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DIFFERENCES OF CO2 EMISSION PERFORMANCE --BASED ON BOHAI BAY COASTAL ZONE IN CHINA

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ABSTRACT

The Bohai Bay Coastal Zone is the third largest economic zone in China, with environmental problems having become a constraint to economic growth in this region. This paper first estimates the CO_2 emissions in Bohai Bay Coastal Zone from 2012 to 2015. Then it constructs directional distance function and assumes two scenarios to evaluate the regional differences of carbon emission performance in this zone. The result indicates that, first of all, the CO_2 emissions intensity in Bohai Bay Coastal Zone is decreasing year by year. And taking energy consumption structure as the indicator can determine CO_2 emissions performance more accurately and effectively. Under the two different scenarios, Hebei, Liaoning and Shandong Province have significant differences, which mean that these provinces have great potential in CO_2 emissions reduction and energy consumption structure is the key factor. While Beijing and Tianjin City, at the advanced level of CO_2 emissions reduction, have shown few differences under the two scenarios. At last, it gives proposal, such as upgrading industrial structure, investing for researches of low-carbon technologies, levying carbon taxes to achieve CO_2 emissions reduction goal.

Keywords: Carbon emission performance; Provincial differences; Directional distance function; Optimal two-stage allocation model; The Bohai Bay Coastal Zone

1. INTRODUCTION

The issue of climate change has become a serious challenge for mankind in the 21st century. According to the National Climate Center, the average temperature in China is 9.01℃from the beginning of 2017 to July 10, 2017,0.85℃ higher than the same period before.

In 1992, United Nations Framework Convention on Climate Change was adopted at the United Nations Conference on Environment and Development, which meant the international community began to respond formally to the issue of global warming caused by greenhouse gases. On February16, 2005, The Kyoto Protocol came into force, which is the first time to limit greenhouse gas emissions in the form of regulations. On November 4, 2016, the United Nations issued a Bulletin to celebrate The Paris Agreement into force. Carbon dioxide has become a typical greenhouse gas due to its large emissions, so its reduction is critical in global climate change.

As the largest developing country, Chinese government has always attached great importance to climate change issues. As early as 2009, China has committed to achieve the goal of a 40-45% decrease than 2005 in carbon intensity by 2020. On December 18, 2017, National Development and Reform Commission enacted National Carbon Emissions Trading Market Construction Plan (Power Generation Industry) that say the China's unified carbon trading market was officially set up on December 19, 2017. In order to achieve China's targets in CO_2 emissions reduction, it is necessary to determine the carbon quota for each province.

The Bohai Economic Rim, consisting of the Beijing-Tianjin-Hebei metropolitan area as the center and the Liaodong Peninsula and the Shandong Peninsula as the two wings, is the third largest economic growth pole in China. In recent years, Bohai Economic Rim has improved its economic strength with its unique geographical advantages and abundant natural resources. Given the differences in resource endowments, industrial structure, technological level, policy inclinations in different provinces in Bohai Economic Rim, as well as considering fairness and efficiency, it is critical to set provincial CO_2 emissions reduction targets.

2. LITERATURE REVIEWS

Recent studies discussed methodologies to measure CO_2 emissions and to allocate carbon quota, offering valuable reference for this research.

The methods of measuring CO_2 emissions can be classified into single indicator analysis models and input-output models. In the first type, the single indicators were defined as carbonization index (Mielnik and Goldemberg; 1999)[1], energy intensity (Ang; 1999) [2]and CO_2 emissions intensity (Sun; 2005). To measure the dynamic changes of CO_2 emissions more comprehensively, studies introduced input-output models to take production factors such as capital and labor into account, and the typical model of it is data envelopment analysis (DEA model). DEA model can be utilized to analyze and evaluate CO_2 emissions (Zaim, 2000; Zofio, 2000; Zhou, 2006)[3,4,5]. Furthermore, it has many variants to calculate for complex situations more precisely, including Malmquist indicator model （Wang, 2010） [6], three-stage DEA model (Hua,2013)[7], DEA model based on slack variables (Du, 2013)[8], DEA – Tobit model (Hu et al.,2012)[9], and SBM model (Cha,2013; Wang et al., 2015)[10,11]. Many researches took China as the example to calculate dynamic changes and to analyze the inequality in CO_2 emissions of regions [12-14]. Other scholars also do more researches in this field [15-21].

