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ARTICLE

Analysis on the Efficiency of Anhui's Industrial Sectors under the Carbon Emission Constraints

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ABSTRACT

This paper uses the SBM-DDF model to measure the green inefficiency of all kinds of industries in Anhui Province under the constraint of carbon emissions from 2006 to 2014. The results show that whether from the perspective of the overall industries in Anhui Province or from the perspective of separate industry groups, the sources of the green inefficiency are mainly from insufficient industrial output, followed by excessive emissions of CO_2. The green inefficiency values of each group (from big to small) are sized down by high-emission industries, medium-emission industries and low-emission industries respectively. During the period of research, the effect of the emission reduction in high-emission industries was not significant, and the potential of reducing the green inefficiency in the medium-emission and low-emission industries by increasing the output was not large.

1. Introduction

Since the reform and opening-up, China's economy has developed rapidly, but the problem of environmental pollution is getting more and more serious. Especially in terms of carbon dioxide emissions, China's emissions in 2007 reached 6 billion tons, which accounted for 21% of the total global emissions. This means China has become the biggest carbon-dioxide emitter instead of the United States. In this paper, CO_2 emissions are introduced into the efficiency measurement framework as the undesirable output, and the SBM-DDF model is used to calculate the green inefficiency of Anhui's industrial sectors under the constraints of CO_2 emissions from 2006 to 2014.The input and output factors are combined to analyze the sources of the inefficiency. The study is of great significance for formulating energy-saving and emission-reduction schemes in Anhui Province of China.

2. Literature Review and Theoretical Basis

When it comes to dealing with undesirable output, the following methods are commonly used. The first method is to deal with the reciprocal of undesirable output as the desirable and then solve the problem in the classical DEA model, but this is contrary to the actual production process. The second method is to introduce undesirable output as traditional input into the model. In both meth-

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ods, variables are changed from output to input. Although the process of taking undesirable output as input allows for the constraints of environmental carbon, it violates the laws of physics and standard production theories, and leads to conceptual confusion as well; therefore, it cannot reflect the actual production process. The third type is the directional distance function method. Chung et al. (1997) proposed the directional distance function (DDF) when measuring the productivity of a Swiss pulp mill and explained that Shephard's output distance function is a special case of directional distance function [1]. Fukuyama & Weber (2009) proposed a directional distance function method based on slack measure on the basis of Tone's (2001) non-radial, non-angle and Slack-based measurement (SBM) efficiency measurement [2, 3]. It theoretically proves that when there is no slackness existing, the result of the directional distance function based on the slack measure is the same as the result of DDF. When slackness appears, the former's result will be larger than the latter's, indicating that the DDF model will overestimate the efficiency of the decision making unit.

The value calculated according to the directional distance function is the efficiency value or inefficiency value of various decision-making units on a static level, and it is needed to introduce productivity index in order to further study the evolution of the green efficiency over time and analyze the change of it according to the change of productivity index. Chambers (1996) developed the non-oriented Luenberger productivity index [4]. The difference between L and M-L productivity index is that the former is additive and the latter is multiplicative. Wang Bin (2010), Liu Ruixiang (2012), Li Ling (2012) et al. used L productivity index to do the dynamical analysis [5, 6, 7].

Thus it can be seen that, although DDF model can well introduce undesirable output, for it's a radial and oriented way, it may overvalue the efficiency of decision-making units when slackness exists. The improved SBM-DDF model can solve this problem. This paper uses the SBM-DDF model to measure the green inefficiency of various industries in Anhui Province of China under the constraint of carbon emissions from 2006 to 2014, decomposes it based on the input and output elements and analyses in depth the evolution of different industry's green efficiency in Anhui province.

3. The Empirical Analysis

3.1 Model Construction

This paper sets each separate industry as a decision making unit (DMU) and constructs an efficiency boundary with the input and output data of all DMUs, and then measures the distance between each DMU and the boundary, which is the inefficiency value of each DMU.

