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Does the Carbon Trading Pilot Policy Have an Inhibitory Effect on the Growth of Carbon Emissions in the Pilot Area?

-- Empirical Research based on DID Model

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Abstract. With the increase of carbon dioxide emissions year by year, how to achieve carbon emission reduction has become an increasing concern of all countries. As the world 's largest carbon emitter, China has put forward the emission reduction targets of "carbon peak" and "carbon neutrality", and formally implemented the pilot policy of carbon emission trading in 2013. By studying the panel data of 30 provinces from 2006 to 2019, this paper uses the DID model to test the actual emission reduction effect of the carbon emission trading policy on the pilot areas. The results show that: (1) The pilot policy of carbon emission trading has a significant inhibitory effect on the growth of carbon emissions in the pilot area, and it gradually decreases with time;(2) There is a significant regional heterogeneity in the policy effect, and the policy effect in the eastern region is the most significant;(3) The placebo test further verifies that the carbon emission reduction effect of carbon emission trading policy is robust. The conclusion of this paper enriches the literature related to carbon emission reduction, and will provide some help to promote the construction of a stable national carbon emission trading market.

Keywords: Carbon Emissions Trading Policy; Carbon Emission Reduction; DID Model.

1. Introduction

According to the " Global Carbon Budget 2022 " report, the total global carbon dioxide emissions in 2022 will reach 40.6 billion tons, which is the second highest in history [1]. The continuous increase of carbon dioxide emissions not only destroys the ecological environment, but also has a huge negative impact on human production and life. Therefore, at this stage, the increasingly severe climate problem and its secondary problems such as frequent occurrence of extreme temperatures and accelerated glacier melting have received widespread attention from all countries [2].

As the world's largest carbon emitter, China has always regarded actively responding to climate issues as an important goal of its own development. In 2020, the president Xi announced at the United Nations General Assembly that China will achieve “carbon peak” and “carbon neutrality” by 2030 and 2060 respectively. The report of the 20th National Congress of the CPC further proposed to "actively and steadily promote carbon peak carbon neutrality", indicating the Chinese government's firm determination, historical mission and sense of responsibility to actively respond to global climate issues. Under the guidance of the "double carbon" goal, the Chinese government has introduced various measures to continuously promote the transformation and upgrading of the domestic economy to a green, low-carbon and environmentally friendly high-quality development model [3]. In October 2011, the National Development and Reform Commission issued a notice on the pilot work of carbon emissions trading, selected seven provinces and cities such as Beijing and Tianjin to carry out carbon emissions trading pilot, and formally implemented in 2013.

The carbon emission trading policy has become an important tool for China to achieve the " double carbon " goal in the new era. Then, does the implementation of the policy have a significant inhibitory effect on the growth of carbon emissions in pilot cities? Is the policy worth promoting? This paper evaluates the emission reduction effect of the pilot policy by conducting quasi-natural experiments in the pilot area, hoping to make a certain contribution to the steady development of the national carbon trading market and the deployment of energy conservation and emission reduction work.

2. Literature Review

At present, most scholars believe that the introduction of carbon trading policy has a positive effect on environmental protection. Alejandro et al. found that the carbon emissions of EU countries have been decreasing within the framework of the carbon trading system [4]. Karan and others believe that the carbon trading system can help achieve global carbon emission reduction targets [5].There are also many similar studies in China. Ji Xinlong et al [6] and Xue Fei et al [7] have used the difference-in-difference method to study the scale emission reduction effect of the carbon emission trading market. Zhou Di found that carbon trading policy has a significant inhibitory effect on carbon emission intensity based on urban panel data [8].

In recent years, more scholars have begun to focus on the spillover effects of carbon trading pilot policies, mainly including two aspects. The first type of research explores the impact on the development of green economy. Qian Li et al. think that the pilot policy has a significant positive effect on the green development of China's regional economy, and there is a positive cumulative dynamic effect [9]. Zhang and others believe that the pilot policy has promoted green economic growth by increasing environmental policies[10]. The second type of research explores the impact on corporate green technology innovation. Song Qinghua et al. have found that the carbon trading mechanism has significantly promoted the green technology innovation of manufacturing enterprises, and the higher the carbon price, the stronger the incentive effect[11]. At the same time, some scholars have also focused on the impact on stabilizing employment[12].

