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SciVerse ScienceDirect
Energy Procedia 16 (2012) 535 – 540
Energy Procedia

2012 International Conference on Future Energy, Environment, and Materials

An Evaluation Study on the Level of China's Low-Carbon Manufacturing Based on Factor Analysis

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Abstract

Based on the absorption of some relevant research results, this paper establishes an evaluation model of the level of China's low-carbon manufacturing and uses the factor analysis method for empirical research. Then it analyses the exist problems of China's low-carbon manufacturing and puts forward some relevant countermeasures and suggestions.

Keywords: low-carbon economy; manufacturing; evaluation of the level of low-carbon; factor analysis

1. Introduction

Nowadays, the development model of low-carbon economy becomes a major goal of national economic development in the new era. As a country's economic lifeline, manufacturing not only brings rich material for people, promotes the country's rapid economic development, but also brings enormous pressure to the resources and the environment. Owing to its large energy consumption, low energy usage and serious environmental pollution, many countries put manufacturing as the key of implementing low-carbon economy. They introduce low-carbon manufacturing and achieve some success. However, compared to developed countries, China has long been known as "manufacturing" rather than "manufacturing power". There are still some gaps between them in the implementation of low-carbon manufacturing. Therefore, scientific and effective evaluation of the degree of China's low-carbon

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 doi:10.1016/j.egypro.2012.01.086

manufacturing is of far-reaching significance for achieving low-carbon industries, and ultimately promoting the sustainable development of China's manufacturing.

2. Literature Review

Throughout the present studies, in the evaluation of low-carbon economy, Zhuang Guiyang, Pan Jiahua and Zhu Shouxian (2011) builded a measure index system, including low-carbon output, low-carbon consumption, low-carbon resources and low-carbon policy. Besides, combined with the real demand they made further suggestions for improvement. From the perspective of low-carbon economy concept and industry chain path, Hu Dali, Ding Shuai (2010) builded a evaluation index system of low-carbon economy, including low-carbon energy, low-carbon industry output, low-carbon consumption, low-carbon waste disposal, low-carbon social environment, low-carbon science and technology 6-level indicators and 20-secondary indicators. Li Xiaoyan and Deng Ling (2010) builded a comprehensive evaluation index system of the city’s low-carbon economy, including economic systems, technological systems, social systems and environmental systems 4-level indicators and 27-secondary indicators, and conducted empirical researches. From the angle of economic development, technological level and natural resources, Ye Yichang and Huang Mingfeng (2011) builded a low-carbon economic development evaluation system, including CO_2 emissions, GDP, proportion of the industrial structure, low-carbon policy, carbon productivity etc. 9 indicators, and used factor analysis to conduct empirical studies. As can be seen from the above studies, the current academic’s evaluation methods of low-carbon economy are still relatively fragmented, and the views vary. However, from different angles, most of them decomposed low-carbon economic evaluation into several different parts and mostly concentrated in several important indicators, that is low-carbon output, low-carbon resources, low-carbon environment and low-carbon technology. Therefore, in order to scientifically evaluate the degree of China's low-carbon manufacturing we should also be reference to that when we establish the evaluation system.

3. Empirical Research

3.1. Construction of evaluation index system

According to the preceding analysis, this study follows the science, importance, feasibility and guiding principles, excluding indicators of large correlation and weak representative, and adds specific indicators which can better reflect the low-carbon manufacturing to establish the evaluation system of the degree of low-carbon manufacturing (table 1).

3.2. Data Collection

In this paper, data are all from "China Statistical Yearbook", "China Industrial Economic Statistical Yearbook", "China Energy Statistical Yearbook" and other statistical literature compiled by National Bureau of Statistics and National Bureau of Energy. The statistical year is 2004-2008. And the statistical object is the seven sectors of high energy consumption, high emission and high pollution in China’s manufacturing, that is Textile Industry, Paper & Paper Products Industry, Petroleum Processing, Coking and Nuclear Fuel Processing Industry, Chemical Materials and Chemical Products Manufacturing, Non-metallic Mineral Products Industry, Ferrous Metal Smelting and Rolling Processing Industry, Non-ferrous Metal Smelting and Rolling Processing Industry. Statistical standards is large-scale manufacturing companies. Manufacturing’s CO_2 emissions are estimated by the method of Sun Ning (2011).

