Comprehensive Evaluation Research of Urban Green Economy Evaluation Index System
——Cases of 31 Cities in China

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ABSTRACT
With the increasingly serious problem about ecological environment, the green economy conforms to the trend of the times. Therefore, it is practically meaningful for China's green economy development to develop green economy, to study the measurement of green economy development, to deeply understand the basic connotation of China's green economy, and to construct a relatively complete and objective urban green economy evaluation index system. Making use of the development data of 31 cities in Guangdong and Hunan province in 2019, this paper combined the index system based on the previous literature and utilized principal component analysis alike to construct a green economy evaluation index system and make a comprehensive evaluation research.

Keywords: *green economy, principal component analysis, evaluation index system*

1. INTRODUCTION

1.1.Background

Since the Reform and Opening-up, Chinese economy developed at a rapid clip, but environment and society paid a heavy price. Problems like the overexploitation of energy and serious environmental pollution brought by the extensive economic growth have a direct influence on the sustainable development of Chinese economy and society. In October 2015, the Fifth Plenary session of the 18th CPC Central Committee proposed five development concepts of "innovation, coordination, green, open and sharing", and in which, the concept of green development is to build a homeland of harmonious coexistence between man and nature. Human activities must respect nature, conform to nature and protect nature, or it punishes human without mercy. The upholding of the harmonious coexistence between humanity and nature is an important content of upholding and developing the basic strategy for developing socialism with Chinese characteristics in the new era. The building of a beautiful China is an important goal of building a great modern socialist country in all respects. Building an ecological civilization and protecting ecological environment have been elevated to unprecedented strategic heights. Green

economy has become an inexorable trend and the tide of the times in the social and economic development of the world and China. It is so vital to coordinate economic, social and environmental development that the model of green economy development has become the strategic choice of China's economic transformation. Therefore, through developing green economy, studying the measurement of green economy development and deeply understanding the basic connotation of China's green economy, it is practically meaningful to build a relatively complete and objective urban green economy evaluation index system for the development of Chinese green economy.

1.2.Literature Review

With the increasingly serious problem about ecological environment, the green economy conforms to the trend of the times, which is recognized and implemented globally. The phrase, green economy, appeared firstly in *Blueprint for a Green Economy* written by economist Pearce and published in 1989[1]. Green economics holds the view that from the perspectives of society and ecology, a "bearable economy" should be built, which means the development of green economyshould be supported by both natural environment and human itself without worrying about

social disruption caused by blindly chasing the growth of production. Most scholars believe that green economy should be discussed in conjunction with Green New Deal, green jobs and green economic thinking on the basis of climate change. One of the subjects of " Rio +20" is to develop green economy in the context of sustainable development and poverty eradication[2]. UNEP[3] has published several reports about the green economy, advocating global development of green economy. Zhang Xiaogang[4] held that green economy is an emerging economy under the influence of the theory of sustainable development, and that it is the only way for mankind to move from industrial civilization to ecological civilization. At the same time, green economy has become the theme of China's current economic development.

Up to now, there are a few study results about the measurement of green economy development, in which, the California government in 2009 published green innovation index to evaluate its green economy development from 4 items and 17 subitems, including low-carbon economy, energy efficiency, green technology innovation and policy system of green economy, etc[5]. *2010 China Green Development Index Annual Report --interprovincial comparison* jointly developed by Beijing Normal University, Southwestern University of Finance and Economics and China Economic Monitoring and Analysis Center of National Bureau of Statistics divided green development index into the green rate of economic growth, resource environmental bearing-capacity and government policy support, which respectively reflected in economic growth productivity and resource use efficiency, resource and ecological protection, pollutant discharge and government investment in green development,

management and governance, etc[6] Synthesizing existing research results, Xue Long combined with China's reality and built the measurement system of green economy development, including 4 first-level goals like green economy efficiency, green resource environment, green technology innovation and green economy policy, 9 second-level criterion and 38 third-level measurable indicators. And he put emphasis on the demonstration analysis and test of green economy development in Jinan during the eleventh five-year Plan period[7]. Making use of the development data of 31 cities in Guangdong and Hunan province in 2019, this paper combines the index system based on the previous literature and utilizes principal component analysis alike to make a comprehensive evaluation research.

2.THE ESTABLISHMENT OF MEASUREMENT SYSTEM OF GREEN ECONOMY DEVELOPMENT

In accordance with the design principles[7] of measurement system of green economy development and the connotation of green economy, this paper constructed a measurement system framework like Table 1.