In summary, most of the academic circles have analyzed the impact of carbon emission trading policies on environmental protection, economic development, technological innovation from a macro perspective, but less from a micro perspective to explore the carbon emission reduction effects of China 's carbon trading pilot policies on pilot areas. Therefore, based on the above literature, this paper uses the DID method to test the impact of the implementation of the carbon trading pilot policy in 2013 on the actual emission reduction effect of the pilot area.

3. Research Hypothesis

Through the pilot policy of carbon trading, the production departments in the pilot areas can formulate more reasonable production activities according to the actual situation, control the carbon emissions in production activities, and rationally allocate resources and achieve positive interaction under the action of the carbon trading market mechanism. At the same time, the limitation of the carbon emission quota will further force the production department to carry out the research and application of energy saving and emission reduction production methods, and reduce the marginal cost of carbon emissions.

Therefore, this paper proposes the following hypothesis:

H1: The carbon trading pilot policy will significantly reduce the growth rate of carbon emissions in the pilot area.

There are differences in economic scale, population flow and industrial structure reform in the pilot areas every year, which are not monotonous. As a result, the effect of carbon trading pilot policy should change with time.

Therefore, this paper proposes the following hypothesis:

H2: The effect of carbon trading pilot policy has time difference.

At the same time, based on the above, the implementation effect of the carbon trading pilot policy on different pilot regions may be different. The pilot policy has a longer impact cycle on regions with higher total carbon emissions, and the policy effect is relatively insignificant; the impact cycle on regions with lower total carbon emissions is shorter, and the policy effect is relatively significant.

Therefore, this paper proposes the following hypothesis:

H3: The effects of carbon trading pilot policy on different pilot regions are heterogeneous.

4. Research Design

4.1. Data Sources

In order to ensure the authority, sufficiency and timeliness of the sample data, this paper uses SPSS.27 and StataMP.17 for data processing. By consulting the "China Statistical Yearbook", "China Energy Statistical Yearbook" and "Statistical Yearbook" of each province, 30 provincial panel data of China from 2006 to 2019 are selected as samples, including 6 pilot provinces and 24 non-pilot cities (excluding Tibet, Hong Kong, Macao and Taiwan).

4.2. Variable Declaration

The explained variable in this paper is the effect of carbon emission trading pilot policy, which is represented by the change of annual carbon emissions (natural logarithm of the actual total carbon emissions) in each region. The change of carbon emissions is the most intuitive manifestation of the impact of policy effects on a region, so it is reasonable to choose annual carbon emissions as the dependent variable. According to the " Notice on the Pilot Work of Carbon Trading " issued by the State Council, this paper takes 2014, the second year after the implementation of the policy, as the time node. The time variable is the binary variable expressed by After, and six pilot areas such as Beijing and Tianjin are selected as the experimental group (because Shenzhen belongs to Guangdong Province, it is not analyzed separately), and the remaining areas are used as the control group, represented by Treat: if it is the experimental group, Treat = 1; if the control group, Treat = 0.

The control variables selected in this paper include the following three types: (1) Economic development level (EDL): the regional gross national product after natural logarithm is selected to represent; (2) Fixed capital investment (FCI): the total annual fixed investment of each region after natural logarithm is selected to represent (2018-2019 data is missing); (3) Total regional population (TRP): The total annual population of the region after the natural logarithm is selected. Table 1 is the variable name and definition given in this paper. (See Table 1)

Table 1. Variable description

Variable Name	Definition
Annual Carbon Emissions (ACE)	Take the natural logarithm of the total annual carbon emissions in the region
Treat	Represents whether it is a binary variable of the experimental group, the experimental group = 1, the control group = 0
After	Denotes the binary variable of the year, greater than 2014 = 1, less than 2014 = 0.
Economic Development Level	The regional gross national product after taking the natural logarithm
Fixed Capital Investment	The total annual fixed investment of the whole society in each region after taking the natural logarithm
Total Regional Population	The total annual population of the region after taking the natural logarithm

