Research on the Development Level of Urban Green Economy based on Principal Component Analysis

-- Take Anhui Provincial Prefecture Level Cities as an Example

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Abstract

In view of the current situation and differences of urban green economy development level in Anhui Province, in order to improve the ecological civilization construction and green economy development level of various cities in Anhui Province, 16 prefecture level cities in Anhui Province are selected as the research objects. Based on the relevant data in the statistical yearbook of Anhui Province in 2021, 14 indicators from three aspects of economic development, environmental protection and solid waste recovery rate are selected to establish a comprehensive evaluation, and a k-means clustering model is established to turn them into high, high, general and low-level green development areas for spatial dimension analysis. Finally, the paper puts forward reasonable suggestions for the green development level of 16 prefecture level cities in Anhui Province.

Keywords

Green Economy; Principal Component Analysis; K-means Clustering Comprehensive Evaluation.

1. Introduction

With the development of economy, the trend of resource constraints, more and more serious environmental pollution, serious ecosystem degradation, the construction of regional ecological civilization has become more and more important. During the "14th five year plan" period, China's ecological civilization construction has entered a critical period of taking carbon reduction as the key strategic direction, promoting the synergy of pollution reduction and carbon reduction, promoting the comprehensive green transformation of economic and social development, and realizing the improvement of ecological environment quality from quantitative change to qualitative change.[1] The construction of ecological civilization is an important part of the overall layout of the "five in one". Strengthening the construction of ecological civilization requires innovative institutional arrangements, overall development planning, protecting the ecological environment, strengthening foreign exchanges, and sharing a better life, which is conducive to the development of urban green economy.[2]In view of the internal differentiation of prefecture level cities in Anhui Province, Hefei, a city with relatively developed economy, the economies of several prefecture level cities with economic level occupying the middle reaches, and many cities with lower economic level are regional urban agglomerations in the province that are conducive to the study. Therefore, this paper selects 16 prefecture level cities in Anhui Province, aiming at the driving effect of urban waste classification on the development level of green economy, establishes an evaluation index system, collects relevant data, integrates principal component analysis, K-means clustering

analysis and other methods, and uses SPSS software to explore the development level of green economy in Anhui Province.

2. Construction of Evaluation Index System

The development of regional green economy level is related to many factors and involves a wide range. Therefore, in order to accurately evaluate the green economy development level of prefecture level cities in Anhui Province, it is necessary to select multiple impact indicators for comprehensive evaluation. This paper selects 12 indicators from three aspects: the level of solid waste recycling treatment, environmental regulation, and the number and scale of enterprises, including the number of scientific research talents, the level of scientific research ability, urban layout planning, and the number of foreign-funded enterprises. Build a comprehensive evaluation index system for the development level of green economy in prefecture level cities in Anhui Province for comprehensive evaluation. See Table 1 for evaluation indicators:

Table 1. Comprehensive evaluation index system of green economy development level of prefecture level cities in Anhui Province

Level 1 indicators	Level 2 indicators	Level 3 indicators
Development level of green economy(A)	Solid waste resource treatment level (B1)	Number of scientific research talents(X1)
		Scientific research ability level(X2)
		Solid waste resource index(X3)
		Regional GDP(X4)
		Resource conversion rate(X5)
	Environmental regulation(B2)	Administrative regulations(X6)
		Urban greening layout(X7)
		Economic means(X8)
		Market mechanism(X9)
	Number and scale of enterprises(B3)	Wastewater discharge(X10)
		Hazardous gas emissions(X11)
		Solid waste disposal(X12)

The technical level of solid waste resource treatment reflects the scientific research and technology level of the region, and has an absolute impact on the green economy of reasonably recycling garbage and realizing the secondary utilization of resources in the region; Environmental regulation includes the government's artificial intervention in residents and markets. Through laws and regulations and the reasonable layout of cities, it guides people to deal with the available resources reasonably, which plays a guarantee role in the development

of green economy; Finally, the number and scale of enterprises is the harm to the urban environment by limiting the random discharge of waste from factories. It is the most direct factor affecting the urban green economy and can better reflect the development level of the urban green economy.

3. Comprehensive Evaluation Model based on Principal Component Analysis

3.1. Research Ideas

According to the data of each evaluation index in Anhui statistical yearbook 2021, combined with the principle of principal component analysis and its model, due to the delay of statistical data, the development level of 16 prefecture level cities in Anhui Province in 2021 was comprehensively evaluated based on spss26.0 software.

