010 to 2025

4.2.1.2 Urban & Rural Population Structure Prediction

The proportion of non-agricultural population and agricultural population is an important indicator of population structure. Although it is different from the proportion of urban and rural population, to some extent, it reflects the process of urbanization in the region. In the following, based on the application of artificial neural network in time series prediction, we predict the future development trend of non-agricultural and agricultural population ratio in this region.

The migration of population between urban and rural areas is a complex dynamic problem. The ratio of non-agricultural population to agricultural population in each year is a non-linear time series which is difficult to deal with. It has strong anti-interference ability and stability to use neural network method to predict.

The ratio of non-agricultural population to agricultural population in 2010-2016 is regarded as a set of time series, with every three-consecutive data as input and the next data as output to establish NAR neural network for prediction. The main parameters of the network are set as follows:

The number of neurons in the hidden layer is 8, the transfer function of the two layers is logsig and purelin respectively, and the training function is the default trainlm. The result is

displayed once every 100 rounds, the learning rate is 0.05, the maximum training times is 1000, and the mean square error is 6×10^{-4}. As shown in the figure, the result of nerve training is good, and the fitting degree is high.

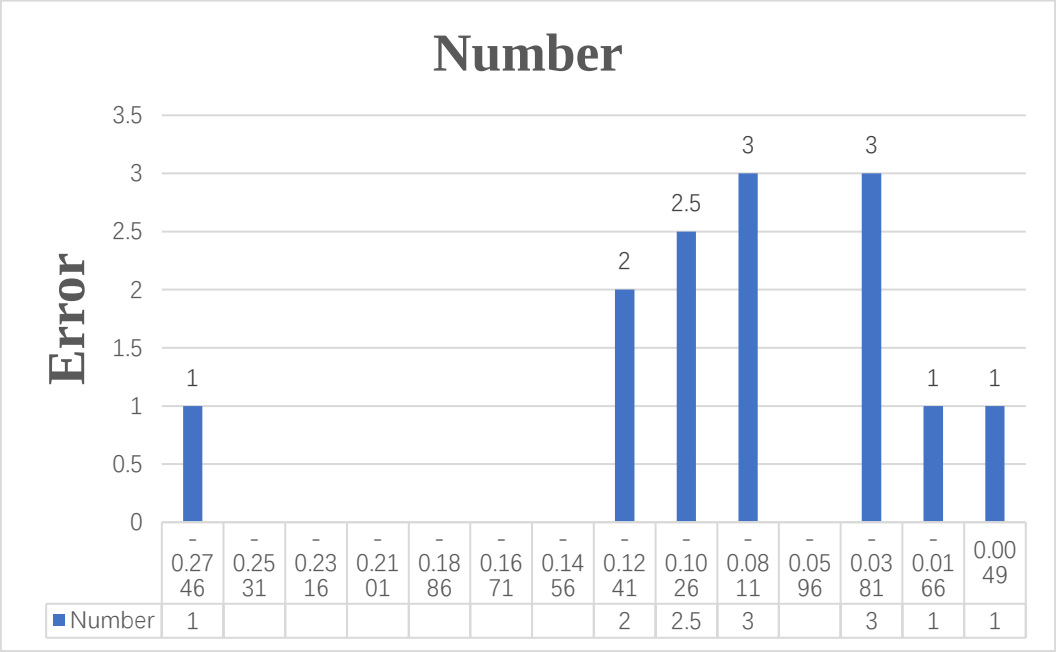

Figure 3: Error histogram

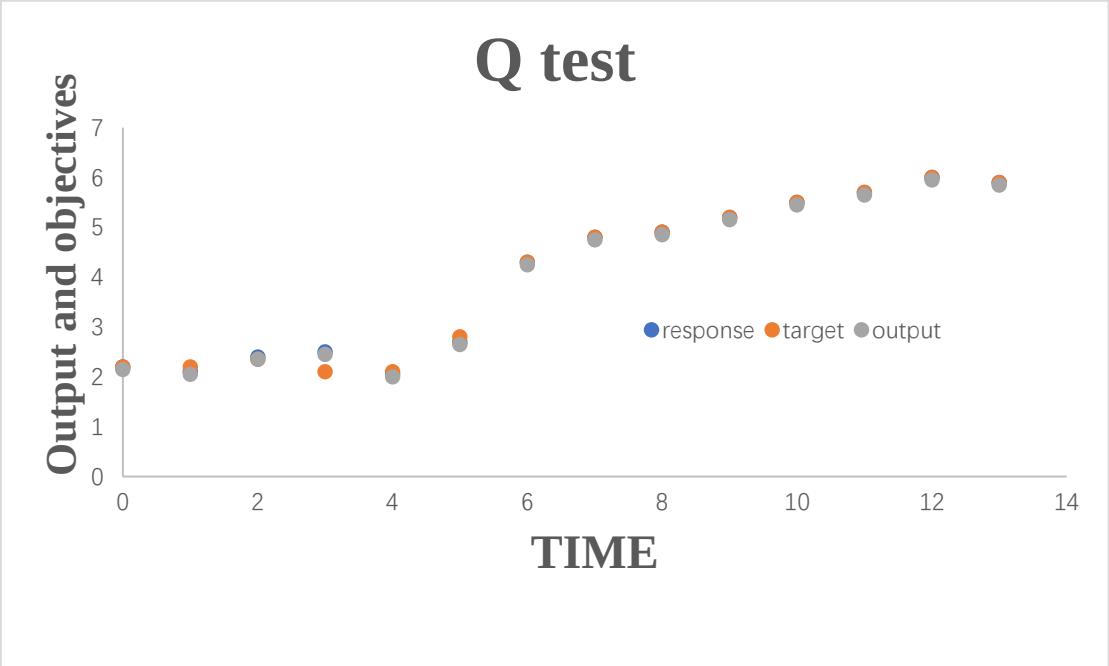

Figure 4: Trend comparison chart

On the basis of well-trained neural network, the future population ratio of cities and towns in this area is predicted:

Table 6: Prediction results of population ratio between urban and rural areas in 2010-2025 based on artificial neural network

Year	2010	2011	2012	2013	2014	2015	2016	2017
Population ratio	6.223	6.458	6.446	6.856	7.158	7.187	7.635	7.79
Year	2018	2019	2020	2021	2022	2023	2024	2025
Population ratio	7.771	7.85	7.85	7.833	7.86	7.861	7.862	7.862

