The Impact of Foreign Trade on Carbon Emission Efficiency in the Yangtze River Delta

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Abstract. Based on the perspective of all factors, this article uses the super-efficiency SBM model that considers undesirable output to measure the carbon emission efficiency in the Yangtze River Delta, and studies the impact of foreign trade on the carbon emission efficiency by establishing the panel model. The study found that the overall carbon emission efficiency in the Yangtze River Delta is relatively high, among which Shanghai has the highest efficiency. In addition, there is a significant positive correlation between foreign trade and carbon emission efficiency, and expanding the level of foreign trade can further improve carbon emission efficiency. Finally, according to the above conclusions, the corresponding policy recommendations are given.

Keywords: Yangtze River Delta; foreign trade; carbon emission efficiency.

1. Introduction

For more than 40 years of reform and opening up, China's economy has made great achievements. As one of the "three engines", foreign trade has made outstanding contributions and plays an important role in the development of national economy. From 2012 to 2016, China's foreign trade volume gradually expanded. In 2017, China's total merchandise import and export reached US $ 4.1072 billion, becoming the world's largest trading nation. With the continuous development of foreign trade and excessive energy consumption, China's carbon emissions have also increased sharply, and China is facing huge pressure of carbon emission reduction. However, China ’s economic development will depend on the stable development of foreign trade for a long period of time, and it is an inevitable choice to change the development mode and improve the efficiency of carbon emissions. Therefore, it is a basic work to study the relationship between foreign trade and carbon emission efficiency, and to clarify the current situation and trend of its development, which can provide a basis for policy guidance and strategic formulation of low-carbon trade development. The Yangtze River Delta is one of China's most dynamic and competitive economic regions. Since 2015, its import and export amount has maintained over 30% in China, which is a typical export-oriented economic city gathering place in China. Therefore, this paper takes the Yangtze River Delta as the research object to explore the impact of foreign trade on carbon emission efficiency.

2. Research Methods and Data

2.1 Regression Model Settings

This article selects data from provinces and cities in the Yangtze River Delta region from 2008 to 2016 for empirical research and builds a panel model with the following expression:

$$E_{it} = \beta_1 trade_{it} + \beta_2 gdp_{it} + \beta_3 ind_{it} + \beta_4 ln(tech)_{it} + \mu_{it} \tag{1}$$

In the formula, μ_{it} is a random error term, β is a variable coefficient, i and t represent time and province, and E represents carbon emission efficiency. Based on a full factor perspective, it is calculated by super-efficiency SBM model that considers undesirable output. *trade* indicates the level of foreign trade, and carbon emissions from economic activities will shift as the factors flow between countries. Therefore, the foreign trade index is measured by the proportion of total import and export to GDP. *Gdp, ind* and *tech* represent the level of economic development, industrial structure and technological level. The constant price per capita GDP based on the year 2000, the proportion of the secondary industry in GDP, and the number of patent grants were selected to represent.

2.2 Calculation of Carbon Emission Efficiency

Summarizing the existing related research results, currently there are two main methods for the measurement of carbon emission efficiency at home and abroad, one is the non-parametric estimation method represented by data envelope analysis (DEA), the other is parameter estimation method represented by stochastic frontier analysis (SFA).In this article, based on the SBM model of undesirable output, further construct a super-efficiency SBM model as follows:

$$\min\rho^* = \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{X_{ik}}}{[1-\frac{1}{s_1+s_2}(\sum_{r=1}^{s_1}\frac{s_r^g}{y_{rk}^g}+\sum_{t=1}^{s_2}\frac{s_t^b}{y_{tk}^b})]} \tag{2}$$

$$s.t.\quad x_{ik} \geq \sum_{j=1, j\neq k}^{n} x_{ij}\lambda_j - s_i^-,\quad y_{tk} \geq \sum_{j=1, j\neq k}^{n} y_{tj}^b\lambda_j - s_t^b$$

$$1-\frac{1}{s_1+s_2}(\sum_{r=1}^{s_1}\frac{s_r^g}{y_{rk}^g}+\sum_{t=1}^{s_2}\frac{s_t^b}{y_{tk}^b}) > 0$$

$$s^-、s^g、s^b、\lambda \geq 0$$

In formula (2), s^g indicates insufficient expected output, s^- indicates excessive input, s^b indicates excessive undesirable output, λ is the weight vector, k indicates the unit being evaluated, and ρ^* represents the efficiency value of the decision-making unit. When using the SBM model to calculate, input variables include three types of capital, labor, and energy, and output variables include GDP and carbon emissions. Some of the indicators are calculated as follows: (1)The capital stock is calculated using the perpetual inventory method at the constant price of each province.(2)The labor input and energy input are based on the number of employed persons and energy consumption at the end of each province. (3)Carbon emissions are calculated based on physical energy consumption in each region. The calculation formula is as follows:

$$\mathrm{TC} = \sum_{i=1}^{3} EC_i = \sum_{i=1}^{3}\sum_{i=1}^{7} E_{ij} \times CF_j \times CC_j \times COF_j \times 3.67$$