Since the efficiency boundary is in a piecewise linear form, the direction distance function is likely to be slack when measuring the degree of inefficiency, which can be simply explained in the following figure:

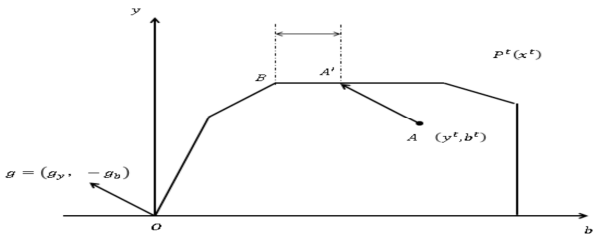

Figure1. Slack of directional distance function

Directional distance function measures the degree of inefficiency from point A to point A′, but we can see clearly in the figure that A ′is not efficient because the undesirable output is reduced without the reduction of the desirable one at point A′, and to B, A′B is slack, so when slack exists, the measure of directional distance function can underestimate the inefficiency of decision making units, namely overestimate its efficiency. Aiming at this problem, Tone(2001) proposed Slack-based measure model (Slack-based measure, SBM)[3], Fukuyama & Weber (2009) turned Tone's SBM model generally into a non-radial, non-angled directional distance function based on the slack measure (SBM - DDF)[2].According to Fukuyama & Weber (2009) and Liu Ruixiang (2012)[2,7], the specific form of SBM - DDF can be expressed as follows:

$$S_V^t\left(x_{i'}^t,y_{i'}^t,b_{i'}^t;g^x,g^y,g^b\right)=\frac{1}{3}\max\left(\frac{1}{N}\sum_{n=1}^{N}\frac{s_n^x}{g_n^x}+\frac{1}{M}\sum_{m=1}^{M}\frac{s_m^y}{g_m^y}+\frac{1}{K}\sum_{k=1}^{K}\frac{s_k^b}{g_k^b}\right)$$

$$s.t.\sum_{i=1}^{I}\lambda_i^t y_{im}^t-s_m^y=y_{i'm}^t,m=1,...,M$$

$$\sum_{i=1}^{I}\lambda_i^t b_{ik}^t+s_k^b=b_{i'k}^t,k=1,...,K$$

$$\sum\nolimits_{i=1}^{I}\lambda_i^t x_{in}^t+s_n^x=x_{i'n}^t,n=1,...,N$$

$$\sum\nolimits_{i=1}^{I}\lambda_i^t=1,\lambda_i^t\geq 0,i=1,...,I$$

$$s_m^y\geq 0,s_k^b\geq 0,s_n^x\geq 0 \qquad (1)$$

We can get the inefficiency of the first i ′decision making unit by solving the linear programming above, which means the first i′ industry in this paper. $\left(x_{i'}^t,y_{i'}^t,b_{i'}^t\right)$ represents

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the input and output of the first i' industry. (g^x, g^y, g^b) represents the direction of the decrease of input, the increase of desirable output and the decrease of the undesirable output, which is positive. (s_n^x, s_m^y, s_k^b) represents input and output slack of the first i'industry. If the direction vector is evaluated as the observed value of each variable in each province, not only can eliminate subjective factors, but can also make the slack variable in the same unit with direction vector without data standardization process, so that the efficiency value of the input and output can be additive. The inefficiency can be decomposed continuously:

$$IE = S_v^t = IE_v^x + IE_v^y + IE_v^b \quad (2)$$

The inefficiency of input: $IE_v^x = \frac{1}{3N}\sum_{n=1}^{N}\frac{s_n^x}{g_n^x}$;The inefficiency of desirable output: $IE_v^y = \frac{1}{3M}\sum_{m=1}^{M}\frac{s_m^y}{g_m^y}$;The inefficiency of undesirable output: $IE_v^b = \frac{1}{3K}\sum_{k=1}^{K}\frac{s_k^b}{g_k^b}$.

In this paper, input includes labor, capital and energy sources; the desirable output is the total output of the industrial sector; the undesirable output is the carbon dioxide emissions of industrial sector. According to the specific input-output factors and formula (2), the inefficiency IE can be decomposed as:

$$IE = IE_{cap} + IE_{lab} + IE_{ene} + IE_{out} + IE_{co_2} \quad (3)$$

The bigger the inefficiency IE is, the smaller the green efficiency will be.

3.2 Data Selection and Processing

3.2.1 Selection of Variables

In this paper, the shown data of industrial sector in Anhui province is used for the analysis, the time span is set as the total nine years from 2006 to 2014. carbon dioxide emissions are regarded as the undesired output, the total output value of the industry as the desirable output, capital stock, labor input and energy consumption as input variables.