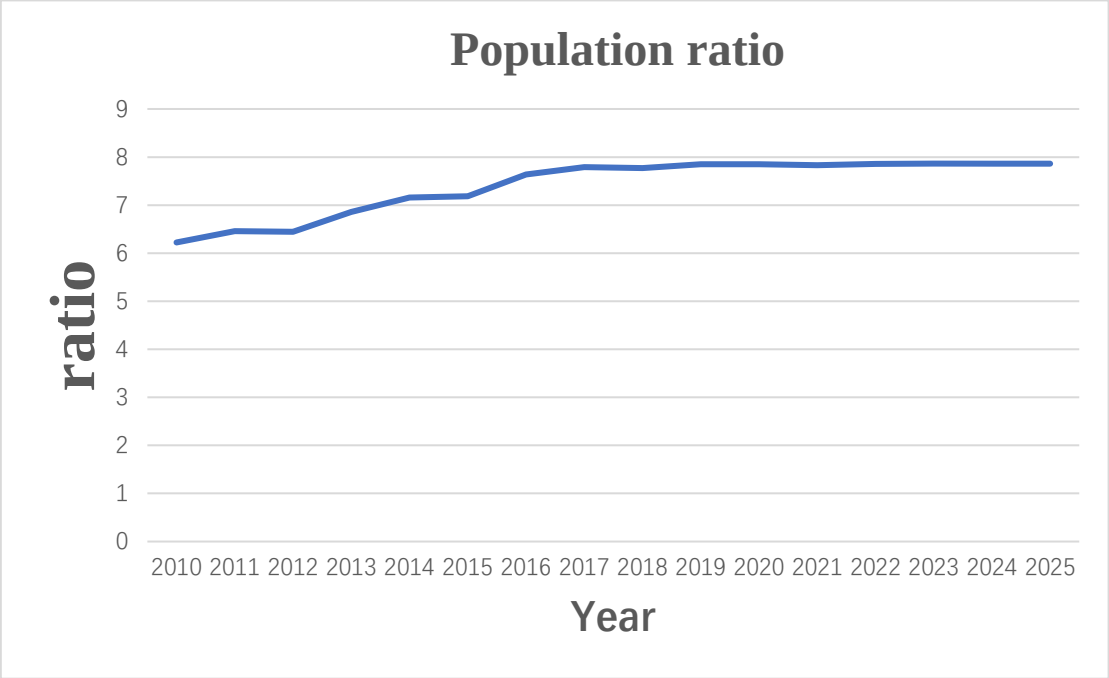

Figure 5: Population ratio of urban and rural areas from 2010 to 2025

4.2.2 Population Structure Model Based on Leslie Matrix

According to one age group every five years, we divide 0-94 years into 19 groups, for example, the first age group is 0-4 years old, the second age group is 5-9 years old, the third age group is 10-14 years old, ..., the 19th age group is 90-94 years old, and the 20th age group is 95 years old and above. Here, we introduce the parameter g, and set g as the ratio of fertility rate in the future to that in the current population, and $g \in$ (0.8, 1.9). Obviously, under the condition of a certain average fertility rate, we can change the number of children born by each couple by changing the value g, and the value g is roughly equal to the number of children born by each couple divided by the total fertility rate (total fertility rate It refers to the average number of children per woman during the childbearing age of women in this country or region). The average fertility vector of women of childbearing age in each age group within five years should actually be

$$B = g \times [B_1, B_2, \cdots B_x]$$

All the newborns survived in t stage was divided into $t+1$ age group, and the survival rate vector of each age group in five years was $[S_1, S_2, \cdots S_{20}]$. Moreover, the $k-1$ age group survived to $t+1$ age group is k age group ($k = 1, 2, 3, \cdots 19$), and those survived in 20 age group after five years still belong to 20 age group. If we use Leslie matrix to build the model, it must satisfy:

$$z_1(t+1) = \sum_{k=1}^{20} p_k g M_k c_k [z_{k1}(t) + z_{k2}(t)]$$

$$z_{12}(t+1) = \sum_{k=1}^{20} (1-p_k) g M_k c_k [z_{k1}(t) + z_{k2}(t)]$$

$$z_k(t+1) = s_{k-1} z_{k-1}(t+1)$$

$$z_{20}(t+1) = s_{19} z_{19}(t) + s_{20} z_{20}(t)$$

$$c_k = z_{(k-1)2} / (z_{(k-1)1} + z_{(k-1)2})$$

$$M_k = M_{k-1} - 0.001$$

We use the data in the Yearbook of 2016 in Liaoning Province to establish the survival rate and fertility rate vector and use Matlab to solve the above equation one by one.

It can be seen that in 2016, the total fertility rate was 1.258. According to the statistics of the National Bureau of statistics, the implementation of family planning, an average couple only had 1.3 children, we adjusted the g-value to 1.048

Because of the popularization of high school education and the increase of gross enrollment rate, most people work only when they are 20 years old. In this paper, the population aged 20-64 is regarded as "labor force", and the population over 65 is regarded as "old people". We introduce the concept of dependency ratio and the child aged ratio:

$$Total\ Dependency\ Ratio = \frac{Population_{aged\ 1-19} + Population_{aged\ over\ 65}}{Population_{aged\ 24-64}}$$

$$Child\ aged\ ratio = \frac{Population_{aged\ over\ 65}}{Population_{aged\ 1-19}}$$

So, we get the population structure trend in 2016-2025.

