Study on Design of Evaluation Index System and Evaluation Method for Green Industry

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***Abstract*—In recent years, green industry is gradually rising in China. This paper screens out the indexes which have significant impact on green industry and establishes an development system based on relevant principles, studies the development of green industry in the main cities of China's first-tier and second-tier cities based on the software of SPSS and thus obtains the comprehensive evaluation of green industry for the above-mentioned cities on the basis of the comprehensive ranking. From these analysis, this paper found out that the average point of the green development index of industries in all provinces and municipalities is still low, there are existing some differences among three regions in China, and at the same time, they show different advantages and disadvantages in different indexes.**

***Index Terms*—evaluation index system; principal component analysis; regional ranking**

I. Introduction

Green industry refers to those industries that actively adopts cleaner production technology and innocuous or low noxious new process and technology, which aim to reduce raw materials and energy consumption to achieve the coexistence of less put, more output and less pollution, and to eliminate the environmental pollutants to the very extent within the production units. Developing green industry is the basis of green development and low-carbon economic development in current China. The green industry evaluation is a comprehensive evaluation of the development level of regional green industry through green production, green consumption and green environment. The development of green industry is evaluated by the indexes screened out.

This paper evaluates the top 16 provinces and municipalities in the first-tier and second-tier cities in 2016 from the indexes of green production, green environment and green consumption. After using relevant analysis as long as key index to mensurably choose out some indexes, figure out every indexes of these 16 provinces which is used for sequencing, comparing the development of the green industry among these different provinces.

There are many green industry evaluation systems. Asian green industry development index system established by the United Nations Industrial Development Organization (UNIDO) [1]. Urban green development evaluation index system established by the World Commission on Environment and Development (WCED) [2]. Low-Carbon economy evaluation index system based on PSR established by the Organization for Economic Co-operation and Development [3]. Urban comprehensive environmental index system and green economy index system established by the United Nation Environment Program (UNEP) [4]. Key indexes of urban ecological development established by the International Ecological Economy Promotion Association (IEEPA) [5].

Quantitative test indicators of urban environmental comprehensive treatment during the "Twelve Five" period established by the State Environmental Protection Administration. Green energy-saving index system established by the Energy Conservation Service Industry Committee of China Energy Conservation Association (EMACA) [6]. In 2003, the SEPA launched the pilot indexes of eco-county, eco-city and eco-province and provided the evaluation criteria of the indexes. The "Green Beijing" index system established by the Beijing Municipal Development and Reform Commission.

The evaluation index system of urban development ecology constructed by Chi Guotai et al [7,8]. Azapagic established the evaluation index system for the sustainable development of the mining industry from the aspects of economy, environment and society. Maxime et al evaluated the impact of Canadian food industry on ecology from the six aspects of energy consumption, greenhouse gas emissions and etc. The evaluation system of regional green industry development effectiveness constructed by Zhu Chunhong et al [9]. The evaluation index system of the regional leading industry constructed by Liu Sifeng et al.

There are two kinds of evaluation methods of green industry evaluation indexes. (1) The expertise-based Screening Method. Liang Zhong et al screened out the index system for evaluating low-carbon industry performance through the expert scoring method. Maes et al screened out 40 evaluation indexes from 157 audition indexes according to expert experience and evaluated the forest management in Belgium from three aspects of composition, structure and function. Yang Jianhua screened the evaluation index of electronic information industry from the connotation of electronic information industry. Liu Renhui et al established the evaluation system of metro construction safety based on analytic hierarchy process. (2) Objective Screening Method of Quantitative Method. Pacheco et al screened out the key variables affecting the evaluation results through quantitative screening methods based on principal component analysis.

Guo Lijuan et al screened the initial index system through variable selection methods based on principal basis analysis. The main problem existing in the objective screening methods is over-reliance on index data, therefore the actual meaning of index was ignored.

II. Construction and Evaluation Method of Green Industry Evaluation Index System

A. *Construction of Index System*

The green industry in this paper is defined based on the generalized green industry, which mainly selects some indexes of the primary industry of agriculture, forestry, fishery, the second industry of production and supply of heat, electricity, gas, water, manufacturing, water environment and public facilities management, and the third industry of finance, scientific research and technical service, information transmission, software and information technology. In the initial screening, according to the data observability criteria, the indexes whose data cannot be obtained are removed accordingly, which ensures the maneuverability of the index system.

