Analysis of the Relationship between Industrial Economic Development and Industrial Environmental Pollution——Based on Empirical Research in Jiangxi Province

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Abstract: Based on the indicators of industrial economic development and industrial environmental pollution, this paper analyzes the industrial economic development and industrial environmental pollution in various regions of Jiangxi Province by using principal component analysis method, and calculates the evaluation score of each region; Through cluster analysis, Jiangxi Province is divided into four categories: sustainable, weak sustainable, weak unsustainable and unsustainable, then making policy recommendations to promote the sustainable and healthy economic development in Jiangxi Province.

1. Introduction

The accelerating industrialization process brings about the rapid economic development as well as the more and more serious environmental pollution and ecological damage. Since the beginning of the 21st century, Jiangxi's industrial economy has grown rapidly. From 2016 to 2017, the total added industrial value of Jiangxi Province reached 811.92 billion yuan, an increase of 8.8% over the previous year. The added value of industrial enterprises above designated size increased by 9.1%. However, environmental pollution caused by economic development is also aggravating. Therefore, we must not only pay attention to the growth rate of the industrial economy, but also pay attention to the quality of industrial economic growth.

For the discussion of the relationship between economic development and environmental pollution, Grossman and Krueger et al. concluded that there is an inverted "U" relationship between economic development and environmental pollution.[1] Shi Jinfang and Wu Xueyan believe that there is an "N" relationship between economic development and environmental pollution.[2] Xu Zhiwei found that the Chinese industry has a development model of “first pollution, then governance” by constructing a theoretical model.[3] Zhang Yingkui et al. studied the relationship between economic growth and industrial environmental pollution in Jiangsu based on VAR model, and found that there is a long-term and stable relationship between per capita GDP in Jiangsu and industrial “three wastes”.[4] Jia Lili et al. studied the relationship between industrial economic development and environmental pollution based on VAR model, and found that there is a long-term equilibrium relationship between industrial economic development and environmental pollution.[5]

On the basis of previous studies, this paper and uses principal component analysis and cluster analysis to analyze and evaluate 11 prefecture-level cities in Jiangxi Province. At the same time, it combines different types of regions to propose policy recommendations to promote the sustainable development of industrial economy and environment in Jiangxi Province.

2. Research methods

2.1 Principal Component Analysis

Principal component analysis considers the relationship between various indicators, and uses the idea of dimensionality reduction to convert multiple indicators into a few unrelated indicators under the premise of losing less information. The comprehensive indicators generated by transformation are called the main component, the linear combination of the original variables is composed of the obtained principal components, and the main components are irrelevant. Let the original variables be $x_1, x_2,\ldots, x_n$, and the new variables obtained by principal component analysis are $y_1, y_2,\ldots, y_m$, and $y_1, y_2,\ldots, y_m$ are the linear combination of $x_1, x_2,\ldots, x_n$(m<n). First of all, standardize the raw data.

$$x_{ij}^* = \frac{(x_{ij}-\bar{x}_i)}{e_i} \qquad i = 1,2,\ldots,\mathrm{n}; \mathrm{j} = 1,2,\ldots,\mathrm{p} \tag{1}$$

Where x_{ij} represents the raw data of the *i*-th index in the *j*-th region, and $\bar{x}_i$ and e_i are the sample mean and standard deviation of the *i*-th index, respectively. Secondly, calculate the correlation coefficient matrix R, $\mathrm{R} = \left(r_{ij}\right)_{n\times n}$.Thirdly, calculate the feature values and feature vectors. Each eigenvalue λ_i is obtained by calculating$|R - \lambda I| = 0$, calculating each eigenvector $u_1, u_2,\ldots,u_n$. Then, calculate the variance contribution rate of each principal component $\mathrm{e} = \lambda_i / \sum_{i=1}^{n} \lambda_i$ and cumulative contribution rate $E_j = \sum_{j=1}^{m} \lambda_i / \sum_{i=1}^{n} \lambda_i$. At last, calculate the principal component to be retained, $y_i = \sum_{j=1}^{p} \sum_{i=1}^{n} u_{ij} x_{ij}^*$.

2.2 Cluster analysis

Cluster analysis is a multivariate statistical analysis method that classifies samples or indicators according to the principle of “objects are clustered”. Cluster analysis classifies individuals or objects such that the similarities between objects in the same class are stronger than those of other classes. The goal is to maximize the homogeneity of the objects between classes and to maximize the heterogeneity of objects between classes and classes. This paper mainly uses K-means clustering method.

2.3 Indicator selection and data source

Based on the research results of previous scholars, this paper selects six industrial economic development indicators and six industrial environmental pollution indicators. As shown in Table 1.

Table.1. Industrial economy and environmental pollution indicator system.