Based on the analysis of existing domestic and foreign literatures, most of the research on the changes in CO_2 emission performance is carried out from the perspective of the state, and there are few studies on the region. As the Bohai Economic Rim is an important economic growth pole in China, this paper will provide reference and guidance for the decomposition of Chinese government's regional emission reduction targets and the formulation of policies.

3. METHODOLOGY AND DATA SOURCES

3.1 Methods

3.1.1 Estimation of carbon emission

Based on provincial classified energy consumption data in Bohai Economic Rim, referring the method in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, we estimate the carbon emission of production activities in Bohai Economic Rim. The equation can be expressed as Eq.(1) .[1]

$$C = \sum_{i=1}^{7} E_i \times F_i \qquad (1)$$

$$F_i = Q_i \times C_i \times L_i \qquad (2)$$

In order to consistent with statistical units, the consumption of various types of fuel is converted into standard coal, and the conversion coefficient of standard coal comes from the China Energy Statistical Yearbook.

3.1.2 Directional distance function

The directional distance function seeks the effective path of undesirable output reduction while increasing the desirable output, avoiding the same ratio increase or decrease of expected output. Following Fare (2005), the profit function and the directional distance function are mutually dual relations. The output set is defined as follows: *x* represents desirable outputs vector, *b* represents undesirable outputs vector, and *P(x)* means all the feasible cases.

$$P(x) = \{(y,b) : x \quad produce \quad (y,b)\} \qquad (3)$$

Where $P(x)$ represents all feasible input-output vectors, if x=0, then y=0. In addition, P(x) is set to meet the four properties[2].

The value of directional distance function denotes valid distance between the research area and low-carbon production frontier that means the degree of carbon emission reduction when GDP increase. The longer the distance, the lower the output efficiency and worse the carbon emission performance. The shorter the distance, the closer the frontier is and the better the performance. Compared with the nonparametric method, the calculation of the parameters is more complicated, but the differential and algebraic processing can be used to calculate the undesired output shadow price of each decision unit.

$$D_k(x_k, y_k, b_k; g_y, g_b) = Max\beta_k$$

[1] Where *C* devotes the total amount of carbon emissions in each region during the year, E_i devotes the consumption of the *i*th fuel in each region during the year , F_i devotes the carbon emission coefficient of the *i*th fuel, Q_i devotes the average low calorific value of the *i*th fuel, C_i devotes the emission factor of the *i*th fuel, and L_i devotes the carbon oxidation rate of the *i*th fuel.

[2] a:Free disposability of input. If $x' \geq x$, then $P(x') \supseteq P(x)$. b: Free disposability of desirable outputs. If $(y,b) \in P(x)$ and $y' \leq y$, then $(y',b) \in P(x)$. c: Weak disposability of undesirable outputs. If $0 \leq \theta \leq 1$, then $(\theta y, \theta b) \in P(x)$. d:Zero correlation between desirable outputs and undesirable outputs . If (y, b)< P(x) and y=0, then b=0.

$$s.t.\begin{cases}\sum_{j=1}^{n}\lambda_j x_j \le x_k \\ \sum_{j=1}^{n}\lambda_j y_j \ge y_k + \beta_k g_y \\ \sum_{j=1}^{n}\lambda_j b_j = b_k - \beta_k g_b \\ \lambda_j \ge 0,\ j=1,2,\dots n\end{cases} \quad (4)$$

Where k denotes the different provinces, λ denotes the intensity of column vector; β denotes the value of directional distance function.

The three input factors of this model are energy consumption, capital stock and labor. The two output factors are provincial economic output value and carbon emission respectively.