According to the principles of scientific nature, maneuverability, conciseness selected from ecological security assessment index system, the establishment of this evaluation system mainly considers the factors that have a bigger impact on the ecological environment and economic development. Establish a relatively specific and targeted green industry evaluation index system reflecting green industry based on principle of maximum information content and principle of miscellaneous information elimination and the high frequency indicator of classical views of international authorities.

Among them, the information content of the index of principle of maximum information content reflects the identification capacity of the annual data difference of the index to the evaluation of green industry. The greater the data difference of the index is, the stronger the identification capacity of this index to the evaluation of green industry is. As for the principle of miscellaneous information elimination, the more redundant indexes are contained in index system, the more chaotic the information reflected by the evaluation results is, which makes different groups of indexes reflect different data characteristics and ensures information reflected by indexes screened out from different groups does not repeat.

Based on the above principles, the indexes that have significant impact on the evaluation of green industry are screened out, the criteria levels of green production, green consumption and green environment are constructed, and ten representative indexes are regarded as the evaluation factors. The index system is as shown in the Table 1.

Table 1. Index system.

Target level	Criteria level	Index level/Evaluation factors	
Green industry evaluation index system	Green production index	X11	The ratio of green industryto regional GDP
		X12	The ratio of expenditures on green scientific research project to GDP
		X13	Headcount of research and development (R&D)
		X14	Value added (hundred million yuan)
		X15	The proportion of environmental protection expenditure on financial expenditure
	Green environment index	X21	Comprehensive utilized volume of industrial solid wastes(ten thousand ton）
		X22	COD emissions(ton)
		X23	SO2 emissions(ton)
	Green consumption index	X31	Growth rate of energy consumption over the previous year (%)
		X32	energy consumption per capita（kg ce）

B. *Principles of Principal Component Analysis*

PCA is often used in the comprehensive evaluation of multiple indexes (variables), the relatively ideal results of principal components can be obtained when the correlation between the evaluation indexes. PCA lowers the dimensions of original indexes, eliminating some irrelevant indexes and converting originally more indexes into fewer comprehensive indexes reflecting research phenomena under the principle of guaranteeing the least loss of information, which can simplify complex researches and improve research efficiency on the premise of research accuracy guaranteed.

The steps of comprehensive evaluation of PCA can be summarized as follows: (1) Standardizing the data of the original index. (2) Determining the number of principal components. (3) Explaining the meaning of principal components. (4) Constructing principal component comprehensive evaluation function Y by principal component and its variance contribution rate. (5) Calculating the sample value of Y and ranking the samples.

III. Comprehensive Evaluation of Green Industry based on PCA

A. *Data Resources*

This paper chooses 16 provinces and municipalities ranked at the higher position of the first-tier and second-tier cities in China as research objects, and searches and calculates the relevant index data on the basis of the above index system. All the data are from “Chinese Statistical Yearbook 2017”, “Chinese Statistical Report 2017”, and “Statistical Yearbook” of every province and city.

B. *Evaluation Method and Mode*

This paper analyzes the data of 16 provinces and municipalities through PCA of SPSS 20.0 software. PCA uses fewer irrelevant comprehensive indexes to represent multi-index-variables with a certain correlation, and determines its reflective capacity to the whole through variance contribution rate of each principal component to avoid the subjectivity of determining index weight by people and the overlapping effects of multi-index-variables.

First, conduct KMO test and Bartlett spherical test, verify whether data is suitable for factor analysis, which mainly refers to KMO results, which are generally considered acceptable when the value is more than 0.5. At the same time, referring to the correlation coefficient, and it is generally considered suitable for factor analysis when the correlation coefficient of analysis variables is more than 0.3. Seeing from the test result, KMO = 0.620, which is greater than 0.5, and most of the correlation coefficients are greater than 0.3, which meets the requirements, passes the test and can be factor analysis. As shown in the Tables 2 and 3.

Tables 2. KMO and bartlett test.

Sampling Kaiser-Meyer-Olkin measurement that is measurable enough		0.620
Bartlett sophericity test	Approximate Square	86.184
	df	45
	Sig.	0.000

Tables 3. Correlation matrix.