Index	Industrial economic development indicator system	Industrial environmental pollution indicator system
X_1	Total assets of industrial enterprises above designated size (100 million yuan)	Total industrial sulfur dioxide emissions (T)
X_2	Total profit of industrial enterprises above designated size (100 million yuan)	Total industrial NOx emissions (T)
X_3	Industrial electricity consumption (100 million kWh)	Total emissions of industrial smoke (powder) dust (T)
X_4	Per capita GDP (yuan)	Industrial exhaust emissions (100 million cubic meters)
X_5	Number of industrial enterprises above designated size (number)	Industrial wastewater discharge (10,000 T)
X_6	Average number of employees per year (person)	Industrial solid waste production (10,000 T)

The relevant data are from China Statistical Yearbook, Jiangxi Statistical Yearbook, and Jiangxi Province Statistical Yearbook.

3. Empirical analysis

3.1 Principal Component Analysis of Industrial Economic Development

Eigenvalues calculated according to the correlation matrix of the standardized data of industrial economic development and the contribution rate and cumulative contribution rate of each principal component are shown in Table 2.

Table.2. Explanation of the total variance of industrial economy.

Component	Eigenvalues	Contribution rate %	Cumulative contribution rate %
Principal component 1	4.062	67.707	67.707
Principal component 2	1.416	23.592	91.299
component 3	0.351	5.849	97.148
component 4	0.091	1.51	98.658
component 5	0.053	0.878	99.537
component 6	0.028	0.463	100

It can be seen from Table 2 that the cumulative contribution rate of the first two principal components reaches 91.299%, which can well reflect a large amount of information of the original data. The coefficient of the *i*-th principal component is obtained by correlation calculation. The first two principal components Y_1 and Y_2 are:

$$Y_1 = 0.373x_1^* + 0.475x_2^* + 0.45x_3^* - 0.053x_4^* + 0.451x_5^* + 0.475x_6^* \quad (2)$$

$$Y_2 = 0.483x_1^* - 0.016x_2^* + 0.021x_3^* + 0.823x_4^* - 0.298x_5^* - 0.01x_6^* \quad (3)$$

Using the contribution rate of each principal component as a weighted average coefficient, a comprehensive score U_1 of the industrial economic development degree can be obtained, and the principal component 1 is represented by Y_1 , and the principal component 2 is represented by Y_2.

$$U_1 = 0.6771Y_1 + 0.2359Y_2 \quad (4)$$

3.2 Principal Component Analysis of Industrial Environmental Pollution

In this paper, the original data is standardized, and the eigenvalues calculated according to the correlation matrix of the industrial environmental pollution standardization data and the contribution rate and cumulative contribution rate of each principal component are shown in Table 3.

Table.3. Explanation of the total variance of industrial environmental pollution.

Component	Eigenvalues	Contribution rate %	Cumulative contribution rate %
Principal component 1	3.281	54.682	54.682
Principal component 2	1.389	23.157	77.839
component 3	0.764	12.738	90.577
component 4	0.361	6.019	96.596
component 5	0.144	2.4	98.995
component 6	0.06	1.005	100

It can be seen from Table 3 that the cumulative contribution rate of the first two principal components reaches 77.839%.The coefficient of the *i*-th principal component is obtained by correlation calculation. The first two principal components Z_1 and Z_2 are:

$$Z_1 = 0.475x_1^* + 0.479x_2^* + 0.525x_3^* - 0.417x_4^* + 0.279x_5^* + 0.131x_6^* \quad (5)$$

$$Z_2 = -0.282x_1^* - 0.244x_2^* - 0.105x_3^* + 0.108x_4^* + 0.621x_5^* + 0.673x_6^* \quad (6)$$

The same as the comprehensive score U_2 of industrial environmental pollution, Z_1 represents the main component 1, Z_2 represents the main component 2.

$$U_2 = 0.5468Z_1 + 0.2316Z_2 \quad (7)$$

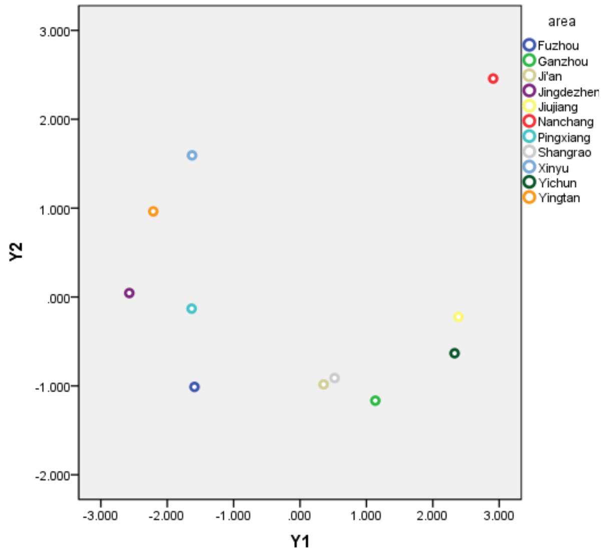
3.3 Comprehensive score results of industrial economic development and environmental pollution

Through the scores of each principal component, the comprehensive score of industrial economic development U_1, the comprehensive score of industrial environmental pollution U_2 and the ranking of each region are calculated. See Table 4 and Figure 1.

Table.4. Comprehensive score and ranking of industrial economic and industrial environmental pollution.