3.2.2 Processing of Data

Based on the average annual carbon dioxide emissions of various industries in the analysis period, industries that emit more than 10 million tons of annual emissions are classified as high-emission industries, including: thermal, power supply industry, nonmetal mineral products industry, ferrous metal smelting and rolling industry. The industries which emit between 100,000 tons and tens of thousands of tons of annual emissions are classified as medium-emission industries, including: textile industry, electrical machinery and equipment manufacturing industry, non-metallic mineral industry, waste resource utilization industry, ferrous metal industry, chemical fiber industry, transportation equipment manufacturing industry, fabricated metal products industry, wine industry, beverage and refined tea manufacturing industry, wood processing and wood, bamboo rattan palm grass products industry, agricultural sideline products processing industry, food, general equipment manufacturing industry, rubber and plastic products industry, medicine industry, non-ferrous metal smelting and rolling industry, paper and paper products industry, the rest belongs to low emission group, including: computer communications and other electronic equipment manufacturing industry, furniture manufacturing industry, water production and supply industry, tobacco products industry, instrument industry, printing and recording media reproduction industry, non-ferrous metal industry, special equipment manufacturing industry, a total of 28 industries.

3.3 Green Inefficiency Result and Decomposition of Industrial Sector under Carbon Emission Constraints

We use the formula (1) and formula (2), build efficiency boundary interface with the value of current samples, select the sample value of each industry as a direction vector, standardize the slack of each input and output, calculate the green inefficiency of the industrial sectors in Anhui province(hereinafter referred to as inefficiency value) between 2006 and 2014 under the assumptions of variable return scale (VRS) and constant return scale (CRS) .The average green efficiency of the industrial sector in Anhui province is 0.9768, while the inefficiency related to CO_2 is up to 0.3263, accounting for 34% of total inefficiency value. The inefficiency of output is up to 0.4876, accounting for 50% of total inefficiency value. Among the three elements of input, energy input contributes the most inefficiency, whose specific value is 0.1037, followed by capital investment 0.0337, and the least is labor input 0.0256, by picking out the contribution of energy input from the input factors and adding it together with the contribution of carbon dioxide, the added contribution inefficiency value is 0.4299, accounting for 44% of the total, the overuse of energy and excess of carbon dioxide emissions cause a greater degree of inefficiency, which suggests that energy conservation and emissions reduction is very important for the sustainable development of the industrial sector in Anhui province and insufficient industrial output and excessive carbon dioxide emissions are the main reasons for the inefficiency of the overall in-

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dustrial industry in Anhui province. This is similar to the conclusion of the national industrial research by Song fan (2013)[8].

Most of the industries whose inefficiency is bigger than the average of the whole province belong to heavy industry such as: non-metallic mineral products industry, ferrous metal industry, black metal smelting industry, general equipment industry, chemical fiber industry, electricity and heat production industry or polluted light industry such as: paper and paper products industry, printing media industry. But among such high inefficient industries, medical manufacturing industry, food manufacturing industry, beverage manufacturing industry and textile industry are also included. Decomposing the inefficiency of medical manufacturing industry, we can see clearly that the inefficiency of its output is 0.9918, contributing 72% to the total inefficiency, but as a high technology industry, it should have high added value, the output should not be the main source of its inefficiency, this paper believes that the possible reason for such a result may be that most of the added value of the medical manufacturing industry is absorbed by the circulation department and the profits from the final distribution to the medical manufacturers are not much and such kind of high technology enterprise also have to pay high research cost, so the output is not enough .For food manufacturing industry, beverage manufacturing industry, textile industry, the output is also contribute no more than 60% of the inefficiency value, especially for food manufacturing industry, it illustrates that this three industry is still in the low side of manufacturing. This consumption industry is in the low side of the industry sector, whose brand effect is not strong, which leads to its low added value and little profits.

The industries whose inefficiency value is smaller than the average of the whole province include agricultural food, communications computer electronic equipment, special equipment, wood processing, nonferrous metal, metal products, transportation, and electrical machinery and so on. Technology of electrical machinery industry is relatively dense, the its total inefficiency is lower for high added value, together with low carbon emissions, the calculation results also show that the inefficiency of its industrial output is 0.0527, and its output inefficiency in recent five years is 0, which shows that its output has reached a completely efficient standard. Although the level of inefficiency for Agricultural food, non-ferrous smelting, special equipment industry is not very high, their carbon dioxide emissions contribute more than 40% of the total inefficiency, especially for agricultural food, if the inefficiency value of the energy is added together, it will account for 60% of the total efficiency, which means these industries seriously need energy conservation and emissions reduction.