4.3. Model Construction

This paper uses the DID model to evaluate the policy effect, that is, to analyze the impact of carbon trading pilot policy on the annual growth of carbon emissions in various regions, and to further explore the heterogeneity of the implementation effects in different pilot regions. The model is set as follows:

$$ACE_{it} = \alpha + \beta DID_{it} + \gamma X_{it} + \mu_i + \sigma_t + \varepsilon_{it}$$

Of which,ACE_{it} is the annual carbon emissions of i province in the t year; $DID_{it}$is the carbon trading pilot policy variable;$X_{it}$is the set of all control variables; μ_i and σ_t are the individual and time fixed effects of each region;$\varepsilon_{it}$is a random perturbation term.

5. Empirical Study

5.1. Parallel Trend Test

As shown in Figure 1 (see Figure 1), before the implementation of the pilot policy, the difference between the experimental group and the control group was not significant, but after the implementation of the pilot policy, the policy effect was gradually significantly negative, so it met the parallel trend test.

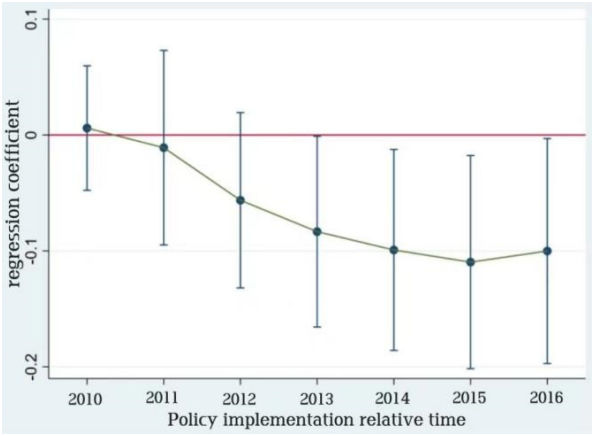

Figure 1. Parallel trend test of difference-in-difference model

5.2. Baseline Regression Results

Table 2. Basic regression results of difference-in-difference model

Explanatory Variables	Explained variable: ACE			
	(1)	(2)	(3)	(4)
DID	-0.22376*	-0.40648***	-0.29810**	-0.14075
	(0.13123)	(0.13816)	(0.11589)	(0.12531)
EDL			0.22128**	0.21882**
			(0.08933)	(0.08827)
FCI			0.21222***	0.30084
			(0.69550)	(0.07446)
TRP			0.30123	0.22316***
			(0.06061)	(0.06501)
Time Effect	×	√	×	√
Individual Effect	×	×	√	√
Constant Term	10.32291	10.21328	2.92661	2.45856
R^2	0.007	0.039	0.646	0.656

Note: ***, **, * are respectively significant at the level of 1 %, 5 % and 10 %, () is standard error, the same below.

This paper first considers the correlation between variables. After determining that the variables have no outliers and strong collinearity, OLS regression is performed on the data. The benchmark regression results are shown in table 2 (see table 2). The results show that the coefficients of the core explanatory variable DID are significantly negative, whether it is a single fixed effect or a double fixed effect, or whether or not a control variable is added. This indicates that the pilot policy significantly reduces the annual carbon emission growth rate, and H1 is verified. Among them, the level of economic development, fixed capital investment, and total regional population all have a positive effect on the growth rate of carbon emissions. That is, without considering the impact of pilot policies, with the continuous development of the economy and society, the growth rate of carbon emissions generally shows an increasing trend.

5.3. Main Model Analysis

First of all, according to the results of the Hausman test, the P value is significant at the 5% level, strongly rejecting the "no individual effect" null hypothesis, indicating that it should be a fixed effect model rather than a random effect model. Secondly, the two-way fixed effect estimation is carried out. The results are significant at the 1 % level, and the original hypothesis of "no time effect" is strongly rejected. It is believed that there is a time effect and the two-way fixed effect model should be used.