		The ratio of green industry to regional GDP	The ratio of expenditures on green scientific research project on GDP	Headcount of R&D	Industrial production growth	The proportion of environmental protection expenditure on financial expenditure	Comprehensive utilized volume of industrial solid wastes	CO_2 emissions	SO_2 emissions	Growth rate of energy consumption over the previous year	Energy consumption per capita
	The ratio of green industry to regional GDP	1.000	.383	-.181	-.352	.260	-.280	-.448	-.250	-.355	.482
	The ratio of expenditures on green scientific research project on GDP	.383	1.000	.549	.140	.524	-.143	.052	-.195	.361	.444
	Headcount of R&D	-.181	.549	1.000	.733	.156	.299	.713	.228	.503	-.032
	Industrial production growth	-.352	.140	.733	1.000	.000	.099	.829	.054	.409	-.227
Correlation	The proportion of environmental protection expenditure on financial expenditure	.260	.524	.156	.000	1.000	-.252	-.269	-.317	.214	.202
	Comprehensive utilized volume of industrial solid wastes	-.280	-.143	.299	.099	-.252	1.000	.295	.876	-.017	-.533
	COD emissions	-.448	.052	.713	.829	-.269	.295	1.000	.273	.417	-.351
	SO_2 emissions	-.250	-.195	.228	.054	-.317	.876	.273	1.000	.123	-.589
	Growth rate of energy consumption over the previous year	-.355	.361	.503	.409	.214	-.017	.417	.123	1.000	-.201
	Energy consumption per capita	.482	.444	-.032	-.227	.202	-.533	-.351	-.589	-.201	1.000

Then use SPSS 20.0 software to make factor analysis on the data set to get the factor the coefficient matrix of the factor score and the principal component with variances greater than 1 by default. It can be seen from total variance diagram that there are three qualified ones. Therefore, the first three ones are the principal components, whose accumulation of the principal components is 75.88% of the total variance. And the variance of the first principal component is 3.626, the variance of the second principal component is 2.635 and the variance of the third principal component is 1.327. As shown in the Table 4.

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Table 4. Total variance explained.

Component	Initial eigenvalue			Extract square and load		
	Total	% of variance	Accumulation %	Total	% of variance	Accumulation %
1	3.626	36.259	36.259	3.626	36.259	36.259
2	2.635	26.352	62.611	2.635	26.352	62.611
3	1.327	13.269	75.880	1.327	13.269	75.880
4	.965	9.649	85.529			
5	.576	5.756	91.285			
6	.423	4.234	95.520			
7	.189	1.889	97.408			
8	.105	1.052	98.460			
9	.080	.795	99.255			
10	.074	.745	100.000			

Extract method: Principal component analysis.

Finally, calculate the score of each principal component according to the equation of principal components, then multiply the scores of each principal component by its corresponding weights and sum them up to get the comprehensive score Y.

The specific calculation models of principal components and total scores as follows:

Principal component 1 score=Factor 1 score*principal square root of 3.626 (1)

Principal component 2 score=Factor 2 score*principal square root of 2.635 (2)

Principal component 3 score=Factor 3 score*principal square root of 1.327 (3)

Overall score Y= $\frac{3.626}{3.626+2.635+1.327}$ * Principal component 1 score+ $\frac{2.635}{3.626+2.635+1.327}$ * Principal component 2 score + $\frac{1.327}{3.626+2.635+1.327}$ * Principal component 3 score (4)

C. Regional Comprehensive Ranking

According to the above research ideas and calculation models, use SPSS 20.0 software to get overall evaluation score and ranking of the green development index of industries of each province and city in China in 2016, (As shown in the Table 5, the data in the table is the original data score).

Table 5. Green development index ranking of 16 provinces and municipalities in 2016 (mainly the provinces and municipalities of the first-tier and second-tier cities).

