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ARTICLE

Regional Economic Vitality Based on Weighted Grey Relational Analysis

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ABSTRACT

The future development of cities has a great relationship with economic vitality. To determine the size of the economic vitality and its main influencing factors. This article takes some cities in China as examples. First, determine the main factors. Aiming at many factors, this paper starts from the perspective of population changes in different cities and changes in corporate vitality. After applying the rough set theory to objectively evaluate index weights, the main factors are screened out. Then, the weights of the corresponding evaluation indexes of each group of cities are calculated by a multiple linear regression to a weighted index system, and then the cities are ranked using the gray correlation analysis method. Finally, we get the ranking of the economic vitality level of different cities. Finally, suggestions are made based on the weighting factors of major factors and economic vitality.

1. Introduction

With the development of society and the aging of the population, the GDP growth of major cities has generally slowed. The level of cities is obviously hierarchical, and the advantages of cities at the same level are also different. Different places need different development decisions. Regional economic vitality can reflect regional competitiveness to a certain extent. Many regions have introduced many related policies to improve regional economic vitality. The industrial structure and economic conditions in different regions are different, and even the industrial structure and economic conditions of cities at different levels are quite different, which leads to different implementation effects of the same policy in different regions. How to grasp the key factors of regional economic development has become a hotspot in social research.

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2. Data Reprocessing

Take the western region as an example, select five cities in the western region: Xi'an, Chengdu, Chongqing, Kunming, and Guiyang. According to the statistical yearbook of the National Bureau of Statistics and the information in Appendix III, collect relevant data from the perspective of population change and changes in corporate vitality. As shown in Table 1:

Table 1. Raw data table

	City	Xian	Chengdu	Chongqing	Kunming	Guiyang
Demographic change	Total number of colleges and universities	63	56	65	51	36
	Number of enterprises (10,000)	37.5	60.6	69.8	23.5	21.8
	Total number of hospitals and health centers	381	888	1644	419	268
	Natural population growth	0.46%	0.80%	0.88%	0.62%	0.07%
	Population migration rate	0.48%	3.35%	5.45%	4.33%	3.74%
	Disposable income of urban residents (yuan)	41657	38918	34889	42988	35115
Changes in corporate vitality	Number of employees (10,000)	532.92	372.3	1714.5	478.3	271.3
	Business Survival Rate, 2009-2018	72.96%	71.29%	71.59%	70.78%	65.27%
	Proportion of corporate tax	8.68%	11.40%	13.05%	9.05%	14.48%
	Number of national high-tech enterprises (home)	1839	2405	893	929	590
	Number of students in colleges and universities (10,000 people)	76.64	81.74	74.69	54.73	37.9
	Proportion of tertiary industry	61.90%	53.20%	45.40%	49.30%	58.50%

Dimensionless processing of indicators, the formula for dimensionless processing is as follows:

$$P_i = \frac{100 \times D_i}{\sum_{i=1}^{n} D_i} (n = 1,2,\ldots,5) \quad (1)$$

In the formula, it is the dimensionless result, and it is the index raw data. The dimensionless results are as follows:

Table 2. Dimensionless results of raw data

	X1	X2	X3	X4	X5
a_1	23.25	20.66	23.99	18.82	13.28
a_2	17.40	28.42	32.36	11.02	10.23
a_3	10.58	24.67	45.67	11.64	7.44
a_4	16.25	28.26	31.10	21.91	2.47
a_5	2.77	19.30	31.41	24.96	21.56
a_6	21.52	20.11	18.02	22.21	18.14
a_7	15.82	11.05	50.88	14.20	8.05
a_8	20.73	20.17	20.22	20.22	18.95
a_9	15.32	20.12	23.03	15.97	25.56
a_{10}	27.63	36.12	13.42	13.96	8.86
a_{11}	23.53	25.10	22.93	16.80	11.64
a_{12}	23.09	19.84	16.93	18.39	21.82

C1-C12 are indicator codes, and X1-X5 are city codes. According to the dimensionless data distribution, press [0-10] [10-15] [15-20] [20-22] [22-24] [24-26] [26-28] [28-30] [30-25] [35-40] [40-50] [50-60] is divided into 12 segments and discretized, and the results are as follows:

Table 3. Discretized data table

	X1	X2	X3	X4	X5
a_1	5	4	5	3	2
a_2	3	8	9	3	3
a_3	2	6	11	2	1
a_4	3	8	9	4	1
a_5	1	3	9	6	4
a_6	4	4	3	5	3
a_7	3	2	12	2	1
a_8	4	4	4	4	3
a_9	3	4	5	3	6
a_{10}	7	10	2	2	1
a_{11}	5	6	5	3	2
a_{12}	5	3	3	3	4

At this point, the data processing is completed.

