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Evaluation of Urban Economic Vitality Based on Principal Component Analysis

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ABSTRACT. *Regional economic vitality is an important part of regional comprehensive competitiveness. How to seize key factors and effectively improve regional economic vitality is a subject worthy of study. By establishing a mathematical model, this paper comprehensively analyzes the influencing factors of regional economic vitality. In this paper, we choose some typical cities in China to rank the urban economic vitality of them. The principal component analysis method was used to obtain three main components based on the selected seven indicators for measuring urban economic vitality, and the first part of the urban economy was calculated Vitality score, then use fuzzy comprehensive evaluation model, based on expert scores to establish a weight set based on indicators, from which the second part of the city's economic vitality score was calculated. Finally, factor analysis was used to analyze the cities in the first and second parts the economic vitality score was weighted, and the city's economic vitality ranking was finally obtained.*

KEYWORDS: *Urban economic vitality; Principal component analysis; Fuzzy comprehensive evaluation*

1. Principal component analysis ranking of economic vitality

1.1 Influencing Factors of Regional Economic Vitality

Measuring regional economic vitality is a complex issue[1-2]. For quantitative analysis, according to research, the vitality of the system is directly related to the following two aspects, that is, the input number of elements and the circulation rate of elements.

First, the input number of elements refers to the amount of elements input from outside the system to the inside of the system [3]. According to the ecosystem theory, the more energy input, the more dynamic the ecosystem is. With the theory of cyclical accumulation of the economy, we can infer that the input of factors can have a positive impact on the vitality of the urban economic system.

Second, the circulation rate of factors, which refers to the flow speed of various factors in the urban economic cycle. The flow speed of factors is affected by various aspects, and the flow speed of different factors is different, and the flow of factors is not random. There are three main characteristics of the flow of elements: mobility, reproducibility, and multi-direction. The characteristics of the factor flow determine that the circulation rate of the element has great changes in space and time. The most important factors affecting the circulation rate of the element are the nature of the element, the quality of the element, and the growth rate of the element. In the following discussion, we will select the indicators to discuss what aspects and how much impact the above aspects have on the vitality of the system. And the way of factors affects indicators.

1.2 Construction of Urban Vitality Index System

In the selection of indicators, we should pay attention to whether there is an inevitable connection with them[4]. Based on the research of other scholars, we can see that the indicator system constructed for different regions and at different times It is not exactly the same, so according to the actual situation of the research object of this article and without violating the above principles, refer to the attached data to flexibly select indicators.

In terms of the input of factors[5], this article selects four representative indicators of the population of the city, general public budget revenue, GDP, and total fixed asset investment in the whole society. In terms of measuring the circulation rate of factors[6], we selected per capita GDP, per capita disposable income, exports, the number of surviving enterprises, and the urban consumer price index. (the enterprise situation = Quantity of Newly established Enterprises from 2009 to 2018\times0.5+Quantity of Cancelled Enterprises from 2009 to 2018\times0.2+ Quantity of Surviving Enterprises in 2019\times0.3). A total of nine evaluation indicators. The

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collected data is shown in the table below.

Table 1 Economic Vitality Evaluation Index

City	Population (Unit10,000)	GDP (per people)	Disposable income (per capita/ Yuan)	enterprise surviving situation	General public budget revenue (Unit 100 million Yuan)	Total investment in fixed assets (Unit 100 million Yuan)	GDP (Unit10,000)
Tianjin	1557	118944	37022	43.7	2310.36	11274.69	18549.19
Shanghai	2418.33	126634	58988	157.4	6642.26	7240.95	30632.99
Shenzhen	1252.83	183544	52 938	174.1	27194	5147.3	22490.06
Beijing	2170.7	128994	57230	118.3	5430.8	8948.1	28014.94
Guangzhou	1449.84	150678	78884	89.6	1536.74	5919.83	89705.23
Chongqing	3389.82	19500.27	18467.35	69.8	2252.38	17440.57	19424.73
Chengdu	1435.33	87258	38918	60.6	1275.53	9404.2	13889.39
Nanjing	680.67	141700	35890	55.8	1271.9	6215.2	11715
Hangzhou	753.88	136600	56276	48.7	1540.92	2734.2	12603.36
Suzhou	678.2	159600	50603	53.6	1908.1	5629.6	17000
Qingdao	803.28	129300	38763	41	1157.24	7777.1	11037.28
Dongguan	834.25	91100	46739	43.4	592	1712.83	7582.12
Zhengzhou	842.25	89900	30556	43.1	1056.67	7573.4	9130.2
Wuhan	853.65	124560	38642	39.8	1402.93	7871.66	13410.34
Xi’an	905.68	76300	32597	37.5	654.5	7556.47	7469.85
Ningbo	596.93	125000	48233	31.1	1245.29	5009.6	9842.1
Changsha	708.79	133300	41131	28.5	800.35	3607.33	10535.51
Shenyang	736.95	69754	41359	21.8	656.24	6444.7	5864.97
Kunming	562.99	71906	29277	23.5	560.86	4217.94	4857.64