3.2. Research Methods

(1) Standardize the original data

Suppose that there are m index variables for principal component analysis: x1, X2, ..., XM, a total of N evaluation objects, and the value of the j index of the I evaluation object is AIJ. Convert each index value AIJ into standardized index.

$$\tilde{a}_{ij} = \frac{a_{ij} - \mu_j}{s_j}, \ (i=1,2,3...,n; \ j=1,2,3,...m)$$

thereinto $\mu_j = \frac{1}{n}\sum_{i=1}^{n} a_{ij}$, $s_j = \frac{1}{n-1}\sum_{i-1}^{n}(a_{ij} - \mu_j)^2$, $(j=1,2, ...m)$, That is, it is the sample mean and sample standard deviation of the j-th index. Correspondingly, it is called

$$\tilde{x}_i = \frac{x_i - \mu_j}{s_i}, \ (i=1,2,3....,m)$$

is a standardized indicator variable.

(2) Calculate the correlation coefficient matrix R

Correlation matrix R= $(r_{ij})_{m \times n}$

$$r_{ij} = \frac{\sum_{k=1}^{n} \tilde{a}_{ki} * \tilde{a}_{kj}}{n-1}, \ (i=1,2,...m)$$

Where = 1,, is the correlation coefficient between the i-th index and the j-th index.

(3) Calculate eigenvalues and eigenvectors

Calculate the eigenvalue of the correlation coefficient matrix R ≥ 0 and the corresponding eigenvector, among them, m new index variables are composed of eigenvectors

$$\begin{cases} y_1 = u_{11}\tilde{x}_1 + u_{21}\tilde{x}_2 +...u_{m1}\tilde{x}_m \\ y_1 = u_{12}\tilde{x}_1 + u_{22}\tilde{x}_2 +...u_{m2}\tilde{x}_m \\ \quad\quad ,,, \\ y_1 = u_{1m}\tilde{x}_1 + u_{2m}\tilde{x}_2 +...u_{mm}\tilde{x}_m \end{cases}$$

Where is the first principal component, the second principal component, ..., and the M principal component.

(4) Select P (P ≤ m) principal components and calculate the comprehensive evaluation value

Calculate the information contribution rate and cumulative contribution rate of eigenvalues (J = 1,2, ..., m). call

$$b_j = \frac{\lambda_j}{\sum_{k=1}^{m} \lambda_k} \ (j=1,2, ...m)$$

information contribution rate of main components;

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

When the cumulative contribution rate of the main components,,..., is close to 1 (= 0.85,0.90,0.95), the first P index variables,,...., are selected as P principal components to replace the original m index variables, so that the P principal components can be comprehensively analyzed.

Calculate the comprehensive score

$$Z = \sum_{J-1}^{P} b_j y_j$$

Where is the information contribution rate of the j-th principal component, which can be evaluated according to the comprehensive score value.

3.3. Evaluation and Analysis of Green Economy Level in 16 Prefecture Level Cities in Anhui Province

Spss26.0 is used to analyze the development level of green economy in 16 prefecture level cities in Anhui Province, and the principal component coefficient matrix of variance decomposition diagram is obtained. See Table 2 for details.

Table 2. Variance decomposition diagram of principal component analysis

principal component	original variable			The principal components were extracted		
	characteristic value	Variance contribution rate is (%)	The cumulative contribution rate is (%)	characteristic value	Variance contribution rate is (%)	The cumulative contribution rate is (%)
1	5.582	36.587	35.587	5.582	35.587	35.587
2	3.074	19.204	54.791	3.074	19.204	54.791
3	1.570	10.813	65.604	1.570	10.813	65.604
4	1.372	8.564	74.168	1.372	8.564	74.168
5	1.106	7.600	81.768	1.106	7.600	81.768

According to table 2, the eigenvalues of the first five principal components are greater than 1. Therefore, according to the principal component analysis, five principal components are selected to describe the development level of green economy. The coefficient matrix of five principal components is obtained by spss26.0, and then the principal component scores and comprehensive scores of the green economic development level of 16 prefecture level cities in

Anhui Province are obtained according to the principal component calculation formula and the comprehensive score evaluation function. See Table 3 for details.