Region \ Index		Factor 1	Factor 2	Factor 3	Principal component 1	Principal component 2	Principal component 3	Overall score Y
1	Guangdong	1.85444	1.99268	-.67307	3.53124	3.23465	-.77535	2.67510
2	Shandong	2.03079	-.69772	2.17818	3.86704	-1.13259	2.50917	1.89341
3	Zhejiang	.53990	.36054	-.50696	1.02808	.58525	-.58400	.59238
4	Henan	.93472	-.62835	-.34812	1.77990	-1.01998	-.40102	.42621
5	Hunan	.75367	-.32060	-1.19958	1.43514	-.52042	-1.38186	.26341
6	Shanghai	-.94015	1.63556	.76972	-1.79024	2.65495	.88668	.22154
7	Beijing	-1.29294	1.78645	.82569	-2.46202	2.89989	.95116	-.00315
8	Sichuan	.07979	-.61669	.80858	.15194	-1.00105	.93145	-.11213
9	Hubei	-.51839	.27708	.68970	-.98712	.44978	.79450	-.17657
10	Chongqing	-.18207	.02430	-.50381	-.34670	.03945	-.58037	-.25347
11	Shanxi	.12503	-.56402	-.45973	.23808	-.91556	-.52959	-.29678
12	Fujian	-.42669	.02215	-.06189	-.81251	.03596	-.07129	-.38825
13	Heilongjiang	-.41396	-.71359	-.93470	-.78827	-1.15835	-1.07673	-.96723
14	Jilin	-.39106	-.83632	-.95189	-.74466	-1.35757	-1.09653	-1.01903
15	Tianjin	-1.07199	-.32144	-1.09378	-2.04129	-.52178	-1.25999	-1.37699
16	Liaoning	-1.08109	-1.40004	1.46167	-2.05862	-2.27264	1.68378	-1.47846

IV. Dynamic Comparison on Green Development Index of Regional Industry

A. Overall Level

In view of the overall situation, the average green development indexes of industries of the main provinces and municipalities of the first-tier and second-tier cities in China is close to 0, the overall score is low, and the regional gap is large. In 2016, Guangdong with the highest score scored 2.6751, Liaoning with the lowest score scored -1.47846, with a gap of 4.15356. As shown in the Figure 1.

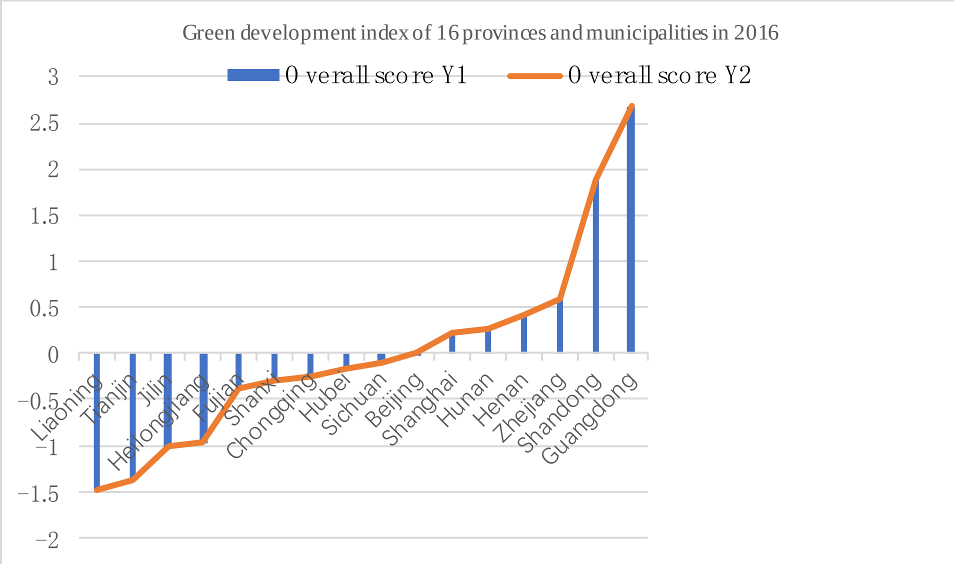

Figure 1. Green development index of 16 provinces and municipalities in 2016.

B. *Comparison on Three Regions*

Seeing the relative gap among the Central, Western and Eastern regions, in 2016, the average score of the Central region was 0.5615895 lower than that of the Eastern region, and the gap was wide; the average score of the Central region was 0.073848667 lower than that of the West region, and both all them were less than 0. As can be seen, there was a wider gap between the Central region and the Eastern region, and the average green development level of the Central region was the lowest. As shown in the Figure 2.