2. Mathematical Solution of Economic Vitality Model

2.1 Standardization of Data

For multi-attribute decision problems, there is usually no direct comparability between attributes, there are no comparable standards of comparison. On the one hand, each attribute is usually divided into different types, such as benefit type, cost type, fixed type, and interval type. These types are not convenient for direct comparison. On the other hand, the units and dimensions of each attribute are usually inconsistent. If the solutions are sorted without processing using the original decision matrix, then either the attributes cannot be compared or the results obtained are inaccurate, which makes the analysis and research unreasonable and leads to model errors. Therefore, when dealing with the decision problem of a known decision matrix, the impact of the dimensions, order of magnitude, and attribute type on the model results must be eliminated before evaluation, for the reasons that the index matrix needs to be standardized and standardized.

In this paper, Z-standardization is used to preprocess the data, and a sample matrix is constructed based on the p-dimensional random vector $X = (x_1, x_2 \dots x_p)^T$ and n samples $X_i = (x_{i1} + x_{i2} \dots x_{ip})^T$,$i = 1,2 \dots n$, $n > p$ collected above.

$$Z_{ij} = \frac{x_{ij} - \overline{x}_j}{s_j},\ i = 1,2,...,n;\ j = 1,2,...p \tag{1}$$

Among them,

$$\overline{x}_j = \frac{\sum_{i=1}^{n} x_{ij}}{n},\quad s_j^2 = \frac{\sum_{i=1}^{n} (x_{ij} - \overline{x}_j)^2}{n-1} \tag{2}$$

Which can get normalized matrix. This article uses SPSS to directly implement.

2.2 Establishment of Weighted Principal Component Analysis Model

Principal component analysis is a method to analyze a new set of unrelated comprehensive indicators instead of the original set of indicators with great correlation. To form a new indicator, it is necessary to perform mathematical processing, that is, to linearly combine the original $p$indicators. The new index is represented by the variance ofF_1, because if $Var(F_1)$ is larger, it means that it contains more information. Among all linear combinations, the one with the largest variance is selected as F_1, which is called the first principal component. If the first principal component cannot represent all the information of the original p indicators, then F_2 should be selected as the second linear combination. In order not to repeat the original information, the information in F_2 does not need to include the existing information in F_1. Information, that is, $Var(F_1, F_2)$ is required, and F_2 is called the second principal component. In this way, the third, fourth, and so on can be finally constructed to the Nth principal component.

The main part of the model is:

$$\begin{cases} F_2 = a_{12} Zx_1 + a_{22} Zx_2 + \dots + a_{p2} Zx_p \\ \quad\quad \dots. \\ F_p = a_{1m} Zx_1 + a_{2m} Zx_2 + \dots + a_{pm} Zx_p \end{cases} \tag{3}$$

In the formula $a_{ij} (i = 1,2 \dots p, j = 1,2 \dots m)$ is the eigenvector corresponding to the eigenvalue of the covariance matrix W of A, and $a_{pm} Zx_p$ is the normalized value of the original variable. $A = (a_{ij})_{p \times m} = (a_1, a_2, \dots, a_m), R_{ai} = \lambda_i a_i$, R is correlation coefficient matrix. $a_i, \lambda_i$are corresponding eigenvalues and unit eigenvectors.$\lambda_1 \geqslant \lambda_2 \geqslant \dots \geqslant \lambda_p \geqslant 0$. Multiplying the component score coefficient matrix by the indicator normalization to calculate the factor score.

$$F = \sum b_i F_i \ \left(\sum b_i = 1 \right) \tag{4}$$

Where F is the total factor score and F_i is the i-th factor score; b_i represents the contribution of the i-th factor. (Contribution of factorial factor = variance contribution rate after factorial rotation / total variance explanation rate). In order to make the evaluation more accurate, the fuzzy evaluation method is used to construct a weighted evaluation matrix, and the more important indicators are appropriately increased in weight. The specific results are as follows:

$$M = A \times (\beta_1 \ \ \beta_2 \ \ \beta_3 \ \ \beta_4 \ \ \beta_5 \ \ \beta_6 \ \ \beta_7)^T \tag{5}$$

In the formula, $\beta_n^T (n = 1,2,...6)$ is the matrix of weighting coefficients obtained by fuzzy evaluation, the results obtained are shown in the table below:

Table 2 Fuzzy Evaluation Value

Index	Population	GDP (/people)	Disposable income	Enterprise surviving situation	General public budget revenue	Total investment in fixed assets	GDP
Evaluation value	0.1	0.2	0.1	0.2	0.1	0.1	0.2

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Last, this paper uses fuzzy evaluation and factor score to define the final score which use S to present.