Table 7: Trend of population structure change in the future without the "Two Child Policy"

Year	Age 0-19	Age 20-64	Age over 65	Total Dependency Ratio	Child Aged Ratio
2016	701358	2190168	542535	0.5679	0.7736

2017	648382	2133653	644745	0.60601	0.9944
2018	581525	2023458	775607	0.6707	1.3337
2019	528062	1893947	882752	0.7449	1.6717
2020	486416	1806298	908246	0.7721	1.8673
2021	461052	1694760	913358	0.811	1.9807
2022	438378	1529743	944141	0.9038	2.1537
2023	408068	1386916	943935	0.9748	2.3132
2024	372203	1312340	874315	0.9507	2.3421
2025	341011	1248649	794260	0.9042	2.3219

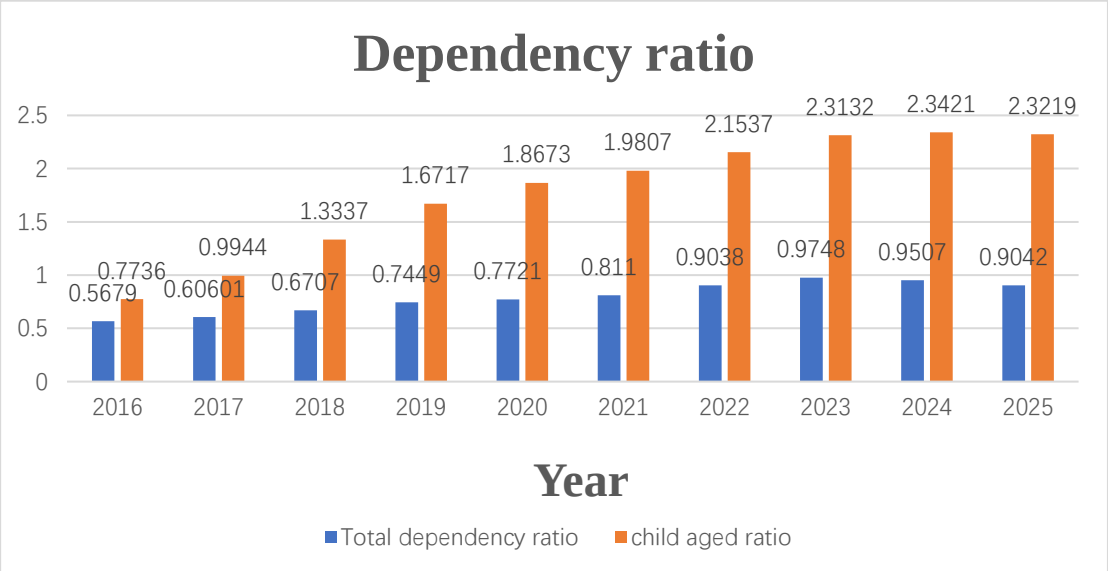

Figure 6: The dependency ratio at fertility rate 1.4

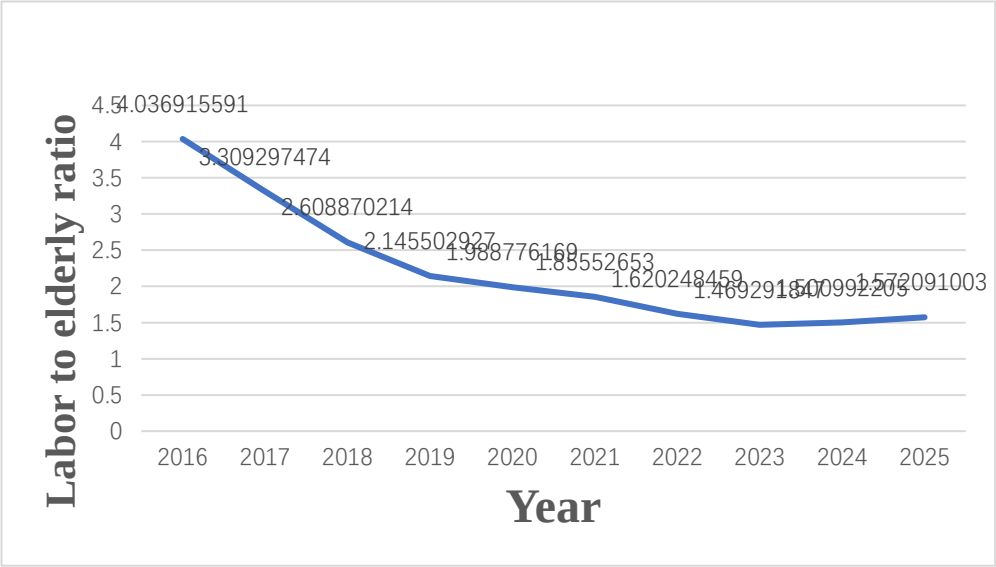

Figure 7: Labor to elderly ratio at fertility rate 1.4

According to results, we can draw the conclusion:

When the two-child policy is not implemented in Liaoning Province, the number of people

of all age groups is greatly reduced. Although the purpose of family planning to control population growth is achieved, the degree of inhibition is still too large. The total dependency ratio is not the lower the better. Between 70% and 80% is most conducive to economic development, employment and social stability (too low, less dependent population leads to insufficient domestic demand, more "idle" people, and high unemployment pressure). The total dependency ratio of the United States and developed countries (as a whole) has been between 70% and 80% for a long time. India's total dependency ratio will remain around 70% for a long time due to the slow decline of fertility rate. Like the United States, employment can be met by domestic demand alone. The proportion of men and women in Liaoning area tends to the ideal 103:100 slowly. The ratio of the old to the young tends to be 2.35:3.6:1. In general, the population of Liaoning Province will be in recession in the next 10-20 years, which will affect economic development, create less GDP, and also need to support the elderly and children.

★ The Optimal Leslie Model When Implement "Two Child Policy"

After the implementation of the "Two Child Policy", the maximum population Z-potential is bound to increase, but the maximum population cannot be unlimited growth. Therefore, in the optimization model, we assume that the correlation coefficient r_{xy} of the two is greater than 0.8.

We optimize the population structure of Liaoning Province after the implementation of the "Two Child Policy" according to the model objective.

Table 7: Proportion of all age groups in the total population after the "Two Child Policy"

Age group	Proportion of total population	Age group	Proportion of total population
0-4	0.073	50-54	0.065
5-9	0.074	55-59	0.064
10-14	0.072	60-64	0.052
15-19	0.071	65-69	0.04
20-24	0.072	70-74	0.027
25-29	0.07	75-79	0.02
30-34	0.071	80-84	0.014
35-39	0.071	84-89	0.008
40-44	0.067	90-94	0.004
45-49	0.066	95+	0.001

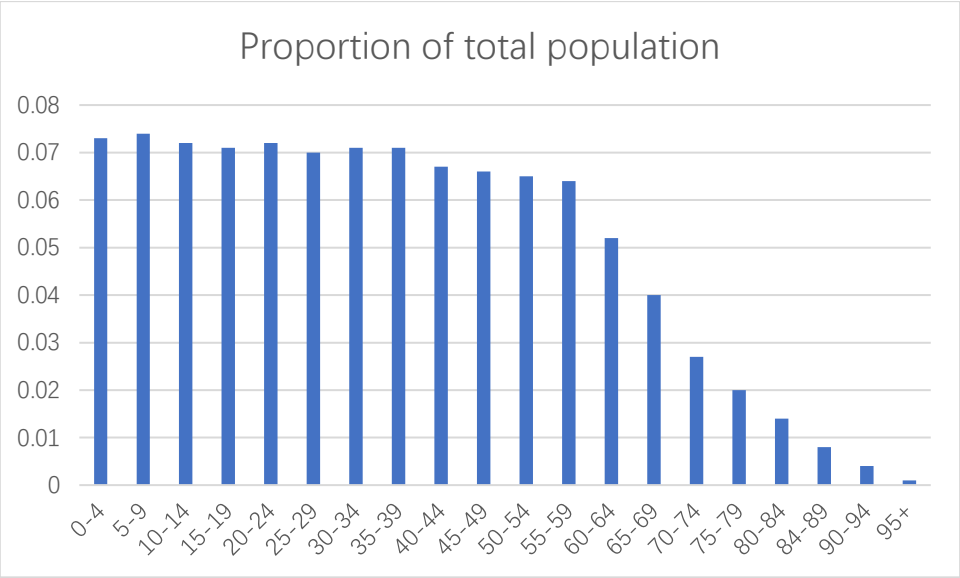

Figure 8: Population model distribution after the implementation of the "Two Child Policy"

4.3 Problem III: Comprehensive evaluation system of regional economic development

4.3.1 Principles of Evaluation System

★ **Scientific principle**

★ **Systematic principle**

★ **Representative principle**

★ **Comparable principle**

★ **Feasibility principle**

4.3.2 Index of Evaluation System

The following mainly uses the research results in the Yearbook 2010-2016, starting from the concept of comprehensive strength of economic development, and comprehensively considering the establishment of a systematic model system, to build two secondary indicators, seven tertiary indicators. This part does not consider some indicators of sustainable development.