3. Calculation of Main Factors

Rough set is a mathematical tool for dealing with fuzzy

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and uncertain problems. Compared with methods such as fuzzy comprehensive evaluation and analytic hierarchy process, it avoids artificial weighting and the result is more objective [3-5]. The specific process of rough set is as follows:

(1) Establishment of indicator system:

According to the trend of demographic changes, six evaluation indexes were selected: the total number of ordinary colleges and universities, the number of enterprises, the total number of hospitals and health centers, the natural population growth rate, the rate of population migration, and the disposable income of urban residents. Six indicators of the number, the survival rate of enterprises in 2009-2018, the proportion of corporate taxation, the number of state-level high-tech enterprises, the number of students in colleges and universities, and the proportion of tertiary industry, establish an index system:

Table 4. Index system

Target level	First level index	Second level index	Unit
A Regional economic vitality	B1 Economic change	C1 Total number of colleges and universities	1
		C2 Number of companies	10000
		C3 Total number of hospitals and health centers	1
		C4 natural population growth%	%
		C5 population migration rate	1
		C6 Disposable income of urban residents	yuan
	B2 Enterprise vitality changes	C7 Number of employees 10,000	10000
		C8 2009-2018 Enterprise Survival Rate	%
		C9 corporate tax share	%
		C10 National High-tech Enterprises	1
		C11 colleges and universities with tens of thousands of students	10000
		C12 tertiary industry	%

(2) Calculate the importance of the indicator: The calculation formula for the importance of the indicator is as follows:

$$\omega(a_n) = \frac{f(X, a_n)}{\sum_{i=1}^{12} i} \quad (2)$$

In the formula, the importance degree of the indicator is divided into 12 levels. After calculating the importance of the indicator, the importance is normalized and converted into weights. The calculation results are as follows:

Table 5. Indicator weights

	Indicator	Weights
Demographic change	Disposable income of urban residents (yuan)	0.243589744
	Total number of hospitals and health centers	0.282051282
	Total number of colleges and universities	0.243589744
	Number of enterprises (10,000)	0.333333333
	Natural population growth	0.320512821
	Population migration rate	0.294871795
Changes in corporate vitality	Proportion of tertiary industry	0.230769231
	Proportion of corporate tax	0.269230769
	Number of employees (10,000 people)	0.256410256
	Business Survival Rate, 2009-2018	0.243589744
	Number of students in colleges and universities (10,000 people)	0.269230769
	Number of national high-tech enterprises (home)	0.282051282

As can be seen from the table, the more critical factors affecting population change are the number of enterprises, the natural population growth rate, and the population migration rate; the more critical factors affecting the vitality of enterprises are the number of state-level high-tech enterprises, the number of college students, and corporate tax revenue. In contrast, the growth of these factors will lead to the growth of population or business vitality. Therefore, it is necessary to propose policies for more critical factors. For the western region, in terms of population, fertility should be encouraged, the introduction of foreign talents and labor, and enterprises should be supported to increase the number of enterprises; in terms of corporate vitality, high-tech enterprises should be encouraged and supported, small and medium enterprises should be supported, and the scale of college admissions should be expanded. By promoting population growth and corporate vitality, the purpose of increasing regional economic vitality is achieved.