$$S = 0.6M + 0.4F \tag{6}$$

2.3 Model Solving and Ranking of Urban Economic Vitality

The extraction method is principal component analysis. The rotation method is Caesar's normalized maximum variance method. The component score coefficient matrix and related results are as follows:

Table 3 Component Scoring Coefficient Matrix

Num	□□□1	□□□2	□□□3	□□□4	□□□5	□□□6	□□□7
$\square_1$	0.421	-0.224	-0.108	0.16	-0.031	0.406	0.119
$\square_2$	0.075	0.129	0.435	0.022	-0.273	-0.03	0.572
$\square_3$	0.089	0.192	-0.061	0.402	0.613	-0.021	-0.253

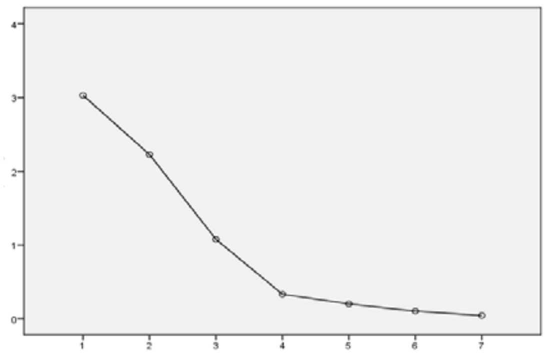

Figure.1 Gravel Chart

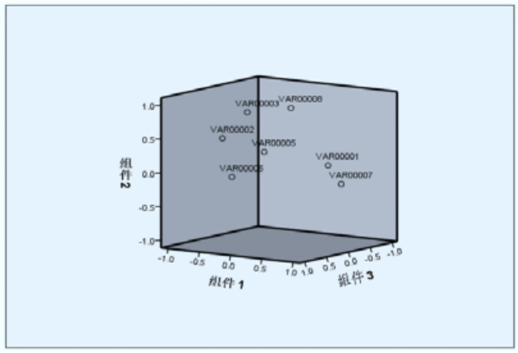

Figure. 2 Space Component Diagram after rotation

Figures above display eigenvalues of descending and factor, and number of components and factors. It can also be seen from the gravel chart that the information contributed by the first three factors represents that the polyline is relatively steep, and the subsequent polyline is relatively flat, so it can be considered that it is reasonable to extract the three factors.

The final result is shown in the table below:

Table 4 Final Result and City Rank

City	$\square_1$	$\square_2$	$\square_3$	*F*	*M*	*S*	Rank
Tianjin	-8143.61399	61432.62629	8453.05145	61742.06375	24531.583	35430	11
Shanghai	-6528.51362	64416.14186	20210.30584	78097.93408	32249.232	46003.84	3
Shenzhen	-4215.10841	86082.36229	12747.86779	94615.12167	36834.245	54168.51	2
Beijing	-6869.97246	66071.27306	18404.48858	77605.78918	31627.008	45420.64	4
Guangzhou	21809.77427	82276.67043	38397.38619	98864.28235	49694.207	64445.23	1
Chongqing	912.45185	21538.30506	5848.62358	28299.38049	11850.68	16785.29	19
Chengdu	-4068.84705	46037.19976	10747.90432	52716.25703	20510.904	30172.51	14
Nanjing	10644.52753	67493.06925	6528.98953	63377.53125	24518.937	36176.52	8
Hangzhou	-7304.93554	63845.88614	16083.03362	72623.98422	27948.512	41351.25	7
Suzhou	-11219.8484	75931.3864	12499.6637	77211.2017	30312.91	44382.4	5
Qingdao	-8502.4465	62984.93212	7919.30034	62401.78596	23872.018	35694.73	10
Dongguan	-3264.90226	42647.55079	14342.8195	53725.46803	20296.812	30325.41	13
Zhengzhou	-5181.91103	45308.21495	6715.73068	46842.0346	17883.092	26570.77	15
Wuhan	-8409.20619	61277.31783	8590.09002	61458.20166	23887.252	35158.54	12
Xi’an	-3153.05069	39231.59899	8061.96681	44140.51511	16562.535	24835.93	17
Ningbo	-6635.27683	59570.16885	12432.96038	65367.8524	24806.422	36974.85	7
Changsha	-9123.66278	62334.2238	9577.27089	62787.83191	24180.649	35762.8	9
Shenyang	-886.81239	35725.47018	11932.06005	46770.71784	17208.343	26077.06	16

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Kunming	-3203.70505	34981.48419	7301.34961	39079.12875	14556.407	21913.22	18

3. Conclusion

From the results, we can see that Beijing, Shanghai, Guangzhou, and Shenzhen rank higher in economic vitality. From the table, we can also see that the economic vitality of southern cities is generally higher than that of northern cities. Cities located in the Yangtze River Delta and the Pearl River Delta rank higher. Due to the relatively good economic conditions and geographical location, coupled with the support of policies, the regional economy in the top rankings can perform a good industrial cycle.

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