Among the industries above, five industries with the lowest efficiency are: tobacco products industry, nonferrous metal smelting industry, electrical machinery manufacturing industry, instrument industry and waste resource industry. Electrical machinery manufacturing industry and instrument industries have high added value, low efficiency output low energy consumption and low carbon dioxide emissions. Tobacco products and furniture manufacturing are light industries and the tobacco products industry is controlled by the state. However, nonferrous metal smelting is a heavy industry with high energy consumption; it should be an inefficient industry. By decomposing the inefficiency according to input and output factors, we can find that the inefficiency of its output is 0.1289, which is the lowest except the electrical machinery, tobacco products, instrument, waste resources, the addition of inefficiency value of its energy and carbon dioxide emissions accounts for 68% of the total efficiency, which shows that the added value of nonferrous metal smelting industry is very high, but at the same time it still has the inefficiency problem of energy use and carbon emissions, which should also be as the focus of energy conservation and emissions reduction. The analysis shows that the characteristics of these industries are that the inefficiency of the total output is relatively smaller and the carbon dioxide emissions contribute most of the inefficiency.

From the perspective of different groups, the efficiency of the high- emission group is 1.2554, which is significantly higher than that of the other two groups, followed by the medium-emission group, the lowest efficiency is the low- emission group. It is worth mentioning that the labor inefficiency of the high-emission group is 0.0068, which is very close to complete efficiency, indicating that it has less labor absorption than other industries.

From the perspective of single output factors, the most inefficient industry is the product and supply of water, reaching up to 2.662.The most inefficient industry associated with energy and carbon dioxide emissions is the electric power industry, which fully reflects the high energy consumption and high carbon emissions of the electric power industry. The industry with the highest inefficiency is the furniture manufacturing and textile industry, respectively 0.0587 and 0.0547. It shows that furniture manufacturing and textile industry are typical labor-intensive industries, which can absorb many workers. However, high inefficiency also reflects the problems of poor skill and inefficient labor input in the furniture manufacturing and textile industry in our province. It is necessary to strengthen the training of employees, improve their proficiency

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and the ability to grasp the new technology.

4. Conclusion

Through empirical analysis, this paper draws the following conclusions: Insufficient output and excessive carbon dioxide emissions are two major factors that lead to inefficiency in the overall industrial sector during the analysis period. From 2006 to 2014, the average efficiency of the industrial industry in Anhui province was 0.9768, the inefficiency of the output were the biggest, accounting for 50% of the inefficiency value, followed by the inefficient value of carbon dioxide emissions, accounting for 34%.In terms of grouping, the high-emission industry group has the highest inefficiency in both input, output and carbon dioxide emissions.

References

[1] Y.H. Chung, R. Färe, S. Grosskopf. Productivity and undesirable outputs: a directional distance function approach, J. Journal of Environmental Management. 51(1997)229-240.

[2] H. Fukuyama, W.L. Weber. A directional slacks-based measure of technical inefficiency, J. Socio-Economic Planning Sciences. 43(2009)274-287.

[3] K. Tone. A Slacks-based Measure of Efficiency in Data Envelopment Analysis, J. European Journal of Operational Research. 130(2001)498-509.

[4] R.G. Chambers, R. Färe, S. Grosskopf. Productivity Growth in APEC Countries, J. Pacific Economic Review. 1(1996):181-190.

[5] Bing Wang, Yanrui Wu. Environmental Efficiency and Environmental Total Factor Productivity Growth in China's Regional Economies, J. Economic Research Journal .5(2010):95-109. (in Chinese)

[6] Ruixiang Liu. An Tongliang, Trend and Factor Analysis of Chinese Economic Growth Performance under Restrictions of Resource and Environment-A Research Based on a New Method of Productivity Index's, Construction and Decomposition, J. Economic Research Journal. 11(2012):34-47. (in Chinese)

[7] Ling Li. The Study on Green Total Factor Productivity and Influencing Factors of China's Industry, D. Guangdong: Jinan University Industrial Economics, 2012. (in Chinese)

[8] Fan Song. Comparisons of Industrial Green Total Factor Productivity, D. Tianjin: Tianjin University of Finance and Economics Applied Economics, 2013. (in Chinese)

 DOI: https://doi.org/10.26549/jfr.v3i1.1363