4. Calculation of Economic Vitality

4.1 Data Collection

Select six indicators for evaluating the economic vitality of cities: the number of students in colleges and universities, the number of state-level high-tech enterprises, the natural population growth rate, the permanent population, the total number of colleges and universities, and the proportion of tertiary industries; reflecting the urban

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Table 6. Appendix III Statistics by Urban District

	Number of students in colleges and universities (10,000 people)	Number of national high-tech enterprises (home)	Natural population growth	Permanent population (ten thousand)	Total number of colleges and universities	Proportion of tertiary industry	Business Survival Rate, 2009-2018	Average GDP growth rate in the past three years	Number of employees (10,000)
Shanghai	51.78	7642	-0.06%	2419.7	49	69.90%	76.86%	6.77%	157.4
Shen zhen	8.62	10988	2.39%	1190.84	13	58.60%	85.72%	8.50%	174.1
Bei jing	58.1	20297	0.85%	2172.9	93	80.60%	77.78%	6.70%	118.3
Guangzhou	108.64	8700	1.04%	1404.35	58	70.90%	81.31%	7.13%	89.6
Chongqing	76.28	2027	0.57%	683.07	38	45.40%	71.59%	8.67%	69.8
.....									
Kun ming	54.73	812	0.59%	667	32	49.30%	70.78%	8.87%	23.5

economic vitality Three indicators: business survival rate, GDP growth rate in the past three years, and the number of enterprises. Find the statistical yearbook and statistical bulletin data from the official websites of the urban statistical bureaus, and combine the number of enterprises and the permanent population in Appendix III, IV, and V. After finishing, the following table is obtained:

The Table 6 records the various index values of different cities. The following will analyze and rank the city's economic activities based on the index values.

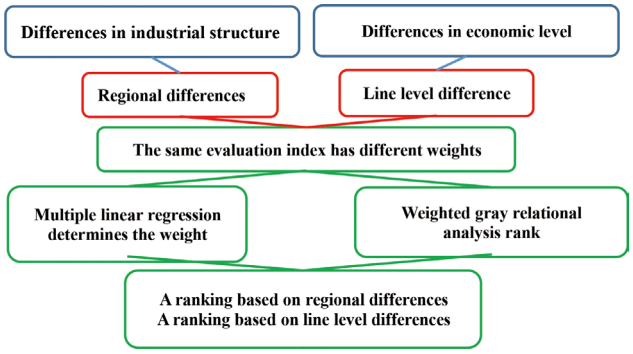

Figure 1. Comprehensive ranking ideas

4.2 Model Establishment and Solution

After analyzing the transformation of industrial structure and the speed of economic development in Question 2, it can be found that the fundamental differences between the four regions of China are the differences in industrial structure, and the fundamental differences between the first and second lines are the differences in economic development models. Considering the different regions and line levels of cities, consider establishing an evaluation system with the same evaluation index and different index weights, so that the economic vitality of cities in different regions and different line levels can be considered on the premise of taking into account the differences between the cities and the line levels. Perform comprehensive sorting.

The cities in Appendix III are grouped by region and line level, and multiple linear regression processing is performed on each group of city index data. Among them, the three indicators that reflect the economic vitality of the company's survival rate, GDP growth rate in the past three years, and the number of enterprises are regression dependent variables, and the other six indicators are regression independent variables. Data regression yields the following results:

East area:

$$\begin{cases} y_1 = 0.11 + 0.055x_1 + 0.77x_2 - 0.0049x_3 - 0.067x_4 - 0.063x_5 - 0.24x_6 \\ y_2 = -0.043 - 0.268x_1 - 0.169x_2 + 0.049x_3 - 0.473x_4 + 0.04x_5 + 2.3x_6 \\ y_3 = -0.21 - 0.37x_1 - 0.416x_2 + 0.61x_3 + 1.268x_4 + 0.0782x_5 + 2.12x_6 \end{cases}$$

Central Region:

$$\begin{cases} y_1 = 0.345 - 0.0485x_2 + 0.0137x_3 \\ y_2 = 0.375 - 0.0626x_2 - 0.0634x_3 \\ y_3 = 0.20568 + 0.113x_2 + 0.27x_3 \end{cases}$$

West and Northeast:

$$\begin{cases} y_1 = 0.193 + 0.04x_2 + 0.053x_3 + 0.058x_4 - 0.117x_5 \\ y_2 = 0.275 + 0.172x_2 + 0.2756x_3 + 0.143x_4 - 0.966x_5 \\ y_3 = 0.21 + 1.5x_2 - 0.0956x_3 - 1.263x_4 - 0.186x_5 \end{cases}$$