Table 1

Scenario description of the indicator

Scenario	Sort	Index	Explanation
Scenario 1	Input factors	Energy consumption	Provincial total energy consumption
		Capital	Net value of fixed assets
		Labor	Employed population
	Output factors	Economic output value	Provincial economic output value
		Carbon emission	Provincial carbon emission
Scenario 2	Input factors	Coal	Provincial coal consumption
		Oil	The consumption of petroleum products
		Natural gas	The consumption of gas
		Capital	Net value of fixed assets
	Output factors	Economic output value	Employed population
		Carbon emission	Provincial carbon emission

Aiming to gain comparable and more accurate results, we assume two scenarios to calculate the provincial carbon emission performance of the Bohai Economic Rim. In the scenario 1, energy consumption structure hasn't been taken into consideration. While in the scenario 2, using the consumption of coal, oil and natural gas index to measure the influence of the structure of energy consumption. The specific indexes are shown in Table 1.

3.2 Data sources and indicator selection

The energy consumption data of the Bohai Economic Rim were derived from China Energy Statistical Yearbook (2006-2015). In order to consistent with statistical units, this paper selects 7 types of fuel (coal, coke, gasoline, kerosene, diesel, fuel oil, natural gas) to measure carbon emissions.

Based on the data of the Bohai Economic Rim from 2005 to 2014, the data used in the calculation of carbon emission performance in each province and city were derived from China Statistical Yearbook(2006-2015).

4. EMPIRICAL RESULTS

4.1 Carbon emission Characteristics

4.1.1 Total carbon emissions

According to the formula in the previous section, we calculate the carbon emissions in various areas around the Bohai Sea in 2005-2014. The results shows that the overall carbon emissions in the Bohai Economic Rim are increasing year by year. Except for Beijing, the annual growth rate of carbon emissions in all other regions is positive, and Beijing's carbon emissions in this decade have dropped by 0.59% annually. Among them, Shandong Province has the largest carbon emissions, with an annual growth rate of 6.14%.

4.1.2 Carbon intensity

According to the calculation results of carbon emissions, we obtain the carbon intensity of each region in the Bohai Economic Rim from 2005 to 2014.

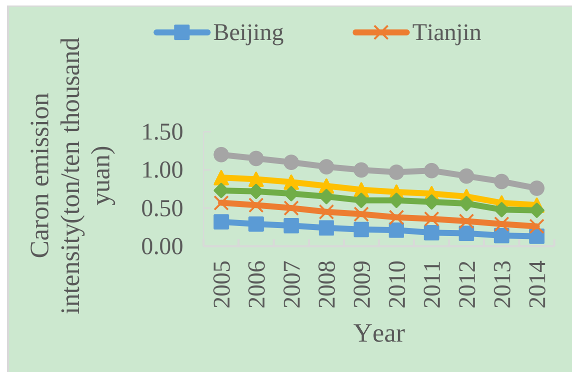

Fig 1 Trends in carbon emission intensity in the Bohai Rim in 2005-2014

It can be seen from Figure 1 that the carbon emission intensity of the Bohai Economic Rim shows a downward trend, indicating that the carbon emissions per unit of economic output continue to decline while economic growth. The carbon emission intensity of Hebei Province is the largest among the five provinces and cities. The average carbon emission intensity in this decade is 1.00 ton/10,000 yuan, which is about 5 times of the average carbon emission intensity in Beijing (0.22 ton/10,000 yuan). The average annual rate of reduction of carbon emission intensity in Beijing, Tianjin, Hebei, Liaoning and Shandong provinces are 9.41%, 8.55%, 4.92%, 5.53%, and 4.88%, respectively. The average annual decline in Beijing is the highest, indicating that the carbon emissions per unit of output are the lowest, and the energy use efficiency is the fastest.

4.2 *Carbon Emission Performance in Bohai Economic Rim*

Figure 2 and Figure 3 show the performance of carbon emissions in the Bohai Rim Economic Zone in scenario 1 and scenario 2.