Table 3. Main model analysis results

Explanatory Variables	Explained variable :ACE	
	(1)	(3)
DID	-0.19404	-0.14075
	(0.13123)	(0.12531)
Treat	-0.21244*	-0.31310
	(0.11934)	(0.08506)
After	0.24987***	-0.21809***
	(0.81527)	(0.07054)
EDL		0.21882**
		(0.08827)
FCI		0.30084
		(0.07446)
TRP		0.22316***
		(0.06501)
Time Effect	√	√
Individual Effect	√	√
Constant Term	10.25577	2.45856
R^2	0.046	0.656

The main model analysis results are shown in Table 3. When the control variable is not added, the DID coefficient is significantly negative, which once again verifies the hypothesis H1. According to the regression results, before the implementation of the pilot policy in 2014, the average carbon emissions of the control group increased by $e^{0.24987}$ ten thousand tons, and the average carbon emissions of the disposal group changed by$e^{0.19404}$ten thousand tons lower than that of the control group. When the control variables are added, the coefficient of DID is still significantly negative. According to the regression results, before the implementation of the pilot policy in 2014, the average

carbon emissions of the control group decreased by $e^{0.21809}$ ten thousand tons, and the average carbon emissions of the disposal group were $e^{0.14075}$ ten thousand tons lower than those of the control group.

5.4. Policy Effects in Different Time Periods

The policy effects of the disposal group at different time periods after the pilot occurred are shown in table 4 (see table 4). Due to the lack of some data, this paper only considers the situation in 2014-2017 for the rigor of the conclusion. As the result, in 2014, the first year after the policy, the negative effect of the pilot policy on the growth rate of carbon emissions reached the highest value, and gradually decreased every year since then, assuming that H2 is verified.

Table 4. The policy effects of the disposal group at different time periods

Explanatory Variables	Explained variable: ACE			
Year	2014	2015	2016	2017
DID	-.174389	-0.14469	-0.12551	-0.11820
	(0.13586)	(0.13608)	(0.13610)	(0.13601)
Treat	-0.31375	-0.31317	-0.31312	-0.31391
	(0.08514)	(0.08519)	(0.08518)	(0.08518)
After	-0.21917***	-0.21811***	-0.21830***	-0.21863***
	(0.07061)	(-0.07064)	(0.07063)	(0.07063)
EDL	0.21958**	0.21895**	0.21876**	0.22017**
	(0.08835)	(0.08842)	(0.08839)	(0.08843)
FCI	0.30147	0.30077	0.30109	0.30051
	(0.07453)	(0.07457)	(0.07456)	(0.07455)
TRP	0.22182***	0.22308***	0.22299***	0.22207***
	(0.06510)	(0.06511)	(0.06510)	(0.06513)
Time Effect	√	√	√	√
Individual Effect	√	√	√	√
Constant Term	2.45425	0.47090	2.45705	2.45956
R^2	0.656	0.656	0.656	0.656

5.5. Heterogeneity Inquiry

This paper studies the policy heterogeneity based on different geographical locations, mainly from two aspects: one is to explore the impact of carbon emissions trading pilot policies on different pilot provinces; secondly, it analyzes the policy effects of the pilot policy on the eastern, central and western regions from the perspective of macro geographical location.

The impact of carbon trading pilot policies on different pilot provinces is shown in Table 5. (See Table 5)

The results show that the pilot policy of carbon emission trading has a significant negative effect on the six pilot provinces, hypothesis H1 is verified again. At the same time, the negative effect of Beijing's policy is the most significant, followed by Tianjin and Hubei, while the negative effect of Shanghai is relatively weak. There is significant regional policy heterogeneity, and hypothesis H3 is verified.