Tier 1 cities:

$$\begin{cases} y_1 = 0.244 + 0.0035x_1 - 0.03216x_2 + 0.0525x_3 \\ y_2 = 0.2576 - 0.04476x_1 - 0.0835x_2 + 0.098x_3 \\ y_3 = 0.4154 - 0.421x_1 - 0.178x_2 - 0.063x_3 \end{cases}$$

Second-tier cities:

$$\begin{cases} y_1 = 0.056 + 0.0566x_1 + 0.1116x_2 + 0.048x_3 - 0.169x_4 - 0.003x_5 + 0.11x_6 \\ y_2 = 0.091 + 0.284x_1 + 0.152x_2 + 0.06x_3 - 0.76x_4 + 0.00058x_5 - 0.1033x_6 \\ y_3 = 0.087 + 0.4537x_1 + 0.535x_2 - 0.00154x_3 - 0.422x_4 - 0.058x_5 - 0.813x_6 \end{cases}$$

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In the above formula, it is the survival rate of enterprises, the growth rate of GDP in the past three years, the number of enterprises, and the six indicators for evaluating the economic vitality of cities. The independent variable coefficients of the regression equations obtained at different regions and line levels are summed, the absolute values are taken and normalized, and the weights of the six evaluation indexes of different regions and line levels are obtained:

Table 7. Weights of different regions and line-level indicators

Region or line level	X_1	X_2	X_3	X_4	X_5	X_6
East	0.087	0.076	0.096	0.109	0.008	0.624
Central	0	0.009754	0.99	0	0	0
West ,Northeast	0	0.4	0.0545	0.25	0.297	0
Front line	0.7064	0.226	0.0674	0	0	0
Second line	0.2028	0.204	0.0272	0.345	0.0154	0.206

X1-X6 respectively represent the number of students in institutions of higher education, the number of state-level high-tech enterprises, the natural population growth rate, the permanent population, the total number of colleges and universities, and the proportion of tertiary industries. Weights. After the index weights are obtained, a gray weighted correlation analysis model is established. Grey correlation analysis is a method to evaluate each group of indicators by calculating the degree of correlation between each group of indicators and the optimal group of indicators [12]. The specific steps of gray correlation analysis are as follows:

(1) Determine the objects to be evaluated and the evaluation criteria. Let there be m evaluation objects and n evaluation indicators.

reference sequence: $x_0 = \{x_0(k) \mid k = 1,2,\ldots,n\}$

comparison series: $x_i = \{x_i(k) \mid k = 1,2,\ldots,n\}, i = 1,2,\ldots,m$

(2) Determine the weight of each indicator. The weights of the indicators are the results in Table 8.

(3) Calculate the gray correlation coefficient:

$$\xi_i(k) = \frac{\min\limits_s \min\limits_t \left|x_0(t) - x_s(t)\right| + \rho \max\limits_s \max\limits_t \left|x_0(t) - x_s(t)\right|}{\left|x_0(t) - x_i(t)\right| + \rho \max\limits_s \max\limits_t \left|x_0(t) - x_s(t)\right|} \quad (4)$$

$\xi_i(k)$ is the correlation coefficient of the city to be evaluated on the k index, of which $\rho \in [0,1]$ is the resolution coefficient. Generally speaking, the resolution coefficient is positively related to the resolution. Reference here [13], the resolution coefficient is 0.05. $\min\limits_s \min\limits_t \left|x_0(t) - x_s(t)\right|$, $\max\limits_s \max\limits_t \left|x_0(t) - x_s(t)\right|$ is the two-stage minimum difference and the two-stage maximum difference, respectively.

(4) Calculate the gray weighted correlation. The formula for calculating the gray weighted correlation is:

$$r_i = \sum_{k=1}^{n} \omega_i \xi_i(k) \quad (5)$$

Among them, r_i is the gray weighted correlation degree of the i evaluation target to the evaluation standard.