The carbon emission efficiency of the Yangtze River Delta in 2008-2016 measured by the above method is shown in Table 1:

Table 1. Calculation results of carbon emission efficiency

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Shanghai	1.17	1.16	1.16	1.14	1.15	1.12	1.13	1.14	1.14
Zhejiang	0.89	0.90	0.90	0.88	0.90	0.88	0.89	0.89	0.90
Jiangsu	0.90	0.92	0.91	0.88	0.88	0.86	0.88	0.87	0.87
Yangtze River Delta	0.99	0.99	0.99	0.97	0.97	0.95	0.97	0.97	0.97

3. Empirical Research

Table 2 shows the measurement analysis results of various models under the panel data framework for comparison. After the F test and Hausmann test, the random effect model is selected, and the results are as follows:

$$E_{it} = 1.57 + 0.22trade - 0.03gdp - 1.36ind - 0.01ln(tech) + \mu_{it} \tag{3}$$

(11.80) (13.38) (-3.07) (-6.30) (-0.56)

The estimation results show that the estimated coefficient of foreign trade level is 0.22, which is significant at the level of 1%, indicating that there is a significant positive correlation between foreign trade level and carbon emission efficiency. According to the theory of scale effect, when the production scale of the Yangtze River Delta region is in the first stage, the amount of inputs is constant. The smaller the scale, the higher the average cost. At this time, there will be more mining, but the efficiency is not high. At this stage, as the scale of production increases, carbon emissions will increase, and the efficiency of carbon emissions will also increase. When the production scale reaches the second stage, the input is constant, and the marginal cost of the product gradually decreases to a fixed level. At this stage, carbon emissions increase with the increase of production scale, but the carbon emission efficiency remains unchanged. In the third stage, when the input amount is constant, the marginal cost of the product will increase, and the carbon emissions will increase as the production scale increases, but the carbon emission efficiency will become smaller. In this study, the carbon emission efficiency of the Yangtze River Delta region increased with the increase of import and export trade, which indicates that the current production scale of the Yangtze River Delta region is still in the first stage. Expanding the scale can increase the carbon emission efficiency of the region, and Increasing the degree of trade is also conducive to increasing the scale of production. Therefore, the degree of foreign trade in the Yangtze River Delta region can be further strengthened.

In addition, the coefficient of economic development level and industrial structure is significant at the 1% level and the coefficient is negative, indicating that the higher the per capita GDP, the higher the proportion of the secondary industry, and the lower the carbon emission efficiency. If we reduce our over-reliance on the secondary industry and vigorously develop the tertiary industry, we can not only achieve the same level of GDP, but also achieve the goals of increasing carbon emission efficiency and improving the environment.

Table 2. Model estimation results and comparison

variable	*C*	*trade*	*gdp*	*ind*	*tech*	R^2	*AD-*R^2	*F value*
Mixed	1.71^{***}	0.20^{***}	-0.03^{**}	-1.55^{***}	-0.01	0.9866	0.9841	403.70
Fixed effect	1.54^{***}	0.24^{***}	-0.03^{**}	-1.29^{***}	-0.01	0.9970	0.9943	382.08
Random effects	1.57^{***}	0.22^{***}	-0.03^{***}	-1.36^{***}	-0.01	0.9941	0.9930	928.35

Note: The statistical values of t in parentheses ***, **, * indicate significant levels of 1%, 5%, and 10%, respectively.

4. Conclusions and Recommendations

Based on the super-efficiency SBM model considering undesirable output, this paper calculates the carbon emission efficiency of Yangtze River Delta in 2008-2016, and studies the relationship between foreign trade and carbon emission efficiency. The results of the study show that (1) The overall carbon emission efficiency in the Yangtze River Delta is relatively high, among which Shanghai has the highest efficiency. (2) The Yangtze River Delta region is currently in the first stage of production scale. There is a significant positive correlation between foreign trade and carbon emissions efficiency. Enlarging the level of foreign trade can further improve carbon emissions efficiency. In addition, the level of economic development and industrial structure will have a negative impact on carbon emission efficiency at a certain level.

From the above research conclusions, we make the following suggestions: (1) Vigorously develop low-carbon foreign trade and change the traditional export of products with high carbon content. (2) Optimize the industrial structure and increase the development of green and low-carbon industries. (3) Guide the development of high-tech enterprises, improve the utilization of coal and other energy sources, increase research funding for clean coal technologies, and develop low-carbon technologies.

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