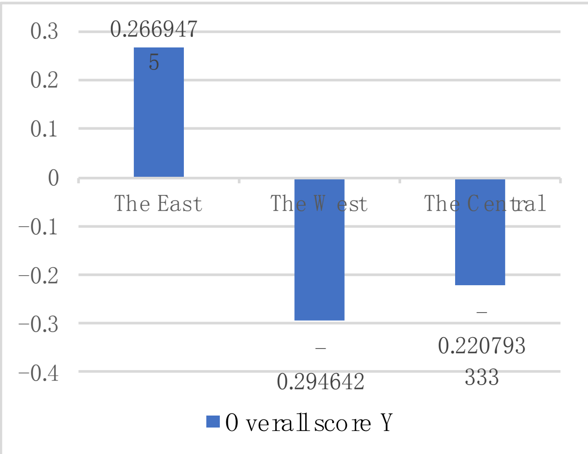

Figure 2. Average score of three region Y.

C. *Comparison on Interiors of Three Regions*

From the comparison on the interiors of the Eastern, Central and Western regions, in 2016, Liaoning with the lowest score in the Eastern regions scored -1.47846, which was 4.15356 lower than Guangdong with the highest score; Jilin with the lowest score in the Central region scored -1.01903, which was 1.44524 lower than Henan with the highest score; Shanxi with the lowest score in the West region scored -0.29678, which was 0.18465 lower than Sichuan with the highest score. As can be seen, in recent years, in 16 main provinces and municipalities of the first-tier and second-tier cities in China, the gap of the interior of the West region is smaller than that of the Central and Eastern regions, and the gap of the interior of the West region is clearly small. As shown in the Table 6.

Table 6. Comparison on interiors of three regions.

	Province	Overall score Y
Central region	Hunan	0.26341
	Henan	0.42621
	Jilin	-1.01903
	Heilongjiang	-0.96723
	Hubei	-0.17657
West region	Shanxi	-0.29678
	Chongqing	-0.25347
	Sichuan	-0.11213
Eastern region	Beijing	-0.00315
	Shanghai	0.22154
	Zhejiang	0.59238
	Shandong	1.89341
	Guangdong	2.6751
	Liaoning	-1.47846
	Tianjin	-1.37699
	Fujian	-0.38825

V. Policy Enlightenment

Based on the above research and analysis on aspects of industrial production, environment and consumption, the following suggestions are given:

Regionally, the Suggestions Are as Follows:

The average point of the green development index of industries in all provinces and municipalities is still low, in view of which, the key is to transform the economic growth mode and achieve green development together. All the regions should phase out backward production capacities, constantly optimize industrial structure, cultivate new green industries, save energy and reduce emission, and pay attention to the balanced and long-term development of resources, environment and economy.

There also exists differences among green industries in three regions of China, the three regions of China show different strengths and weaknesses in various indexes, in view of which, The three regions should implement differentiated green transformation development strategy, and each province should formulate green industry policy suitable for each province according to its own strengths and weaknesses.

Overall, Three Suggestions for Development of Green Industry are as follows:

1. Rigorously develop circular economy, promote efficient and intensive use of green ecological resources, construct the development pattern of circular economy promoted multidimensionally coordinately. Rigorously promote energy conservation and emission reduction, save resources in all the fields such as production, construction, circulation and consumption, and push a deeper development of circular economy in key areas through the construction of pilot projects.

2. Accelerate the green ecological transformation and upgrading of traditional industries, promote the conversion of new and old kinetic energy of industrial development, and implement the promotion of clean energy and energy recycling.

3. Cultivate the green development of new industries and modern service industries. Implement E-commerce demonstration project, cultivate and develop new formats and new business models such as digital economy and share economy. Cultivate and strengthen the ecological environmental protection industry, speed up the construction of green manufacturing and vigorously develop green finance.

China has a vast territory with numerous industries and resources, which are all our precious wealth. We should make reasonable, effective and full utilization of them and find out a suitable way for the green economy development and the improvement of the level of ecological civilization with their pplementing and improving each other. Relying on the advantages of green ecological resources and the basis of green industry, strengthen and improve the development of green industry, strive to build an environment-friendly green ecological industrial system, and promote economic development with green industry.

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