4.3.2.1 Index of Economic Strength

★ **Continued stock of enterprises**

★ **Enterprise write off volume**

★ Registered capital

The number of enterprises is an important index to measure the vitality of regional economy. The number of enterprises can directly affect the existing employment opportunities. It promotes the circulation of resources to a large extent and determines the economic benefits of enterprises. Data shows that: in 2009-2018, 31 provinces and municipalities (excluding Hong Kong, Macao and Taiwan) had 40176400 registered enterprises. As of September 2019, 9.7538 million enterprises have been cancelled (cancellation rate is 24.28%), and 30.4226 million existing enterprises have been cancelled.

4.3.2.2 Index of People's Wealth

★ Per capita GDP

GDP per capita refers to the quotient value obtained by dividing the GDP of a region and the total population in a certain period of time. It is the most common indicator to measure the material living standards of residents in the region. Compared with GDP, it can better reflect the per capita economic level of the region. Generally speaking, if GDP per capita increases, it means that consumers can get more goods and services, or their disposable income increases, and consumers are in a more favorable position when they buy.

★ Per capita disposable income

This index is to deduct the remaining income of taxes and social insurance from the total household income, which can reflect the income control freedom of urban population, and thus reflect the actual income and living standard of urban residents. Due to the lack of data in districts and counties and the lack of rural data in some districts and counties, only the per capita disposable income of residents in urban areas is selected as one of the evaluation indexes in this paper.

★ Average wage of employees

In today's economic development mode, the economic output and driving role of urbanization in the process of regional economic development is more and more significant, and the town is also the basis of the development of the second industry and the third industry. The economic income of urban residents' accounts for a large proportion of the income of urban and rural residents, most of which comes from wage income. The average wage of on-the-job employees in urban units can indicate the level of wage income of urban employees in a certain period, which is the main indicator reflecting the wage level of urban employees and helps to understand the wage status of urban residents.

★ Per capita savings balance

Compared with the world average level, China's residents' income has always been characterized by high savings rate and low consumption rate. Especially in recent years, although China's residents' savings rate has been decreasing year by year, it still remains at a

high level. For example, in 2017, China's national savings rate was 47.0%, far higher than the world average savings rate of 26.5%, and also higher than the average of developing economies and developed countries Average level. This shows that urban and rural residents' savings account for a considerable proportion of their economic income and have a large consumption potential. It also provides a reference for understanding people's living surplus level from the side. Therefore, this paper chooses the per capita savings balance of urban and rural residents as one of the indicators to measure people's wealth level.

4.3.3 Entropy Weight-TOPSIS Model

In the following, the entropy weight TOPSIS model is mainly used for calculation and analysis. This method is actually an improvement of the traditional TOPSIS method. The main idea is to first determine the weight of each index by entropy weight method, and then use TOPSIS method for comprehensive evaluation. At the same time, this method uses the idea of objective weighting of entropy weight method and TOPSIS method to approach ideal solution, which can effectively eliminate the influence of human subjective factors and has better effect than the simple entropy weight method and TOPSIS method. The main process of the model is as follows:

Step 1: Determining entropy weight:

▲ Determine the weight of the index value of the j in the i scheme:

$$p_{ij} = x_{ij} / \sum_{i=1}^{n} x_{ij}$$

▲ Determine the entropy value of the j th index:

$$e_j = -\frac{1}{ln\, n} \times \sum_{j=1}^{n} p_{ij}\, ln\, p_{ij}$$

▲ Determine the entropy weight of the j th index:

$$w_j = (1 - e_j) / \sum_{j=1}^{m} (1 - e_j)$$

Step 2: Use TOPSIS method for evaluation:

▲ If there are m schemes and n indexes, then there is a decision matrix $X = (X_{ij})_{m \times n}$. The data of the decision matrix is standardized and the matrix $Y = (Y_{ij})_{m \times n}$ is obtained

▲ Standardized decision matrix after weighted calculation V:

$$V = (v_{ij})_{m \times n} = (w_j y_{ij})_{m \times n}$$

▲ The positive ideal solution and negative ideal solution are calculated by the weighted standardized decision matrix. In TOPSIS method, the monotonicity is usually required. The positive and negative ideal solution formula is as follows:

$$X^+ = (v_1^+, v_2^+, \dots, v_n^+)$$
$$X^- = (v_1^-, v_2^-, \dots, v_n^-)$$

Where

$$v_j^+ = max_{1\le i\le m} v_{ij}, v_j^- = max_{1\le i\le m} v_{ij}$$

▲ Calculate the distance between each scheme and its positive and negative ideal solutions, usually using the Euclidean distance:

$$s_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, i = 1,2, \dots, m$$

$$s_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, i = 1,2, \dots, m$$

▲ Calculate the relative proximity of each scheme:

$$c_i^+ = s_i^- / (s_i^+ + s_i^-)$$

▲ The value of c_i^+ is the comprehensive score index of each scheme. The larger the value of c_i^+ is, the better the scheme is.

4.3.4 Overall Evaluation of Regional Economy

The development of regional economy is a comprehensive concept. It is necessary to consider many aspects of many fields comprehensively and analyze the secondary indicators and the tertiary indicators. The entropy weight TOPSIS Model and 2016 related economic data are used for analysis. The main results obtained in the calculation process are index entropy weight (e-weight), Euclidean distance of positive and negative ideal solutions of each district and county, comprehensive score index, etc. the specific calculation results are shown in the table below.

Table 8: Entropy weight of each index

First Level Index	Second Level Index	Third Level Index	E-Weight
Comprehensive evaluation of regional economic development	Economic level	Continued stock of enterprises	0.134
		Enterprise write off volume	0.235
		Registered capital	0.084
	People's wealth level	Per capita GDP	0.148
		Per capita disposable income	0.256
		Average wage of employees	0.087

		Per capita savings balance	0.056

Table 9: Appendix 3 rating table of each city

City	s+	s-	c+	Ranking
Beijing	0.2348	0.0725	0.2412	1
Shanghai	0.2225	0.0688	0.2389	2
Shenzhen	0.2102	0.0651	0.2366	3
Guangzhou	0.1979	0.0614	0.2343	4
Hangzhou	0.1856	0.0577	0.232	5
Tianjin	0.1733	0.054	0.2297	6
Suzhou	0.161	0.0503	0.2274	7
Wuhan	0.1487	0.0466	0.2251	8
Chengdu	0.1364	0.0429	0.2228	9
Zhengzhou	0.2205	0.0392	0.1241	10
Changsha	0.2182	0.0355	0.1118	11
Nanjing	0.2159	0.0318	0.0995	12
Dongguan	0.2136	0.0281	0.0872	13
Chongqing	0.2113	0.0244	0.0749	14
Xi'an	0.209	0.0207	0.0626	15
Qingdao	0.2067	0.017	0.0503	16
Shenyang	0.2044	0.0133	0.038	17
Ningbo	0.2021	0.0096	0.0257	18
Kunming	0.1998	0.0059	0.0134	19

4.4 Problem IV: Development Proposal

According to the conclusions for Problems 1-3, we will provide a development proposal for Liaoning Province.

★ Comprehensively deepening reform to stimulate market vitality

▲Further deepen the reform of the administrative examination and approval system, streamline administration and delegate power, transform functions, take the initiative to do what we need to do, improve the level of macro-control, maintain a market environment of fair competition, and maximize the vitality of market players.

▲Promote the process of marketization and legalization unswervingly, give full play to the role of market mechanism, create an atmosphere of employment and entrepreneurship, and create a good environment for the development of enterprises, especially private enterprises.

★ Accelerate urban renewal and release industrial development space

▲Accelerate the renewal and renovation of key areas, release industrial space, and accelerate the comprehensive planning of underground space.