Table 5. The policy effects of different pilot provinces

Explanatory Variables	Explained variable: ACE					
Province	Beijing	Tianjin	Shanghai	Hubei	Guangdong	Chongqing
DID	-0.152	-0.149	-0.127	-0.143	-0.137	-0.131
	(0.123)	(0.123)	(0.124)	(0.125)	(0.125)	(0.124)
Treat	-0.285***	-0.362***	-0.326***	-0.348***	-0.346***	-0.206**
	(0.084)	(0.090)	(0.084)	(0.095)	(0.089)	(0.094)
After	-0.221***	-0.203***	-0.225***	-0.220***	-0.225***	-0.218***
	(0.069)	(0.071)	(0.070)	(0.071)	(0.071)	(0.070)
EDL	0.342***	0.248***	0.105	0.244***	0.210**	0.134
	(0.093)	(0.090)	(0.097)	(0.093)	(0.088)	(0.093)
FCI	0.223***	0.266***	0.383***	0.286***	0.315***	0.357***
	(0.076)	(0.078)	(0.080)	(0.077)	(0.075)	(0.077)
TRP	0.150**	0.238***	0.274***	0.206***	0.205***	0.258***
	(0.067)	(0.066)	(0.067)	(0.068)	(0.066)	(0.066)
Time Effect	√	√	√	√	√	√
Individual Effect	√	√	√	√	√	√
Constant Term	2.975	2.543	1.977	2.568	2.501	2.792
R^2	0.669	0.658	0.662	0.656	0.657	0.662

The impact of pilot policy on different regions is shown in Table 6. (See Table 6)

Table 6. The policy effects of different regions

Explanatory Variables	Explained variable: ACE		
Region	Eastern Region	Central Region	Western Region
DID	-0.10568***	-0.05686**	-0.06435**
	(0.03758)	(0.02687)	(0.02712)
EDL	-0.47615***	0.53998***	0.78448***
	(0.11806)	(0.15580)	(0.19657)
FCI	0.59366***	-0.07471	-0.26015*
	(0.08970)	(0.09987)	(0.12954)
TRP	1.43163*	-0.59659	0.07931
	(0.72106)	(0.55613)	(0.48179)
Time Effect	√	√	√
Individual Effect	√	√	√
Constant Term	-6.44477	13.93934	6.70132
R^2	0.959	0.981	0.980

The results show that the policy effect in the eastern region is the most significant, stronger than that in the central and western regions, assuming that H3 is verified again. The reasons may be as follows: First, the eastern region is superior to the central and western regions in terms of economic

development level, industrial structure upgrading and market development, and the pilot provinces are mostly in the eastern region, so the policy effect is also more significant; second, due to the guidance of the relevant national inter-regional industrial transfer policies, the central and western regions are easy to become the transfer destinations of high-polluting enterprises in the eastern region, and their emission reduction capabilities are weakened.

5.6. Placebo Test

In this paper, the placebo test is carried out by randomly assigning carbon trading pilots, and it is found that there is a conspicuous difference from the original policy effect; at the same time, in order to increase the effectiveness of the placebo test, the above experimental process was repeated 500 times. The estimated coefficients were basically around 0, and most of them were not significant at the level of 10 %, and the influence of other unobservable factors on the empirical results is excluded.

6. Conclusion and Foresight

Based on the panel data of 30 provinces in China from 2006 to 2019, this paper uses the DID method to conduct quasi-natural experiments, and draws the following conclusions: First, the pilot policy has indeed played a certain inhibitory effect on the growth rate of carbon emissions in the pilot area; secondly, this paper finds that the policy effect is the strongest in the first year, and then weakens with the increase of time. Third, through the exploration of heterogeneity, this paper finds that there are some differences in the policy effects of different pilot regions, and the policy effects in the eastern region are significantly stronger than the central and western regions.

The empirical research of this paper directly contains policy implications: First, the country should accelerate the construction of the national carbon trading market and build a national unified carbon trading platform covering more provinces, cities and industries; second, when designing and implementing carbon trading policies, the government should consider regional heterogeneity, do not blindly copy the successful experience of other regions, and should combine its own characteristics.

This paper also has the following shortcomings: Firstly, the choice of pilot provinces for carbon trading is not random. In reality, the choice of pilot provinces may be affected by other potential factors and interfere with the research results. Secondly, there are many factors affecting carbon emissions in various regions. This paper only considers factors such as the level of economic development, and subsequent research can add more control variables for in-depth research. Thirdly, the change trend of carbon emission intensity in each province and city will be affected by the carbon emission intensity of its neighboring provinces and cities. The spatial spillover effect of policies can be studied by SEM, SAR, SDM and other models in the future.

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