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Impact of Carbon Emissions Trading Policies on the Level of Green Development of Cities

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ABSTRACT
As a product of the international political game, the carbon emissions trading system, which trades carbon emission rights as physical goods through the market mechanism, is of great significance in helping China to achieve carbon peak and carbon neutrality at an early date. Taking the launch of China's carbon emissions trading policy as a natural experiment, this paper quantitatively analyses the impact of carbon emissions trading on the green development level of each prefecture-level city based on the carbon emissions performance data before and after the implementation of carbon emissions trading in 281 prefecture-level cities in China from 2010 to 2020 by using a double-difference model. The results of the study show that the carbon emissions trading policy has a positive impact on improving the green development level of prefecture-level cities. Therefore, it is important to further improve the carbon emissions trading system and take multiple measures to promote the transformation of energy consumption structure.

KEYWORDS
Carbon Emissions Trading; Carbon Emissions Performance; Level of Green Development

1 Introduction

1.1 Policy Background

Promoting a comprehensive green transformation of economic and social development has become the focus of efforts to address China's resource and environmental problems. In order to reduce China's carbon dioxide emissions, China has issued a series of policy documents such as the State Council's Guiding Opinions on Accelerating the Establishment of a Sound Green, Low-Carbon and Circular Development Economic System, the Implementation Programme for Reducing Pollution and Carbon Synergy, and the Green Development of China in the New Era. As the development of green transformation has a time lag and long-term nature, in order to achieve efficient, harmonious and sustainable green development, it is very necessary to study the significance of the policy for the realisation of green and comprehensive economic and social developmentcarbon emissions trading . ChinaFor 12 consecutive years, the world's largest primary energy consumer and the world's largest carbon emitter. How to improve energy efficiency, abandon the short-sighted behaviour of "environment for development", and improve the green and low-carbon economic system is called the theme of the new era to promote green development. Carbon emissions trading policy is referred to as carbon trading, a concept first put forward by the American economist Dale in 1968, and now the object of carbon trading policy is mainly the amount of carbon dioxide emissions generated by various combustion methods. Government departments at all levels control the total amount of carbon emissions, and under the role of the market mechanism, through the trading of carbon emission allowances to achieve the optimal solution of economic development and environmental protection. Its main principle is to use the market mechanism to carry out environmental governance, and enterprises will use the carbon emission reduction targets assigned by the government for the act of selling.

In 2011, the National Development and Reform Commission (NDRC) issued the "Notice on Carbon Emission Trading Pilot Work", which formally opened the pace of exploring the establishment of a carbon emission trading market. 2013 was carried out in batches, with Shenzhen in June, Beijing and Shanghai in November, and Tianjin and Guangdong opening the pilot work of carbon trading in December. 2014 saw the implementation of the carbon trading programme in Hubei in February, Chongqing in June, and Fujian in September 2016, which also successfully started trading. also started trading successfully. Subsequently, China embarked on the construction of a national carbon market.In 2020, the Ministry of Ecology and Environment issued the Administrative Measures for Carbon Emission Trading (for Trial Implementation) as well as a plan for allocating allowances.In 2021, the national carbon emission trading market was formally put into operation. The study of the impact of carbon emissions trading policy on the level of green development of cities can objectively assess the effect of the policy and provide a reference for the direction of the next implementation.

1.2 Literature review

The green development level of a city is a dual consideration of the city's economic development level and environmental quality, and the travelling of the carbon emissions trading policy is to achieve a "win-win" situation for both economic development and environmental protection. At present, the measurement of green development level is mainly from the perspective of indicator system construction and green total factor productivity, which is applicable to the use of comprehensive indicators measured from multiple perspectives, Zheng Jie et al. chose to assess the green development level of the city's green total factor productivity. With the development of economy and society, the single-factor indicator evaluation system is no longer complete. The total factor indicator system is mainly based on the production theory, comprehensively considering the joint role of capital, labour, energy and other factors on economic growth and carbon emissions [2], and using data envelopment analysis, stochastic frontier methods, and improved models for measurement and evaluation. Various DEA methods have become the most commonly used type of environmental performance measurement methods in recent years, but the related DEA models all have the problems of biased production frontier setting or unsolved linear programming to different degrees, to address this kind of problems, Shao Shuai (2020) combines the concept of overall technology frontier proposed by Afsharian and Ahn (2015) with the concept of non-angular non-transferential technology frontier proposed by Zhou et al. combined the concept of overall technology frontier proposed by Afsharian and Ahn (2015) with the non-angle and non-radial DDF proposed by Zhou et al. (2012), and constructed a DEA model based on the overall technology for the environmental TFP growth index (2020), which isused in this paper to measure the level of green development.