This paper designed a measurement of green economy development whose target value is the comprehensive embody in the process of developing green economy. In order to further reflect the influence of various indicators on the measurement of green economy development in the process of developing green economy, this paper designed 3 first-level indicators, that is, population, economic development and technology innovation, environment carrying capacity and pollutant discharge. The second-level indicators are the specific manifestations of corresponding first-level indicators.

Table 1. Framework of green economy measurement system

First-level indicators	Second-level indicators	Indicator attribute
Population, economic development and technology innovation	Natural population growth（X1）	Positive
	Regional GDP (current price)（X2）	Positive
	Per-capita regional GDP (yuan)（X3）	Positive
	Regional GDP growth rate（%）（X4）	Positive
	The proportion of tertiary industry in regional GDP（X5）	Positive
	Patent numbers (piece)（X6）	Positive
Environment carrying capacity	Per-capita water resource（m^3/person）（X7）	Positive
	Total volume of water resource（$10000m^3$）（X8）	Positive
	Greenery coverage of urban area (%)（X9）	Positive
	Green area (hectare)（X10）	Positive
	Multipurpose utilization rate of general industrial solid waste	Positive
	Centralized treatment rate of wastewater treatment plant（%）	Positive
The discharge of pollution	The discharge of industrial wastewater (10000 tons)（X13）	Negative
	Industrial sulphur-dioxide emissions (ton)（X14）	Negative
	Industrial nitrogen oxide emissions (ton)（X15）	Negative
	Industrial smoke (dust) emissions (ton)（X16）	Negative
	Mean annual concentration of PM2.5 (ug/m^3)（X17）	Negative

3. EMPIRICAL ANALYSIS

3.1. Data Sources and Data Processing.

The data in this paper is from the *China City Statistical Yearbook* and the official websites of the related cities. Considering the data integrity and differences, this article selected 31 cities from Guangdong province and Hunan province(not including Xiangxi, Dongguan, Qingyuan, Zhongshan due to the loss of the data) .

3.1.1. The Standardized Processing of Sample Data

Because there are differences of the value, unit and the positive and negative of each index in the evaluation system, the index data must be standardized first.

3.1.2. The KMO Test and the Bartlett Test

Before doing the Principal Component Analysis (PCA), KMO test and Bartlett sphericity test should be performed to assure whether the index data to be analyzed is suitable for this method. The closer the KMO value is to 1, the more suitable the PCA method is, and if the significance level of Bartlett test is less than 0.05, it is suitable for factor analysis. In this paper, 31 cities in Hunan and Guangdong Province in 2019 are taken as an example, the results are shown in Table 2: KMO value is 0.581, about Bartlett Sphericity Test, P=0.000<0.05. It can be concluded that the existing data is suitable for principal component analysis and the results are valid.

Table 2. KMO test and Bartlett Sphericity test

Inspection method	Test Value	Judging Criteria	Result
KMO test	0.581	Kaiser standard	Suitable for PCA
Bartlett Sphericity test	445.025	Less than 0.05	
	136.000		
	0.000		

3.2. Principal Component Analysis Process

3.2.1. Solve the Principal Component

It can be seen from Table 3 that the first 6 principal components explain 83% of all variance, and the eigenvalue is greater than 1, indicating that the 6 extracted principal components can represent 83% of the original 17 indicators, and the extracted principal component evaluation has a certain grasp of the green economy evaluation index system. Therefore, the six principal components were extracted, namely F1, F2, F3, F4, F5 and F6.

Table3. Total variance interpretation

Composition	Initial Eigenvalues			Extraction Sum of Squared Loadings			Square sum of Rotating Loads		
	total	Percentage of variance	accumulation %	total	Percentage of variance	accumulation %	total	Percentage of variance	accumulation %
1	4.878	28.693	28.693	4.878	28.693	28.693	4.516	26.563	26.563
2	3.138	18.457	47.151	3.138	18.457	47.151	2.918	17.164	43.727
3	2.042	12.009	59.159	2.042	12.009	59.159	2.104	12.378	56.105
4	1.825	10.733	69.892	1.825	10.733	69.892	1.986	11.683	67.788
5	1.255	7.383	77.275	1.255	7.383	77.275	1.453	8.549	76.337
6	1.060	6.234	83.509	1.060	6.234	83.509	1.219	7.172	83.509
7	0.813	4.781	88.290						
8	0.546	3.214	91.504						

