Study on Low-Carbon Economic Development in Guangdong Province Based on Principal Component Analysis

Zhuohang Liu[1], Qiwen Wu[2*]
Email: 779562612@qq.com, *Email: wuqiwen@stu.xmu.edu.cn

[1]College of Humanities and law, Wuhan University of Technology, Wuhan, China
[2]School of Management, Xiamen University, Fujian Province, China

Abstract. Low-carbon economy is an inevitable trend for urban sustainable development under the background of global warming. Although the concept of low-carbon economy has received worldwide attention, there is still a lack of in-depth research on the evaluation method for the low-carbon economic development, and the regional studies of carbon emissions difference also need to be further explored. Taking the principal component analysis method as the quantitative evaluation method, this paper constructs an evaluation index system of five dimensions and provides a reference for the evaluation of low-carbon economic development in 21 cities in Guangdong Province.

Keywords: low-carbon economy; Principal Component Analysis; regional studies

1 Introduction

As the world enters the era of climate change, the issue of carbon emissions has increasingly attracted extensive attention of the international community. With 10.523 billion tons of carbon emissions in 2021, China has become the largest carbon emission demand country around the world [1]. Therefore, the development of low-carbon economy has become a major concern in China's 14th Five-Year Plan. For now, Guangdong is facing severe pressure to reduce CO2 emissions because a great number of welding consumables have been used in local industries. Even though Guangdong has made excellent results in recent years, there are still some problems of low-carbon economic development in some cities Guangdong.

From the existing researches, scholars have already made in-depth studies on the driving forces of carbon emissions and the environmental results of CO2 pollution. But till today, researches on the development of carbon emissions from the microscopic aspect were not many. Therefore, this study will take 21 cities in Guangdong as research objects, conduct a quantitative research on the development of low-carbon economy in each city by using Principal Component Analysis, and then target to give political suggestions from the provincial aspect.

2 Methodology

This study mainly adopts Principal Component Analysis, which emphases the idea of reducing the dimensions.

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2.1 Selection and Source of Data

(1) Selection of data

This study based on the meaning of low-carbon economy, adhering to the scientific criteria, select precise indicators to interpret properly low-carbon operation value in reality. According to the experience of existing research [2][3], this paper builds the framework of the five dimensions: low-carbon production, low-carbon consumption, low-carbon technology, low-carbon and low-carbon society. The above five dimensions can fully explain the low-carbon economy of 21 cities in Guangdong. And according to the specific situation of low-carbon economy in Guangdong, we select the indicators that can cover a wide range of information with some emphasis in these regions.[4]

(2) Source of data

The relevant indicators what are described above are all obtained from the Guangdong Statistical Yearbook and the statistical yearbooks of different cities, which to a large extent ensure the unity and authority of the statistical standards, and have stronger stability and reliability so as to truly reflect the situation of every city in the research process.

2.2 Data Processing

(1) Relative transform

In the index system of low-carbon economic development in Guangdong, there is always a positive or inverse relation between the indicators and the low-carbon operation level, so we conduct the non-dimensional treatment for the experimental data in the analysis process and obtain corresponding related data. Here, we assume that there are m variables being analyzed in the Principal Component Analysis: x_1, x_2, …, x_m. There are n evaluation objects, and the value of the jth variable of the ith evaluation object is xij, we convert each index value xij into a standard sum $\tilde{x}_{ij}$:

$$\tilde{X}_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j}, (i = 1,2,...,n; j = 1,2,...,m)$$

In the formula, we have to state the following formula to explain that $\bar{x}_j$ and sj are mean and standard deviation of variables:

$$\bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}, \quad s_j = \frac{1}{n-1}\sum_{i=1}^{n}(x_j - \bar{x}_j)^2, (j = 1,2,...,m)$$

Correspondingly, we call $\tilde{X}_i = \frac{x_i - \bar{x}_i}{s_i}$, (i=1, ..., n) is a standardized variable.

(2) Eigenvalue and contribution rate of relevant matrix

According to the above relative transform, we can have the correlation matrix R=(rij)m×m. Then, dividing the correlation matrix by the original unit of measurement, we can obtain the following formula:

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

Where r_{ij}=1, r_{ij}=r_{ji}, r_{ij} are the correlation coefficient between the ith variable and the jth variable.

The concrete data are shown in Table 1. Based on the principle that the eigenvalue should be greater than 1 and the cumulative contribution rate greater than 85%, the principal components ranked from first place to fourth place in the table are selected, whose eigenvalues are respectively 8.074, 2.359, 2.078 and 1.479, represented by F1, F2, F3 and F4 components. Their percents of variance are 50.459%, 14.746%, 12.986% and 9.241% respectively, and the cumulative contribution percent is 87.432% in total, indicating that these four components covered most of the information contained in the 16 initial indicators, so they can be safely used to replace original indicators.