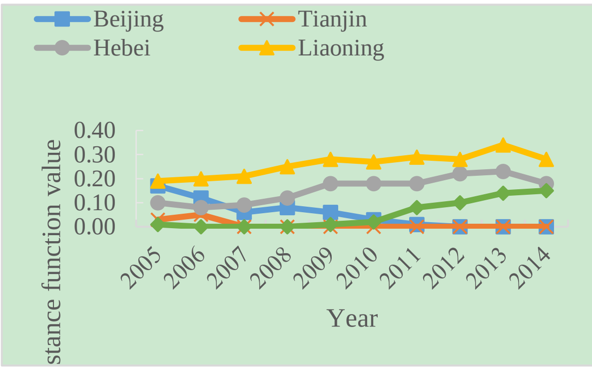

Fig 2 The carbon emission performance level in scenario 1

Figure 2 and Figure 3 show that carbon emission reduction performance level of the Bohai Economic Zone will be underestimated if the constraints of energy consumption structure are not considered. The reason is that there is an implicit assumption in scenario 1 that the energy consumption structure can be adjusted arbitrarily. However, the optimization and adjustment of energy consumption structure will not be completed in a short period and the scope of change is limited due to various factors such as the difference of resource endowment and geographical location in Bohai Economic Rim. Therefore, ignoring the constraints of energy consumption structure will lead to inaccuracy and unfairness in the calculation of carbon emission reduction performance, resulting in a large distance function value and underestimating the performance level of carbon emission reduction in some regions, so the results of scenario 2 are closer to the true level of each region.

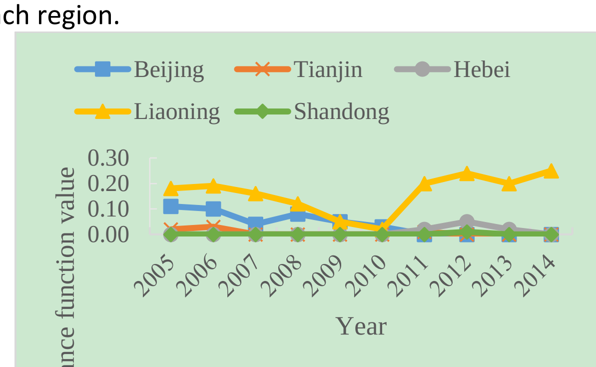

Fig 3 The carbon emission performance level in scenario 2

Further analysis shows that the differences of distance function from high to low in the two scenarios is Hebei Province, Liaoning Province, Shandong Province, Beijing and Tianjin. The greater the difference, the more unreasonable the energy consumption structure and the greater the space for emission reduction. The distance function values of Beijing and Tianjin are small in both scenarios, and the carbon emission performance level is relatively high. The analysis shows that it is difficult to reduce emissions in Beijing and Tianjin. The difference of the distance function values in Hebei, Liaoning and Shandong provinces is relatively large. The carbon emission performance level is significantly higher in scenario 2, indicating the energy efficiency of provinces mentioned above is high. The reason for the gap between the two scenarios is that the energy consumption structure in these regions is unreasonable, and fossil energy consumption accounts for a high proportion. Therefore, the primary task of reducing carbon emissions in such provinces is to adjust the energy consumption structure, improve the utilization efficiency of high-carbon energy, and strive to reduce the proportion of consumption of high-carbon energy.

5. CONCLUSIONS

According to the results above, some main conclusions are drawn as follows:

(1) Carbon emission intensity tends to decrease during the research interval, which indicates that the carbon emission of unit economic output is decreasing constantly with economic growth. The average annual degree of declining in Beijing is largest indicates that the promotion in efficiency of energy consumption is most significant.

(2) The level of carbon emission reduction is high relatively and decomposition of energy structure can estimate the provincial differences in carbon emission accurately. Carbon emission performance level in Beijing and Tianjin is higher and don’t show significant differences in two scenarios. The degree of carbon emission reduction in this two cities is low, so the gain from carbon emission reduction by adjusting the energy consumption structure is small. While the carbon emission reduction performance differences among Hebei, Liaoning, Shandong are obvious in two scenarios. Energy consumption structure with high carbon emission is the main constraints. So the aim of carbon emission reduction in these provinces can be achieved

by improving energy efficiency and applying clean low-carbon technology widely.

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