▲Continue to optimize the industrial spatial layout and create the electronic information professional market industrial belt, commercial building, high-tech and modern service industrial belt with high standards.

★ Build a diversified innovation system and improve the core technology innovation ability

▲Make full use of the advantages of the host place of the fair to attract more national major scientific and technological infrastructure, new research and development institutions and high-end intellectual property service institutions to settle in and create a high-end innovation cluster area;

▲ Strengthen top-level design, build a policy system for independent innovation, strengthen the use and protection of intellectual property rights, improve the incentive mechanism for technological innovation, and create a good environment for independent innovation.

★ Promote industrial transformation and development and optimize economic structure

▲Focusing on industrial transformation and upgrading, we should cultivate emerging industries, enhance the strength of high-tech industries, strengthen modern business logistics, business services, science and technology services, information services and other emerging services, and foster new economic growth points;

▲Give full play to the adjacent advantages of Free Trade Zone, actively undertake a new round of international high-end industrial transfer, build a "high, new, soft and excellent" industrial system with the theme of international trade and modern logistics and coordinated development of export processing and high-tech manufacturing industry, and stimulate a new round of industrial vitality.

★ Consolidate the development advantage of financial industry and strengthen the position of financial center area

▲Make use of the advantages of Liaoning Stock Exchange to further develop Shenyang into a gathering center of large-scale insurance, securities, funds, banks and other financial institutions, and establish a modern financial organization system with banks, securities, insurance institutions as the main body and other financial institutions coexisting, reasonable structure and complete functions;

▲Take the opportunity of Liaoning International Internet finance industrial park settling in Shenyang, and to build Shenzhen's "Internet Finance CBD" as the goal, and strive to build Shenyang into a leading intelligent and innovative financial characteristic urban area in

Liaoning and even in China.

★ Improve infrastructure and social services and build a first-class urban area with comprehensive environment

▲Continue to adhere to the work concept of people-oriented and people's livelihood first, continue to increase investment in affordable housing, education, social public security, medical and health care, community services, social security and employment, and strive to create a sustainable ecological urban area and build a first-class living environment.

§5 Evaluation of Model

5.1 Advantage

▲ In the model, as many factors affecting future population change are considered as possible, and the changing rules of factors affecting future population change are determined according to the different short-term and long-term predictions, and the parameter models suitable for different prediction methods are found out, so that the evolution rules of medium-term and long-term simulated population can be better carried out, which provides an exciting forecast for future population growth Convincing results, in turn, reflect economic dynamism.

▲ Due to the limited data and large fluctuation, when constructing the Leslie matrix, we synthesize the existing data to reasonably process and simplify the way of various factors acting on the Leslie matrix, so as to achieve a more practical purpose. The results of the model prediction have better accuracy and simplicity.

▲ For the social system with large inertia, the multi factor economic vitality is actually a dynamic simulation of the evolution process of the complex economic vitality system, and finally realizes the prediction of the future economy combined with the trend of factor change shown by the existing data.

7.2 Disadvantage

▲ Leslie model, when analyzing the influence of various factors, only based on the demographic data of all age groups in 2010, combined the population proportion, birth rate and other relevant data of all age groups in 2010 China population Yearbook with the statistical data of Liaoning district. The possible particularity of population structure in Liaoning Province. When the prediction time span is large, the prediction results may not be accurate due to the large change of the situation.

▲ In order to simplify the model, when analyzing the birth ratio of men and women, we

assume that the annual decrease is 0.01 from the current 1.18.

▲ When we consider the time series of the distribution of fertility and mortality by age, we only use the time series of length 4 to predict the age distribution of fertility and mortality in the future time, and it has nothing to do with the time value. This has its shortcomings for long-term population prediction.

▲ The sex ratio at birth and the overall fertility rate are obviously affected by national policies, and it is impossible for the country to let them develop according to the current trend in a short period of time, so it is impossible to accurately consider the impact of this factor when predicting future population changes.

▲ In the long-term prediction, we simply assume that the annual increment of the average life expectancy remains constant, which is different from the annual change of the actual life expectancy.

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