Table 4 is a composite score based on the principal component score calculated by the principal component equation and the weighted ratio of the contribution of each principal component to the total variance of the six principal components, judging from the principal component score and the overall score, the cities with the highest principal component score of F1 are Guangzhou and Shenzhen, which are the first-tier cities in our country and have been far ahead of other cities, it shows that these two cities have advantages over other cities in economic development, scientific and technological innovation, and green space area. Foshan, Zhuhai, Changsha are also

developing well, their scores are above 1. Changsha, the capital city of Hunan province and is named "Media and art capital of the world" by the United Nations, is also developed rapidly in these areas. On the one hand economy and Innovation promoted green development, on the other hand, the green-developed mode stimulate the development of economy. Yongzhou, Zhangjiajie, Shenzhen, Chaozhou, Shanwei and Huaihua all scored above 1.5 on the principal component score of F2, these cities performed well in terms of industrial wastewater emissions, industrial sulfur dioxide emissions industrial nitrogen oxide emissions, and industrial smoke emissions, the emission of the "three wastes" is lower than that of other cities, China's cities should firmly win the battle to protect our blue sky. For F3, Yongzhou scores higher than any other cities, which indicates that Yongzhou is rich in water resources. Yongzhou has three water systems: the Xiang river system, followed by Guangzhou and Loudi, which are also relatively rich in water resources. Of F4, The top scores were Maoming, Meizhou, Huizhou, Yongzhou, Shanwei, Jieyang, Chaozhou, Zhaoqing and Zhanjiang, these cities' natural growth rate of the population and the growth rate of the gross regional product are higher than those in the previous year, the annual average concentration of respirable fine particulate matter is lower than that of other cities and the particulate matter concentration has been effectively controlled. The F5 reflect the proportion of tertiary industry and the regional GDP, Jieyang, Shaoguan, Chenzhou, Heyuan, Yongzhou, Shaoyang, Hengyang, Jiangmen, Zhangjiajie, Yueyang, Zhuhai, Guangzhou and Huizhou scored higher, while other cities were below the

average. At this stage in our country, the role of the tertiary industry is not only in the contribution of output to the national economy, but also the development of the tertiary industry has played an important role in fostering market relations, improving market mechanisms, and solving the employment problem of the labor force. Among the F6 scorers, Changde, Meizhou, Yiyang, Changsha and Xiangtan have higher rates of centralized sewage treatment and green coverage in built-up areas than other cities.

Based on the table above, the following conclusion can be obtained: according to the composite scores, Shenzhen, Guangzhou and Zhuhai ranked the top 3 in the green economic factor analysis in 2019; The three cities with the lowest score are Xiangtan, Hengyang and Loudi, while the rest are medium-sized cities with green economic development. It is important to note that the first three cities are all from Guangdong province, for the province is an economic developed areas across China, which shows that the provinces with higher green economy level are mostly economically developed regions, since sufficient economic support is an indispensable condition to promote the economic transformation, develop green economy and information technology, to build on the basis of the information technology of green economy development mode. The imbalance of green economy development in various cities in China is universal and different, so it is necessary to jointly rectify and develop with characteristics, learn from each other, and promote the development of green economy together.

Table 4. Principal component scores and composite scores and ranking of each city