Table 1. The evaluation index system of the degree of low-carbon manufacturing

Level indicators	Secondary indicators	Formula	Direction of indicators
Low-carbon economic development indicator (A_1)	Per capita GDP (Ten thousand yuan, A_{11})	Total industrial output value / The number of practitioners	Positive
	Per capita wages (Ten thousand yuan, A_{12})	Total wages / The number of employees	Positive
Low-carbon energy indicator (A_2)	Average carbon emission factor (A_{21})	Carbon emissions / Energy consumption	Negative
	Carbon productivity (One hundred million yuan / Ten thousand tons, A_{22})	Total industrial output value / Carbon emissions	Positive
	Energy consumption per unit of output (Ten thousand tons / One hundred million yuan, A_{23})	Energy consumption / Total industrial output value	Negative
Low-carbon environmental disposal indicator (A_3)	Disposal rate of industrial solid waste (%, A_{31})	The amount of industrial solid waste disposal / Total amount of industrial solid waste generated	Positive
	Comprehensive utilization rate of industrial solid waste (%, A_{32})	The amount of industrial solid waste utilization / Total amount of industrial solid waste generated	Positive
	Compliance rate of industrial wastewater discharge (%, A_{33})	The compliance amount of industrial wastewater discharge / Total discharge of industrial wastewater	Positive
	Removal rate of industrial waste gas (%, A_{34})	The removal amount of industrial waste gas / Total emissions of industrial waste gas	Positive
Low-carbon carbon emission indicator (A_4)	Carbon emission intensity (Ten thousand tons / One hundred million yuan, A_{41})	Carbon emissions / Total industrial output value	Negative
	Per capita carbon emissions (Ten thousand tons / million people, A_{42})	Carbon emissions / The number of practitioners	Negative

3.3. Statistical Analysis

Factor analysis is a data reduction technique. The basic idea is using a few key factors which can largely reflect the original numerous variables to summarize and explain a large number of observed facts of complex relationships, whose goal is minimal information loss, in order to facilitate analysis and judgment.

This paper uses SPSS13.0 to conduct factor analysis of the data. Firstly, indicators should be conducted positive and standardized treatment; next is the KMO and Barlett's test, among which KMO test value is 0.720 and the significance probability of Bartlett's test is 0.000, so the variables are suitable for factor analysis; then it estimates and analyzes the main factors. In general, the number of appropriate main factors should be determined by the number of eigenvalues greater than 1. Therefore, we select three factors as the main factors according to the output of factor analysis, and their cumulative variance contribution rate is 86.896% (greater than 80%). So, the three main factors can sufficiently represent the degree of China’s low-carbon manufacturing. Table 2 shows the rotated eigenvalues, contribution rate and factor loading matrix.

Table 2. Rotated eigenvalues, contribution rate and factor loading matrix

	Component		
	1	2	3
Per capita GDP	-.204	.162	.898
Per capita wages	-.227	.290	.891
Average carbon emission factor	.659	.398	-.593
Carbon productivity	.975	.074	-.196
Energy consumption per unit of output	.955	-.080	.073
Disposal rate of industrial solid waste	.099	.880	.003
Comprehensive utilization rate of industrial solid waste	.027	-.908	.065
Compliance rate of industrial wastewater discharge	.006	-.336	.745
Removal rate of industrial waste gas	-.119	.804	.110
Carbon emission intensity	.975	.075	-.195
Per capita carbon emissions	.893	-.285	-.261
Eigenvalues	4.163	2.725	2.671
Contribution rate (%)	37.841	24.769	24.286
Cumulative Contribution rate (%)	37.841	62.610	86.896

It can be seen from the factor loading matrix, the first main factor’s load on the carbon productivity, energy consumption per unit of output, average carbon emission factor, carbon emission intensity and per capita carbon emissions is much larger than the load on other indicators, and these indicators majorly reflect manufacturing’s energy structure, energy use and carbon emissions, so they can be defined as energy, carbon emission factor F1. It is the first contribution factor which combines 37.841% of all index information. The second main factor’s load on the disposal rate of industrial solid waste, removal rate of industrial waste gas and comprehensive utilization rate of industrial solid waste is relatively larger, so it can be named as environmental governance factor F2, which combines 24.769% of all index information. The third main factor’s load on the per capita GDP and per capita wages is larger and balanced, so it can be defined as economic development factor F3, which combines 24.286% of all index information and is an important factor in the evaluation.

3.4. Computation of the composite score

According to the output of SPSS13.0, it can directly get three main factors’ scores of 35 samples. In order to comprehensively evaluate the degree of China's low-carbon manufacturing, this article sets three main factors’ variance contribution rate as weight, then does weighted summation to draw the final composite score of 35 samples, whose formula is $F = 0.44912 * F1 + 0.24777 * F2 + 0.17207 * F3$. Then, the average value of different sectors’ factor scores can be got. So, in the last, it can get the factors’ average scores and composite scores of the degree of low-carbon in seven manufacturing sectors. The final scores are shown in table 3.