From the perspective of high-quality economic development and the construction of "Beautiful China", the existing research Zheng Jie, Yuan Yongzhi et al. (2023) concluded that the carbon emissions trading policy significantly enhanced the level of green development of the city, and the mechanism of action is to play a role through the quantity and quality of green technological innovation, and to achieve the upgrading of the industrial structure of the two channels [5]. . Zhang Jie et al. (2023) focused on the relationship between the construction of innovative pilot cities and the level of urban green development, using the EBM-GLM model to decompose the green total factor productivity, divided into the urban green technological progress and the urban green technological efficiency of the two perspectives of the study, that the level of green development of the city can be improved through the improvement of the level of science and technology, increasing financial support and significant upgrading of industrial structure to improve [3].

The possible marginal contributions of this paper are as follows: first, the existing literature mostly focuses on carbon emission performance at the provincial level, while this paper studies 281 prefecture-level cities in China after removing cities with residual data, and examines the role of in promoting the level of green development of the cities the carbon emissions trading policyfrom the prefecture-level city level.

2 Research Methods and Data

2 .1 Modelling the Impact of Local Carbon Trading Policies on Green City Creation

This paper adopts the double difference (DID) model. Firstly, the difference is performed in the time dimension to compare the impacts before and after the launch of carbon emissions trading. 7 carbon emissions trading pilots in China launched their pilots successively after 2013, and among the seven pilots, Shenzhen Carbon Emissions Exchange was officially opened in June 2013, the four pilots in Beijing, Tianjin, Shanghai, and Guangzhou were all opened at the end of 13 years, whereas Chongqing and Hubei were launched in the second quarter of 14 years. Referring to the related papers, this paper sets 2013 as the for China's carbon emissions trading policytime point , and takes the six pilot provinces and regions as the control group that did not implement the policy .

In this paper, we set up the benchmark model as follows:

$$\mathrm{TFECP}_{it} = \delta_0 + \beta \mathrm{district}_{it} \times \mathrm{post}_{it} + \rho X_{it} + \eta_i$$

The core explanatory variable of the model is $\mathrm{district}_{it} \times \mathrm{post}_{it}$, i , t denote the city and time respectively, and its coefficient is a double difference estimator, the main meaning is the effect of carbon emissions trading policy before and after the implementation of the carbon emissions trading policy on the carbon emissions performance of the treatment and control groups. The coefficient if urban area i has implemented the policy in year ttakes 1 ; otherwise, it takes 0. TFECP_{it} is the explanatory variable, which represents the carbon emission performance. X_{it} is the control variable, and η_i is a fixed effect.According to the established research model, following the theoretical relevance and exogeneityprinciples of , the variables that have the potential to influence the carbon emission performance are controlled, including the population agglomeration level , the green coverage rate, the level of human capital, and total energy consumption . After the F-test on the city dummy variables, there are individual effects and a fixed effects model is chosen. Soη_i a set of fixed effects is introduced to control for city fixed effects and to reduce the impact on the results of factors that do not vary with city differences . At the city level, robust variance-covariance estimators are used simultaneously.If $\beta > 0$, it means that the local pilot carbon emissions trading policy helps to promote the carbon emissions performance of the pilot area to improve .

2.2 Data sources

In this paper, the carbon emission performance is firstly calculated by applying the non-angle, non-radial DDF model based on the overall technology frontier. The data sources for the relevant control variables are as follows: EPS database, China Statistical Yearbook, China Energy Statistical Yearbook, New China 60 Years of Statistical Compilation, China GDP Accounting Historical Data, China Urban Statistical Yearbook, and China Environmental Statistical Yearbook.

Since the breakdown of energy consumption by prefecture-level cities in China is uniformly combined to remove years with a lot of missing data when calculating carbon emission performance, We select the panel data of 281 prefecture-level cities outside some prefecture-level cities with more missing data in China from 210 to 2020 as the initial sample.

(1) Sample Selection for Carbon Emission Performance

Desired output GDP is deflated to a comparable series at constant 2000 prices, and non-desired output carbon emissions are estimated based on the reported continuously by prefecture-level citiesconsumption of all 17 fossil energy sources . Input factors include capital, labour and energy . The capital factor is measured by capital stock, which is estimated based on the perpetual inventory method. The specific estimation method, depreciation rate of fixed assets, and the initial capital stock are calculated and set using the treatment of Howie Shan (2008) , and then the capital stock is deflated to a comparable series of constant prices in the year 2000[1]. Labour input is using the average annual employmentmeasured . Energy inputs are calculated using total energy consumption [2].