Table 3. Principal component scores and comprehensive scores of green economy development level of 16 prefecture level cities in Anhui Province

region	F1 score	F2 score	F3 score	F4 score	F5 score	Comprehensive score	ranking
Anhui Province	2.248	1.812	0.016	1.235	-0.106	1.553	
Hefei City	2.032	2.415	0.369	1.341	0.128	1.759	1
Wuhu City	3.015	1.759	0.258	1.165	0.345	1.683	2
Chuzhou City	1.500	2.443	0.354	1.354	0.361	1.668	3
Fuyang City	3.023	1.952	-0.345	0.913	0.336	1.665	4
Anqing City	2.762	1.752	-0.123	1.381	0.128	1.573	5
Ma'anshan City	2.338	1.966	-0.056	1.158	0.212	1.562	6
Bengbu City	2.851	1.421	0.351	1.340	0.355	1.525	7
Suzhou City	3.062	1.449	0.642	0.654	-0.018	1.519	8
Bozhou City	3.009	1.546	-0.109	0.994	0.164	1.503	9
Lu'an City	1.955	2.266	-0.752	1.058	0.125	1.496	10
Xuancheng City	1.901	1.954	-0.106	1.351	0.281	1.474	11
Huainan City	3.154	1.31	0.215	0.854	0.208	1.464	12
Huaibei City	3.251	1.238	-0.125	1.352	0.201	1.461	13
Tongling City	2.905	1.352	-0.009	0.953	0.150	1.400	14
Chizhou City	2.345	1.624	0.044	0.684	0.288	1.382	15
Huangshan City	2.814	1.224	0.264	0.873	-0.103	1.325	16

It can be seen from table 3 that in general, among the 16 prefecture level cities in Anhui Province, Hefei has the best level of green economy development, with a comprehensive score of 1.759, and Huangshan has the worst, with a comprehensive score of only 1.325. The variance fluctuates significantly, as shown in Table 4. Moreover, among the 16 prefecture level cities evaluated, only Hefei, Wuhu, Chuzhou, Fuyang, Anqing and Ma'anshan have a comprehensive level of green economic development higher than that of the whole region of Anhui Province. 62.5% of the low-level cities have a green economic development level below that of the whole region of Anhui Province, indicating that there is a slight imbalance in the development level of green economy in various regions of Anhui Province, and there are differences between regions. The analysis of variance is carried out according to the scores of the principal components in Table 3. See Table 4 for details.

Table 4. Score difference analysis of green economy development level

	minimum value	Maximum value	variance
First principal component	1.5	3.251	0.516
Second principal component	1.224	2.443	0.400
Third principal component	-0.752	0.642	0.324
Fourth principal component	0.654	1.381	0.243
Fifth principal component	-0.103	0.361	0.128
Comprehensive score	0.918	2.292	0.403

It can be seen from table 4 that the variance of the score of the first principal component fluctuates most obviously, followed by the second principal component, indicating that the first

principal component has the greatest impact on the development level of green economy, that is, there are obvious differences in the scientific and technological level of regional green construction, regional GDP and solid waste recycling treatment level across Anhui Province; The third, fourth and fifth principal component scores do not fluctuate significantly, indicating that in the construction of green development in various regions of Anhui Province, there are no obvious differences in urban planning, market mechanism and enterprise management level, which need to be improved.

4. Classification of the Development Level of Yangtze River Delta Urban Agglomeration based on K-means Clustering Analysis

4.1. Research Ideas

Based on the above factor comprehensive score of the green economy development level of prefecture level cities in Anhui Province, K-means clustering analysis algorithm is used to classify the 16 cities in the selected prefecture level cities in Anhui Province according to their regional ecological civilization development level, so as to study the spatial heterogeneity of the green economy development level of prefecture level cities in Anhui Province.

4.2. Research Methods

It is divided into different categories for analysis by K-means clustering.

Table 5. Clustering results of green economy development level of prefecture level cities in Anhui Province

Development level of ecological civilization construction	City name	Average comprehensive score
High level development area	Hefei City, Wuhu City, Fuyang City	1.7023
High level development area	Chuzhou City, Anqing City, Bengbu City, Bozhou City, Lu'an City, Ma'anshan City	1.5545
General level development area	Huaibei City, Huainan City, Xuancheng City, Suzhou City	1.4795
Low level development area	Huangshan City, Chizhou City, Tongling City	1.3690

According to the clustering results in Table 5, the development level of green economy in prefecture level cities in Anhui Province is divided into four categories, namely, high-level development areas, high-level development areas, general level development areas and low-level development areas. Its overall development level is relatively balanced.