Table 3. Factor Score

Sectors	Main factor F1		Main factor F2		Main factor F3		Composite	
	Factor Score	Sort	Factor Score	Sort	Factor Score	Sort	Composite Score	Sort
Textile Industry	2.13868	1	-0.77464	7	-0.28512	3	0.71953	1
Paper & Paper Products Industry	0.07462	3	-0.50344	4	-0.66556	6	-0.20575	5
Petroleum Processing, Coking and Nuclear Fuel Processing Industry	-0.45024	4	-0.57024	5	1.74020	1	-0.04406	3
Chemical Materials and Chemical Products Manufacturing	-0.47215	5	-0.10065	3	-0.39961	5	-0.25588	6
Non-metallic Mineral Products Industry	-0.79368	7	-0.65267	6	-0.76811	7	-0.65034	7
Ferrous Metal Smelting and Rolling Processing Industry	-0.58945	6	0.25232	2	0.72339	2	-0.07774	4
Non-ferrous Metal Smelting and Rolling Processing Industry	0.30794	2	2.14802	1	-0.34518	4	0.61112	2

3.5. Results Analysis

The degree of China's low-carbon manufacturing is compositely ranked as follows: Textile Industry, Non-ferrous Metal Smelting and Rolling Processing Industry, Petroleum Processing, Coking and Nuclear Fuel Processing Industry, Ferrous Metal Smelting and Rolling Processing Industry, Paper & Paper Products Industry, Chemical Materials and Chemical Products Manufacturing, Non-metallic Mineral Products Industry.

Textile Industry’s degree of low-carbon ranks first. Its score in F1 is number one, far ahead of other sectors, and in F3 also ranks third, which indicate that it attaches great importance to the investment in low-carbon manufacturing, and focus on optimizing energy structure, improving energy efficiency and reducing carbon emissions, with maintaining a rapid economic growth. However, its score in F2 comes last, with poor environmental benefits, which may be related to that the Textile industry is the traditional high-polluting industry.

Second is the Non-ferrous Metal Smelting and Rolling Processing Industry. Its scores in F2 and F1 are higher, respectively rank first and second, explaining that it pays more attention to low-carbon manufacturing. However, its score in F3 ranks middle, indicating that economic development has been neglected and should be strengthened

Third is the Petroleum Processing, Coking and Nuclear Fuel Processing Industry. Its score in F3 ranks first, but in F1 and F2 rank on the list. This shows that in the context of economic development, carbon emissions, energy use and environmental management must be indispensably balanced.

Ferrous Metal Smelting and Rolling Processing Industry ranks fourth. Its scores in F2 and F3 are higher, all ranking second. However, its score in F1 ranks the last second, which greatly affects the composite rankings.

Fifth and sixth are respectively the Paper & Paper Products Industry and Chemical Materials and Chemical Products Manufacturing. The former's score in F1 ranks third, but in the others ranks on the list. Similarly, the latter's score in F2 ranks third, but in the others ranks on the list, which exactly matches the original data of the indicators, showing that low-carbon must take the whole into account.

Non-metallic Mineral Products Industry's degree of low-carbon is the lowest. Its scores in the three factors all rank on the bottom, indicating that its energy structure, energy efficiency, environmental management and economic development, etc. are to be improved, which is also a serious impediment to the realization of low - carbon industry.

4. Conclusions and Recommendations

Through the above analysis, as opposed to F2 and F3, the energy and carbon emission factor F1 is the most important one affecting the degree of low-carbon manufacturing. We can also find that China's manufacturing attaches little importance to low-carbon manufacturing, lacking in investment, and the use efficiency is low. On the other hand, some sectors' carbon emissions benefits and energy efficiency are all low, leading to a lower degree of low-carbon; some sectors' carbon emissions benefits and energy efficiency are relatively high, but because the environmental governance or economic development can't keep up, hindering the realization of low-carbon.

Therefore, in order to improve the degree of China's low-carbon manufacturing and achieve low-carbon industry as early as possible, we should firstly establish the awareness of low-carbon development. Secondly, we should co-ordinate economic development, low consumption, low emissions and low pollution Lastly, we should focus on the optimization of energy structure and improvement on energy and carbon emissions efficiency. Through the optimization of industrial structure, extension of industry and value chain and increase in low-carbon research investment we can improve the energy structure and reduce carbon emissions, ultimately achieving the sustainable development of China's manufacturing industry.

Acknowledgments

The authors are greatly thankful to the fund of Jiangsu College Philosophy and Social Science Key Research Base Major Project (S7910006001), Jiangsu "Six Talent Summit" Project(S7410008001) and Industry(meteorology) Special Research (GYHY201106032-03).

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