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Research on the Impact of China's Carbon Trading Policy on the Carbon Emission Efficiency of Manufacturing Industry

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Abstract: China is under enormous pressure to cut emissions. This study enriched the empirical research on carbon trading at the industry level, in order to further test the contribution of carbon trading to China's carbon emission reduction. The results show that :(1) the implementation of carbon trading policy has a significant positive impact on the carbon emission efficiency of the six manufacturing industries, and the impact of each industry is heterogeneous. (2) Carbon trading policies do not significantly improve the carbon emission efficiency of each industry and region.

1. Introduce

According to the Fifth Assessment report of the Intergovernmental Panel on Climate Change (IPCC) of the United Nations, global climate warming has been undoubted in the past century, and the greenhouse gases generated from fossil fuel combustion and industrial production are the main sources [1]. By 2021, global carbon emissions reached a record high of 36.3 billion tons, further increasing the pressure of global emission reduction [2]. As an environmental policy tool under the market mechanism, carbon emission trading (referred to as carbon trading) is considered to be one of the effective emission reduction tools at present [3]. With advantages of low policy cost and flexible implementation, it covers 22% of global greenhouse gas emissions [4][5]. Therefore, it is imperative to realize low-carbon transition and establish an effective and sound carbon trading market in the face of increasingly serious environmental damage and energy shortage.

The main contributions of this study are reflected in the following three aspects. First of all, the empirical research on carbon trading at the industry level is enriched. Therefore, the uniform policy time cannot accurately reflect the effect of carbon trading policy; Finally, this study adds empirical research on carbon trading in developing countries. As one of the first developing countries to implement carbon trading, China can provide experience for other developing countries preparing to implement carbon trading. In addition, it can provide more empirical support and policy suggestions for the national carbon trading market.

2. Literature review

Early scholars mainly used modeling or simulation methods to test its effectiveness, and most of them adopted the CGE model. The use of CGE proves that China's emissions trading system is an effective tool for reducing CO2 emissions and helps to achieve China's "dual control" (volume and intensity) goals. The CGE model is used to construct five scenarios, the results show that the launch of a national carbon trading market can generate economic and environmental benefits and help China achieve its NDC goals [6][7].

According to the research of the above scholars, it is found that the carbon trading policy can indeed bring environmental dividends and promote the development of low-carbon economy to some extent, but there are still deficiencies in the research process. Scholars mostly use DID and other empirical research methods to discuss the emission reduction of carbon trading policy on provincial level, industrial sector or enterprise, but scholars seldom pay attention to the impact of carbon trading policy on manufacturing industry [8]. Secondly, most scholars use carbon dioxide emission or intensity to measure the effectiveness of carbon trading policy, and measure efficiency unilaterally through the proportion of carbon emission and economy [9]. Therefore, the carbon emission efficiency of major industries included in carbon trading in pilot areas and non-pilot areas is measured to reveal whether carbon trading system can promote significant improvement of emission reduction effect along with economic development, and then the policy effect of carbon trading pilot is evaluated.

3.Methodology and data

3.1 Method of efficiency measurement

The basic idea of the model is to divide all the sample data into two groups. One group is affected by the policy, which is called the treatment group or the experimental group. One group was not affected by the policy, called

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the control group. Select an individual index to be investigated and make two difference before and after, that is, the difference between the experimental group and the control group, and finally get the net effect of policy implementation. The model is as follows:

$$D_{it} = treat_{it} * post_{it} \quad (1)$$

$$E_{it} = \alpha_0 + \alpha_1 D_{it} + \alpha_2 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

Among them,i Denotes the province,t Represents the year,E_{it} Is carbon emission efficiency. When the region i is in a policy shock year t,post=1,Otherwise it's 0,When the electricity industry was a pilot industry in the region i,treat=1,Otherwise it's 0.D_{it}Is the interactive term, that is, whether the province has started the carbon trading pilot in the year, if yes =1; otherwise, 0.Table 1 shows the start time of carbon trading in each pilot area. In addition,X_{it}Is the control variable,ε_{it}Is the random disturbance term. θ and β Is the coefficient to be estimated;∝Is a constant term. This paper controls the provincial fixed effect (μ_i). And time fixed effect(γ_t).In order to control the influence of non-time-varying factors and time-varying factors on empirical study at the regional level.

3.2 Definition of Variables

In this paper, the mixed distance function method is used to measure the carbon emission efficiency of six manufacturing industries included in carbon trading in Chinese provinces by formula (1). Input indicators include labor, capital and energy, while output indicators are expected output and undesirable output respectively. The employment of employees in various industries and urban units in provinces; Expression of net fixed assets of each industry with capital input; Energy input is expressed by the total energy consumption of various industries in provinces represented by standard coal; Expected output is expressed by the main business income of various industries in each province. The undesirable output is expressed in terms of individual carbon dioxide emissions.

$$\gamma^* = min\frac{\theta - \varepsilon^- \sum_{j=1}^{m} \frac{\omega_j^- S^-}{P_j}}{\eta + \varepsilon^+ \left(\sum_{r=1}^{S1} \frac{\omega^{+S1} S^+}{Y_r} + \sum_{r=1}^{S2} \frac{\omega^{+S2} S^{+b}}{Y_r} \right)} \quad (3)$$

$$s.t. \begin{cases} \lambda P - \theta P_j + S^- = 0 \\ \lambda Y - \eta Y_r^+ - S^+ = 0 \\ \lambda Y - \eta Y_r^{+b} + S^{+b} = 0 \\ \lambda_1 + \lambda_2 + \cdots + \lambda_n = 1 \\ \lambda \geq 0, S^-, S^+, S^{-b} \geq 0, \theta \leq 1, \eta \geq 1 \end{cases}$$

Where, γ^* denotes the optimal carbon emission efficiency of decision making unit when considering the undesired output,$0 \leq \gamma^* \leq 1$.S^- represents the relaxation variable of the input P_j . S^+ and S^{+b} the relaxation variables of expected Y_r^+ and non-expected outputs respectively Y_r^{+b};ω^- is the weight of input P_jt; ω^{+S1}、ω^{+S2} are the weights of expected output and undesirable output respectively, $\sum \omega^{+S1} + \sum \omega^{+S2}$ =1(arbitrary $\sum \omega \geq 0$). ε is a key parameter that represents the importance of the non-radial part in the calculation of the efficiency value.