City	F1	F2	F3	F4	F5	F6	F Composite	Rank
Shenzhen	7.36	2.37	0.16	0.13	-0.60	-0.64	2.50	1
Guangzhou	6.88	0.77	1.22	-1.67	0.19	-0.69	2.06	2
Zhuahai	1.90	0.71	-0.67	0.74	0.20	0.69	0.73	3
Yongzhou	-2.69	2.69	6.66	1.44	0.78	-0.63	0.7	4
Foshan	2.77	-2.68	0.65	0.44	-0.67	0.51	0.41	5
Changsha	1.10	0.99	0.19	-2.07	-0.10	1.11	0.36	6
Maoming	0.05	0.98	-0.95	2.24	-0.39	0.50	0.32	7
Shantou	-0.07	0.95	-0.83	0.98	-0.11	0.53	0.19	8
Jiangmen	0.58	-1.18	0.12	0.94	0.41	0.82	0.14	9
Heyuan	-0.64	1.45	-0.90	0.6	0.91	-0.03	0.11	10
Huizhou	0.86	-2.06	0.05	1.98	0.09	0.15	0.10	11
Jieyang	-0.54	0.60	-2.04	1.24	3.22	0.04	0.09	12
Zijiajie	-1.10	2.61	-0.09	-1.44	0.40	0.31	0.05	13
Meizhou	-0.59	-0.56	0.21	2.00	-0.37	1.48	0.03	14
Shanwei	-0.85	1.95	-1.04	1.31	-1.12	-0.73	0.00	15
Shaoguan	0.4	-2.42	0.28	0.42	2.62	0.14	-0.05	16
Changde	-1.01	1.41	-0.35	-1.12	-0.41	1.91	-0.10	17
Zhanjiang	0.16	-1.49	-0.51	1.04	-0.66	0.74	-0.18	18
Huaihua	-1.30	1.50	-0.23	-0.73	-0.28	-0.43	-0.25	19
Shaoyang	-1.28	0.56	-0.15	-1.11	0.77	0.29	-0.32	20
Yangjiang	-0.84	0.40	-0.47	0.34	-0.88	-1.50	-0.34	21
Chenzhou	-0.68	-1.31	0.10	-0.88	2.11	0.01	-0.36	22
Chaozhou	-1.89	1.97	-1.18	1.17	-1.90	-0.86	-0.39	23
Zhuzhou	-1.02	0.07	-0.04	-1.40	-0.32	0.70	-0.41	24

Yiyang	-1.92	0.86	-0.20	-1.37	-1.18	1.44	-0.56	25
Yueyang	-0.58	-1.10	-0.49	-1.31	0.38	-1.15	-0.61	26
Zhaoqing	0.11	-4.18	0.97	1.12	-1.25	-0.73	-0.64	27
Yunfu	-1.25	-0.24	-1.23	0.50	-0.31	-2.51	-0.67	28
Xiangtan	-1.22	-1.91	0.30	-1.92	-0.81	1.08	-0.87	29
Hengyang	-1.45	-0.75	-0.70	-2.29	0.60	-2.24	-0.98	30
Loudi	-1.24	-3.00	1.14	-1.36	-1.34	-0.32	-1.04	31

4.CONCLUSIONS

As first-tier cities, Guangzhou and Shenzhen's scores are in the first category and are far ahead of other cities. From the perspective of provinces, especially among the first and the second category, four cities in Guangdong Province, namely Guangzhou, Shenzhen, Shaoguan and Jieyang, are on the list. While in Hunan, there is only one city Chenzhou is listed. Among the fifth and sixth cetegory, the cities listed in these last two categories are all from Hunan Province. But most cities in Guangdong and Hunan Province are in the third category, not only this condition indicates that each city needs to make efforts on improving the development of green economy and avoiding the decline of the green economy, but also it can be seen the universality of the uneven development of green economy in various cities. The unbalanced development of economy, society, resources and environment is hindering the steady development of China's green economy. A good way is that all cities cooperate with all efforts and have a mutual supervision in all aspects. Therefore, it is possible to build an ecological environment supervision platform to protect the ecological environment in all aspects, while accelerating the development and innovation of green technologies and cultivate "green talents."

5.POLICY RECOMMENDATIONS

According to the analysis results of this paper, policy suggestions are put forward as follows:

The backward cities should learn from the developed cities in China, combine the national conditions of our country to carry on the development of green economy in all aspects and to create good environmental protection measures for economic growth.

(1) Strengthen cross-regional exchange and cooperation on green innovation is a good way. While further developing green economy, economically developed regions should enhance their influence on other regions and make full use of their own advantages to drive economically backward cities

(2) China should formulate a medium and long-term plan as current direction of developing green economy. In terms of developing green energy and technology, Our country should also actively face and vigorously promote the technological revolution of green economy and develop new energy technologies such as clean energy and renewable energy.

In conclusion, the development level of green economy varies among cities in China, so it is necessary for cities to make clear the status and problems at present and pay closely attention to the green economy. According to the situation of each city, it is inevitable to accelerate the green transformation of industry, formulate more effective policies and implement effective governance policies and avoid the regression of the level of green economy are inevitable. Therefore, all cities should firmly follow the concept of "Green mountains and clear water are equal to mountains of gold and silver", deepen practice and strive to promote regional coordinated green economic development and improve the level of green economy under the leadership of the CPC and the country.

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