(2) Sample selection of local carbon emissions trading pilot policies

Beijing, Shanghai, Guangdong, Tianjin, Hubei, Chongqing, Fujian and Shenzhen are taken as the treatment group, and the rest as the control group. The double difference method is used to empirically test the role of carbon emissions trading on the carbon emissions performance of each prefecture-level city. After the above treatment, 3033 observation samples were selected [4].

2.3 Measurement of Carbon Performance

In this paper, we refer to the Shao Shuai (2022) after referring to non-angular, non-radial DDF model for carbon emission performance based on the aggregate technology frontier proposed by the concept of aggregate technology proposed by Afsharian and Ahn (2015) [2]. Descriptive analyses of input and output factors are carried out before the calculation, with the time span from 2008 to 2023, and the results are shown in Table 1 below . Referring to Shao Shuai et al. (2022), GDP and carbon emissions (C) are selected as desired and non-desired outputs, respectively, and fixed capital stock (y), labour (L), and energy consumption (E) are selected as input factors. Set the direction vector g=(GDP,-C,-y,-L,-E), assign 1/3 weights to desired outputs, non-desired outputs, and input factors, respectively, and also set the weight vector as (1/3,1/3,1/9,1/9,1/9), and calculate the TFECP .Define the carbon performance (TFCEP) in the period t+1 as [2]:

$$\mathrm{TFCEP} = \overrightarrow{D}^0(x^t, y^t, b^t; g^t)\text{-}\overrightarrow{D}^0(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1})$$

Since DDF measures the distance of the decision cell from the production frontier (i.e., the corresponding inefficiency value), TFCEP > 0 implies an improvement in total factor carbon productivity.

Table 1 Descriptive statistics of input-output variables

variant		unit (of measure)	average value	(statistics) standard deviation	Minimum value	Maximum values
Elements of outputs	GDP(Y)	billions	1881.634	2704.196	50.028	30720.18
	Carbon emissions (C)	tonnes	3360	3300	129.513	30800
input element	Capital stock (K)	Thousands	546 00000	663 00000	1894723	792000000
	Labour (L)	all the people	54.936	81.354	4.29	970.605
	Energy consumption (E)	Hundred tonnes of standard coal	134406.1	114439.2	6786.201	806909.5

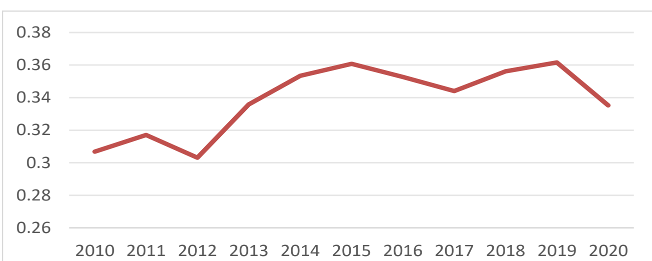

Fig. 1 Year-on-year trend of average performance carbon emission

On average, the mean value of the change in China's total factor carbon emission productivity (i.e., carbon emission performance) from 2010 -2020 is 33.87% , which indicates that the total factor carbon emission productivity is improvedgenerally , and it is worth noting that after 2013 there is a relatively large increase in China's mean value of carbon emission performance , which is initially suspected to be to carbon emission right trading related the implementation of the policy. In order to measure whether the city has achieved a "win-win" situation in terms of economic growth and environmental protection, this paper chooses the carbon emission performance (TFECP) as the explanatory variable.

Table 2 Interpretation of model variable names and descriptive statistics

variant	variable name	Variable Definition	Mean	Min	Max
TFECP	Carbon emission performance	Changes in total factor carbon productivity	0.3184	0.1214	0.7067
$district_{it} \times post_{it}$	dummy variable for policy implementation	0 if has implemented this policy in that year, 1 otherwisethe prefecture level city		0	1
jiju	population concentration	Degree of agglomeration of the urban population in urban areas	0.63	0.192	1
LK	Level of human capital	Number of students enrolled in general higher education/number of household members	185.69	0	1329.75
green	green coverage	Percentage of urban built-up area covered by greenery in relation to the built-up area	38.66	0	95.25
E	Total energy consumption (million tonnes of standard coal)	Total energy consumed by sectors	13.46	0.982	80.69