5. Conclusion and Suggestions

Based on spss26 software, this paper uses the collected data to comprehensively evaluate the development level of green economy in prefecture level cities in Anhui Province. It can be seen that the development level of green economy in Anhui Province is relatively high. Using k-means cluster analysis, 16 prefecture level cities in Anhui Province are divided into the following four categories: Hefei, Wuhu and Fuyang are high-level development areas; Chuzhou City, Anqing City, Bengbu City, Bozhou City, Lu'an City and Ma'anshan City belong to high-level development areas; Huaibei City, Huainan City, Xuancheng City and Suzhou city belong to the

general development level areas; Tongling City, Chizhou City and Huangshan City belong to low-level development areas. However, there are still many problems in its regional development: uneven urban development, a large gap between the level of green economy and the overall economic level of the city, etc. according to the results of the above comprehensive evaluation model, the relevant factors affecting the development level of green economy in prefecture level cities in Anhui Province are analyzed and obtained, and the following relevant suggestions are put forward for the further improvement of the development level of green economy in prefecture level cities in Anhui Province in the future:

(1) Promote technological innovation and promote high-quality development of green economy

Technological level and innovation play an important role in regional economic development, are the direct driving force for the development of low-carbon green economy, and help promote energy conservation and emission reduction, resource conservation and ecological environment protection. Hefei and Wuhu, which have certain regional advantages in economic development, should integrate steady and orderly economic growth, technological progress and environmental protection, and reduce water, air and soil pollutants, Improve resource utilization efficiency and reduce energy consumption, further develop and expand high-tech industries, increase investment and subsidies in scientific and technological research and development, create a high-quality scientific research environment, attract high-tech talents, encourage scientific and technological progress and innovation, strive to promote the transformation of scientific and technological achievements, create strategic new industrial clusters, and achieve high-quality development of regional green economy.

(2) Adjusting measures to local conditions to realize the coordinated development of regional green economy

For Xuancheng, Suzhou, Huainan, Huaibei and other traditional resource-based industrial cities, we should actively promote the economic supply side reform and adjust the industrial structure, introduce high-tech transformation and upgrading or eliminate traditional industries with high energy consumption and high emissions, do everything possible to reduce the emission of industrial waste gas and solid waste, actively undertake the spillover industries in high development gradient areas inside and outside the province, reduce energy consumption, and promote the development of photovoltaic, photovoltaic, wind power and other new energy industries, Based on the green circular economy, we should develop a new type of manufacturing industry that is resource-saving and environment-friendly. For areas in southern Anhui, such as Huangshan and Chizhou, that have the advantage of green natural resources, and areas in northern and Western Anhui that mainly rely on agricultural development, we should focus on cultivating green tank industry, modern tourism service industry and developing green ecological agriculture, accelerate the pace of agricultural mechanization and modernization, build towns with green economic characteristics and new rural communities to build beautiful villages, and effectively combine regional economic development with green resources, Turn the advantages of ecological environment into development capital, improve the output of green products and services, and constantly promote the transformation and development of regional green economy, so as to realize the steady and coordinated development of green economy in Anhui Province.

(3) Increase green credit and financial supply to promote the sustainable development of green economy

Financial markets can provide sustainable financial support for green development and provide diversified products and services for green production and environmental protection. Therefore, it is necessary to guide banks and other financial institutions to establish the concept of green credit and green finance, effectively play the role of capital resources optimization and supervision of the financial system, support regional adjustment and upgrading of industrial

structure, and provide reliable financial support for the cultivation of new green industries, high-tech industries and modern agricultural service industries. Appropriately reduce the financing threshold, and help enterprises speed up the transformation and upgrading and eliminate excess and backward production capacity with high pollution and energy consumption. We will focus on increasing the investment of green credit in banks, keep the ratio of green credit to all loans rising, expand the financing scale of capital market instruments such as green stocks, green bonds and green funds, improve the supply and coverage of green insurance products, innovate green enterprise property rights trading and carbon emission rights trading in regions, and explore new financing methods such as PPP and BOT financing of green projects. At the same time, establish and improve the statistical monitoring and assessment mechanism of green financial business of financial institutions, promote the formation of the green financial system in the province and give play to the financial agglomeration effect, so as to provide a good financial environment for the sustainable development of green economy in Anhui Province.

Acknowledgments

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