(3) Calculate eigenvectors

The eigenvalues of the correlation coefficient matrix R have the following rules: $\lambda_1 \geq \lambda_2 \geq ......\geq \lambda_m \geq 0$, corresponding to the eigenvectors u1, u2, ..., um, where u_j=(u_{1j}, u_{2j}, ..., u_{mj}) Thus, we gain new indicators formed by eigenvectors above and construct the following formulas:

$$\begin{cases} Y_1 = u_{11}\tilde{x}_1 + u_{21}\tilde{x}_2 + ...+ u_{n1}\tilde{x}_n \\ Y_2 = u_{12}\tilde{x}_1 + u_{22}\tilde{x}_2 + ...+ u_{n2}\tilde{x}_n \\ ...... \\ Y_m = u_{1m}\tilde{x}_1 + u_{2m}\tilde{x}_2 + ...+ u_{nm}\tilde{x}_n \end{cases}$$

Therefore, we calculate the eigenvector coefficients of each principal component, namely the coefficients of principal component expressions, the details are as follows:

Table 1. Component matrix (Table credit: Original)

	Component			
	1	2	3	4
Carbon emissions per unit of GDP (ten thousand tons)	-0.812	0.483	-0.240	0.143
Per capita carbon emissions (ton)	-0.207	0.353	0.676	-0.268
The ratio of primary industry in GDP (%)	-0.812	0.483	-0.24	0.143
The ratio of secondary industry in GDP (%)	0.218	-0.629	0.712	0.182
The ratio of tertiary industry in GDP (%)	0.626	0.228	-0.595	-0.375
Electricity consumption(kwh)	0.926	0.022	0.054	0.234
Household consumption of natural gas (10 cubic meters)	0.471	0.351	0.087	-0.742
Comprehensive utilization and disposal of hazardous waste (10 tons)	0.842	0.247	0.070	0.244
Comprehensive utilization capacity of general industrial solid waste (10 000 tons)	0.327	0.58	0.457	0.27
R&D personnel (person)	0.927	0.04	-0.225	0.221
Internal expenditure of R&D funds (RMB 100 million)	0.887	0.058	-0.296	0.243

Per capita park green space area (m^2)	0.282	0.479	0.322	-0.344
Treatment rate of urban sewage (%)	-0.085	0.735	0.241	0.436
Number of buses (ownership per million people)	0.938	0.133	-0.251	0.128
Per capita GDP (10 000 yuan)	0.935	0.054	0.107	-0.122
Per capita consumption expenditure of all residents (10 000 yuan)	0.944	-0.071	0.216	-0.086

According to Table 1, the indicators in the matrix system are X_1, X_2, X_3, …, X_{16} (they are carbon emissions per unit of GDP, carbon emissions per capita, the proportion of the primary industry and so on), we can conclude F_1, F_2, F_3, F_4 in the following formulas:

$F=8.074F_1+2.359F_2+2.078F_3+1.479F_4$

From the above expressions, we can see that the first principal component has a significant loading coefficient with the number of buses, per capita consumption expenditure of all residents, R&D personnel, internal expenditure of R&D funds and electricity consumption of each city, indicating that the first principal component mainly reflects the relationship between urban scale and low-carbon development.

(4) Principal component score and total score

According to the several principal components obtained above, while evaluating the low-carbon economic development of each city in the province, we calculate the score of each principal component and total score of each city in Guangdong. The results are shown in Figure 1:

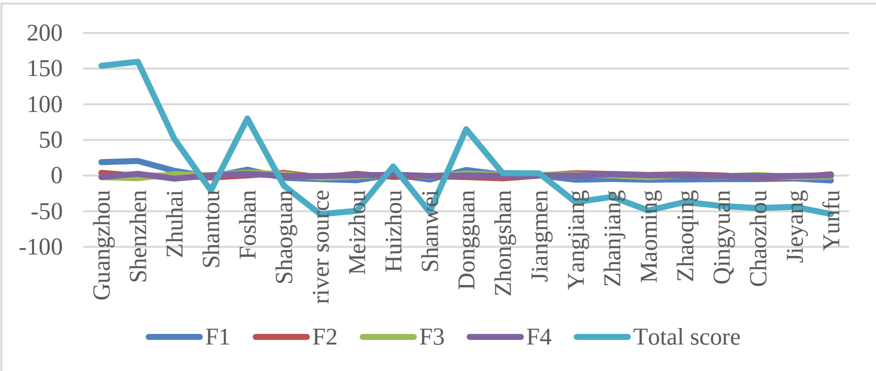

Figure 1. Score table of Principal Component Analysis（Photo credit:Original）

3 Conclusions and Recommendations

This study takes 21 cities in Guangdong as the research object, and uses Principal Component Analysis to carry out the research of low-carbon economic development in each city. The study draws the following conclusions and recommendations:

From the score of each principal component, it can be seen that high-quality development of regional economy and the waste management capacity directly affect the carbon emissions of a city. Guangzhou ranks first place in the first and second principal component, indicating that people pursue health-related lifestyle. Besides, the industrial structure plays a crucial role in the development of low-carbon economy of a city. In this regard, Foshan and Dongguan have done well. Other cities can learn from the experience of the two cities to further upgrade the urban industrial layout. However, from the score of the fourth principal component, it can be seen that the technical support of low-carbon construction in many cities in Guangdong is still insufficient. It is necessary to strengthen technical construction to ensure low-carbon economic development.

Overall, low-carbon economic development in Guangdong has achieved results, especially Guangzhou, Shenzhen and Foshan have significantly higher scores than other cities, which are 153.8527, 159.7276 and 80.0414 respectively. There are 13 cities in Guangdong still have great development potential and opportunities. Governments should further implement the low-carbon guidelines to small and medium-sized cities to guide their low-carbon economic development.

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