In this paper, 28 provinces in China from 2008 to 2019 were selected as research samples. Among them, the data of labor, capital and expected output in the calculation of carbon emission efficiency are derived from China Industrial Statistics Yearbook. Data on energy consumption and unwanted output of carbon dioxide are derived from China carbon accounting Database; Data of control variables are derived from China Statistical Yearbook.

4. Empirical results and analysis

4.1 Baseline Regression

For the accuracy of regression, fixed effects of province and time are added in this paper. On this basis, regression is carried out respectively according to model (1). The benchmark regression results are shown in Table 2. Columns (1) to (6) of the regression results are the benchmark regression results of papermaking, petroleum, chemical industry, building materials, steel and non-ferrous metals, and it can be seen that the coefficients of explained variables are significantly positive. That is, the implementation of carbon trading has significantly improved the carbon emission efficiency of all industries in the pilot area, which supports hypothesis 1.

It can be seen from Table 1 that carbon trading policies have different policy effects on different industries in pilot areas, that is, there is heterogeneity among industries. Non-ferrous metals and construction industries are significantly positive at 5% and 10% respectively, and their policy effect is poor compared with other industries.

Table 1 Results of baseline regression

	(1)	(2)	(3)	(4)	(5)	(6)
D_{it}	0.1051***	0.1072***	0.0568***	0.0995*	0.0665***	0.0550**
	(2.7067)	(3.5466)	(2.7311)	(1.9292)	(2.5617)	(2.4807)
X_{it}	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES
Provence fixed	YES	YES	YES	YES	YES	YES
_cons	0.6525***	0.8231***	0.8413***	0.4879**	1.0272***	1.2504***
	(4.2821)	(5.5300)	(3.9669)	(2.0918)	(4.9050)	(6.5572)
N	336	336	336	336	336	336

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.2 Robustness test

Before the implementation of the carbon trading policy, the change of carbon emission efficiency of the experimental group and the control group was largely consistent, which basically met the requirements of the parallel trend. The baseline regression results of this paper were robust.

Table 2 Parallel trend test

	(1)	(2)	(3)	(4)	(5)	(6)
p2012	0.0767 (1.4933)	0.0886* (1.6820)	0.0122 (0.2918)	0.0725 (1.4044)	0.0353 (0.7784)	0.0671 (1.3063)
p2011	-0.0002 (-0.0034)	0.0548 (1.0060)	0.0263 (0.6096)	0.0242 (0.4529)	-0.0365 (-0.7793)	-0.0344 (-0.6489)
X_{it}	YES	YES	YES	YES	YES	YES
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time-fixed effect	YES	YES	YES	YES	YES	YES
_cons	0.7009*** (4.5447)	0.8369*** (5.2898)	0.8771*** (6.9903)	0.5216*** (3.3616)	1.0863*** (7.9772)	1.2718*** (8.2423)
N	336	336	336	336	336	336

In order to exclude the influence of measurement methods on regression results of explained variables, this paper will use the natural logarithm (diff) of carbon emission efficiency of each industry As shown in Table 3, it is further proved that the regression results in this paper are robust.

Table 3 Alternate explanatory variable

Explained variable	(1)	(2)	(3)	(4)	(5)	(6)
			diff			
Dit	0.1251** (2.2956)	0.1436*** (2.7327)	0.0791** (2.5519)	0.1380* (1.8056)	0.0993*** (2.6511)	0.0721* (1.8274)
Xit Regional fixed	YES	YES	YES	YES	YES	YES
effect	YES	YES	YES	YES	YES	YES
Time-fixed effect	YES	YES	YES	YES	YES	YES
_cons	-0.6344*** (-2.7589)	-0.2507 (-1.0531)	-0.2818 (-0.8822)	-0.8688** (-2.3666)	-0.0154 (-0.0414)	0.2144 (0.6312)
N	336	336	336	336	336	336

5. Conclusions

In this study, carbon trading pilot was taken as a quasi-natural experiment, and multi-period DID and its spatial econometric model were used to study the influence of carbon trading policy on carbon emission efficiency of six manufacturing industries. The results show that: (1) The implementation of carbon trading policy has a significant positive impact on the carbon emission efficiency of the six manufacturing industries, and there is heterogeneity in the impact of each industry. (2) The carbon trading policy has a significant impact on the carbon emission efficiency of 6 manufacturing industries in eastern and central China respectively. (3) The carbon trading policy does not significantly improve the carbon emission efficiency of various industries and regions.

Our economy is still in the period of high development, unbalanced development between regions and industries. In view of the heterogeneity of carbon trading policies among industries, the paper industry should continue to promote the adjustment of raw material structure, increase investment in energy conservation transformation, and optimize the distribution of inter-regional industrial chain. We will strengthen inter-regional industrial cooperation and technology sharing, optimize industrial distribution, promote coordinated development strategies among regions, guide inter-regional industrial transfer and undertaking cooperation in an orderly manner, and improve inter-regional cooperation and mutual assistance mechanisms for integrated development.

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