(5) Evaluation and analysis. The cities are ranked according to the gray weighted degree of correlation. The greater the degree of correlation, the higher the economic vitality of the city. MTLAB software was used to calculate the normalized data to obtain the following results:

Table 8. Ranking of cities' economic vitality

Ranking of cities by region		Ranking of cities with line level as the main difference	
Beijing	1	Guangzhou	1
Shanghai	2	Beijing	2
Guangzhou	3	Wuhan	3
Shenzhen	4	Shenzhen	4
Zhengzhou	5	Zhengzhou	5
Nanjing	6	Tianjin	6
Hangzhou	7	Chengdu	7
Tianjin	8	Xi'an	8
Xi'an	9	Nanjing	9
Wuhan	10	Changsha	10
Qingdao	11	Hangzhou	11
Chengdu	12	Chongqing	12
Dongguan	13	Shenyang	13
Shenyang	14	Qingdao	14
Chongqing	15	Suzhou	15
Suzhou	16	Kunming	16
Kunming	17	Dongguan	17
Changsha	18	Shanghai	18
Ningbo	19	Ningbo	19

In the above table, the main differences correspond to different ranking results. This is because the division basis of the city's region and the line level is different. The area is divided by geographical location and the line level is based on economic development. Situations are divided

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by criteria. For the cities in Appendix III, the main differences are regional differences, so the left ranking can be used as the final ranking result of economic vitality. From the above results, it can be seen that the model is effective. The ranking of cities at the same line level can be based on the regional differences, and the ranking of cities in the same area can be based on the linear differences.

5. Conclusion and Suggestion

By analyzing and solving three problems, the following rules can be summarized:

(1) Influential factors of economic vitality:

The trend of changes in the number of enterprises and the rate of population migration can largely reflect the trend of regional population changes. Changes in the number of state-level high-tech enterprises and the number of colleges and universities can reflect the changing trend of corporate vitality to a large extent.

(2) Regional and line-level differences:

The same policies will have different implementation effects in different regions or line levels. Therefore, in-depth analysis of the benefits of urban policies is required based on the region and line level of the city. The economic vitality of the first-tier cities is not necessarily higher than that of the second-tier cities. For example, Shanghai ranks lower in the ranking of economic vitality with the main difference being the level.

Based on the analysis of the collected data, the proportion of tertiary industry in Beijing exceeds 80%, reaching the late stage of industrial structure transformation. Under the premise of a large population base, there is still a high natural population growth rate, high population quality, and a large number of colleges. But the number of students is relatively small, compared with other first-tier cities, the number of enterprises in Beijing is smaller. According to the analysis results, make suggestions for Beijing's economic development:

(1) Through the coordinated regulation of the government and the market, the number of enterprises will be increased and the scale of enterprises will be increased. The number of enterprises is an important indicator reflecting the economic vitality of the region, while the number and scale of Beijing's enterprises is relatively inadequate. Therefore, we must pay attention to the development of enterprises, establish preferential policies to support small and medium-sized enterprises, encourage high-tech enterprises, and improve the competitiveness of urban enterprises.

(2) Increase the number of students enrolled in universities, lower the threshold for university admission, raise the threshold for graduation, and further improve the quality of the population. Beijing has a large number of universities and relatively few students, and high-quality talents are an indispensable element for Beijing's future economic development and economic transformation. Therefore, it is necessary to increase the number of college students, increase graduation requirements, and meet the future urban development for talents. Demand to ensure sustainable urban development.

(3) Maintain the stability of the industrial structure and improve the development quality of the tertiary industry. The tertiary industry accounts for a relatively high proportion in Beijing. Such an industrial structure is conducive to the economic development of the city. However, we must pay attention to the development quality of the tertiary industry, regulate the tertiary industry's market behavior through government macro-control, and guide the high-tech research and development of the tertiary industry. To ensure the steady development of the tertiary industry.

(4) Accelerate the transformation of the speed of economic development, focusing on long-term interests, and change from rapid economic development to high-quality and stable economic development. Beijing's development has entered a later stage. The transformation of the economic development rate is conducive to the stability of the city's development. Therefore, the Zhongguan village can be used as the center to diverge outwards, accelerate the upgrading of traditional service industries, and improve the quality of economic development in various regions.

(5) Family planning is fully liberalized to encourage childbirth and slow the aging trend of the population. By analyzing the data of Shanghai, the reason for considering its lower economic vitality is the negative growth of the natural population growth rate, and the population aging is more serious. Therefore, Beijing must not only improve the quality of its population, but also appropriately increase the number of labor forces to ensure the sustainable development of the city.

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