Area	Industrial economic development				Industrial environmental pollution			
	Y1	Y2	U1	Rank	Z1	Z2	U2	Rank
Nanchang	2.9089	2.4579	2.5494	1	-0.885	0.0801	-0.4653	8
Jingdezhen	-2.5715	0.0447	-1.7306	11	-0.7591	-0.057	-0.4283	7
Pingxiang	-1.6321	-0.1311	-1.136	8	-0.551	-1.0817	-0.5518	9
Jiujiang	2.3855	-0.2235	1.5625	2	0.2654	1.2892	0.4437	4
Xinyu	-1.6264	1.5936	-0.7253	7	0.793	-0.655	0.2819	5
Yingtan	-2.2105	0.9632	-1.2695	9	-1.615	-0.3045	-0.9536	11
Ganzhou	1.1335	-1.1659	0.4925	4	0.8633	0.2429	0.5283	3
Ji'an	0.3555	-0.9831	0.0088	6	-0.6025	-0.2543	-0.3883	6
Yichun	2.3273	-0.6329	1.4265	3	2.9488	-1.6906	1.2208	1
Fuzhou	-1.5903	-1.0116	-1.3154	10	-1.2381	-0.3008	-0.7467	10
Shangrao	0.5201	-0.9114	0.1372	5	0.7801	2.7318	1.0593	2

It can be seen from Table 4 and Figure 1. Nanchang is distributed in the first quadrant, Jingdezhen, Yingtan and Xinyu in the second quadrant, Fuzhou and Pingxiang in the third quadrant, and Jiujiang, Ganzhou, Ji'an, Yichun and Shangrao in the fourth quadrant. It can be seen from Figure 2 that Jiujiang, Ganzhou and Shangrao are located in the first quadrant, Nanchang in the second quadrant, Jingdezhen, Yingtan, Ji'an and Fuzhou in the third quadrant, and Xinyu, Yichun in the fourth quadrant. Among them, Yichun, Shangrao, and Ganzhou have better industrial economic benefits, but environmental pollution is more serious.



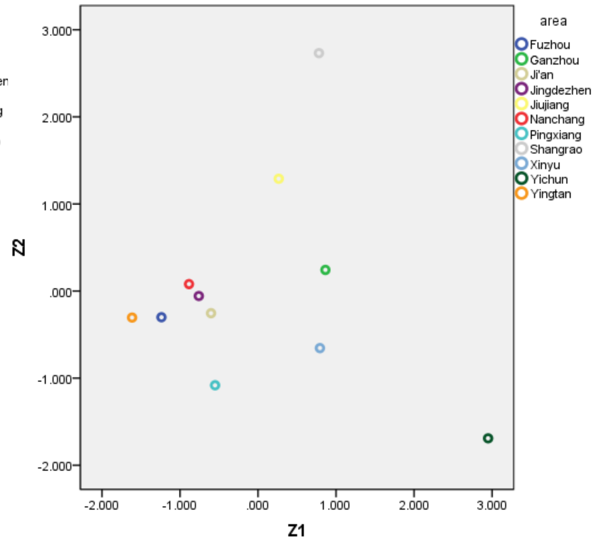


Figure 1. Economic component score chart. Figure 2. Environmental pollution component score chart.

3.4 Cluster Analysis of Industrial Economic Development and Industrial Environmental Pollution

According to the comprehensive scores U_1 and U_2, this paper uses K-means clustering method to cluster the two comprehensive indicators of each city.

The first category: Nanchang; the second category: Jingdezhen, Pingxiang, Yingtan, Fuzhou; the third category: Xinyu, Ji'an; the fourth category: Jiujiang, Ganzhou, Yichun, Shangrao.

According to the results of the cluster analysis, Nanchang in the first category is in a better development condition and the degree of environmental pollution is lighter; the industrial pollution in the four cities in the second category is lighter, but at the same time their industrial economic development is also relatively weak; the third category is mainly those areas where industrial economic development is relatively better, but environmental pollution is more serious; the fourth category of four regions has better industrial economic development, but The industrial pollution caused by it is also quite serious.

4. Conclusion and suggestion

By selecting six indicators representing industrial economic development and industrial environmental pollution, this paper uses principal component analysis and cluster analysis to comprehensively analyze the industrial economic development and environmental pollution in Jiangxi Province, and divide it into sustainable development, weak sustainable development, weak unsustainable development and unsustainable development areas.

For sustainable development areas, we must actively promote its industrial development model, optimize industrial structure, increase environmental protection policies, avoid “pre-pollution governance”, and further ensure at the basic of the better industrial environment to promote industrial economic growth.

For sustainable development areas, the current main task is how to vigorously promote the development of the industrial economy. All regions should use their own characteristic industries to build a distinctive industrial system, accelerate the transformation and upgrading of traditional industries, and improve the level of industrial economic development.

For the regions with weak and unsustainable development and unsustainable development, most of them are industrially developed regions, but environmental pollution is more serious, and their economic growth is at the expense of the environment. Therefore, governments in various regions should strengthen the level of environmental regulation, give priority to the development of new industries of high quality and environmental protection, and accelerate the adjustment of the structure of the industrial sector. At the same time, we should vigorously encourage and support various industrial enterprises to actively research and develop technologies for environmental pollution control, and pursue a high-quality and sustainable development model of industrial economy.

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