3 Empirical results

Using the model as a base, the regression using stata regressionresults in Table are obtained . The coefficients of the core explanatory variables (e. g., (0.014) in the first column in the base regression and in each of the columns)are significantly positive at the , indicating that there is a significant positive effect on the explanatory variables. The small standard errors of the columns indicate high estimation precision. 1% level of significanceThe coefficients of green coverage are all positive and some of them are significant at the 10% level, indicating that the variable has a weak positive effect on the explanatory variables, which may be influenced by policy spillovers. population concentration level (jiju) The coefficients ofare all negative and partially significant levels, indicating that an increase in this variable significantly reduces the explanatory variablesat 10% and 5% , i.e., all other things being equal, the higher the level of centrality of the city and the degree of population concentration, the lower the city's carbon emission performance. The coefficients of total energy consumption are negative all and at the 1% levelhighly significant , indicating that they have a significant negative effect on the explanatory variables, which is also consistent with common sense, i. e., all other things being equal, the more the total energy consumption of a prefecture-level city, the lower the city's carbon emission performance. The coefficient of is positive and human capital level highly significant , indicating that the variable has a strong positive driving effect on the explanatory variables. at the 1 per cent levelIt indicates that human capital level has a significant enhancing effect on urban carbon emission performance. After adding control variables, the R - squared from of the model improves to 0.833, indicating that 0.828the explanatory power of the model on the explanatory variables gradually increases.

Table 3 Impact of carbon trading on carbon performance

variant		return to baseline	(1)	(2)	(3)	(4)
$\mathbf{district_{it} \times post_{it}}$		0.014*** (0.005)	0.014*** (0.005)	0.014*** (0.005)	0.018*** (0.005)	0.016*** (0.005)
$\mathbf{X_{it}}$	green		0.002 (0.005)	0.000174 (0.000117)	0.001* (0.000119)	0.001* (0.001)
	jiju			-0.030* (0.016)	-0.029** (0.0144)	-0.028* (0.014)
	E				-0.002*** (0.001)	-2.22e-07*** (3.96e-08)
	LK					0.002*** (2.15e-05)
R-squared		0.828	0.828	0.829	0.830	0.833
fixed effect		YES	YES	YES	YES	YES
observed value		3030	3024	3023	3023	3023

***, **, * represent 1%, 5% and 10% significance level respectively, the following table is the same.

4 Conclusions and Implications

In the combing of theories related to the local pilot policy of carbon emissions trading and carbon emissions performance, this paper mainly illustrates the impact of carbon emissions trading policy on the green development level of prefecture-level cities. The observation sample of prefecture-level cities in China from 2010 to 2020 is selected, and the year 2013 is taken as the time point of the policy shock, and a double difference model is used to study the impact of the carbon emissions trading policy on the level of green development of cities. The study finds thatCarbon emissions trading policies have a positive impact on the carbon emissions performance of each prefecture-level city in China .

From the conclusion of the study, it can be seen that the carbon emissions trading policy has improved the green development level of cities, indicating that it is effective. However, China's national situation is complex, and the implementation effect is different among cities with different locations and different innate resource conditions. Based on these issues, this paper proposes the following policy implications:

(1) Aiming at a "dual-carbon" goal, further improving the carbon emissions trading system, and promoting a virtuous cycle of low-carbon economic development and industrial structure optimisation. We will increase the efficiency of single-factor and total-factor energy use, and summarise regional and sectoral pilot experiences, taking into account our national conditions, on the basis of full reference to the international carbon emissions trading market. The relevant departments should draw on the development experience of existing regions and adopt a two-pronged approach in terms of carbon emissions and productivity, so as to make good short- and long-term development plans.

(2) Differentiated positioning and targeted strategies based on the different characteristics of different cities. Local and national should both coexist and clarify their respective goals. For resource-rich and eastern regions, attention should be paid to the use of its talent, technology, foreign trade and other advantages, to play the role of the core city of the demonstration of the role of leading, and to do a good job of Beijing-Tianjin-Hebei, the Yangtze River Delta, Guangdong, Hong Kong and Macao, the Greater Bay Area and other urban agglomeration group of the carbon emission reduction linkage mechanism; for non-resource areas and western regions and so on, the introduction of high-tech and high-technology industries, and to do a good job of the urban density management and functional configuration and so on.

(3) Promote the transformation of the energy consumption structure and make good use of the "technological dividend" generated by the innovation capacity of green technology. Carbon emission performance improvement and industrial structure, energy consumption structure has a close relationship , expand the scope of carbon emission concentration industry, do a good job of expanding the scope of key emission units [9], the allocation of quota methodology for the relevant key industries, reporting accounting methods, etc. to carry out relevant research and evaluation demonstration. Take a new step forward in covering greenhouse gas emissions. Do a good job of relevant policy support, focusing on key areas and key industries of the relevant enterprises, by increasing innovation subsidies, talent and technology, etc. to lead the good enterprise capital expenditure. Not only support a single green technology innovation capacity, but also pay attention to the organic cooperation of related policies, focusing on the effect of good stacking.

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