Analysis on the Emission Reduction Effect of China's Carbon Trading Policy—Research on pilot policies based on carbon emissions trading

QinRun Yu[1,*]

[1]South China University of Technology, GuangZhou, 510641, China

*Corresponding author: fssc@scut.edu.cn

Abstract. With the development of industrialization, environmental problems have attracted much attention. In response to this problem, China has proposed a "dual carbon" goal: basically all regions will achieve "carbon peak" by 2030, and basically all regions will achieve "carbon neutrality" by 2060. This paper attempts to study whether the pilot carbon trading policy has really contributed to the emission reduction work in the region and the research results show that the implementation of carbon trading policies will have a positive impact on energy conservation and emission reduction in regions, which also means that further expansion and development of the carbon trading market is important for the realization of our country's "dual carbon" goal. It is very necessary; only by further upgrading and improving our country's carbon trading market can we ensure the smooth progress of energy conservation and emission reduction in the future.

Keywords: Two-Carbon Goal, Carbon trading pilot, Differences-in-Differences, the net policy effect.

1. Introduction

1.1 literature review

China's carbon financial market is not yet perfect, there are still many problems, and it is in the stage of coexistence of risks and opportunities; the risk problem brought by the financialization of the carbon market has therefore become a major issue for scholars to study; the classification of carbon market risks. There are also numerous studies related to measurement and management approaches.

At present, China's research on carbon financial risks is mainly based on the traditional financial market, focusing on products closely related to the carbon financial market, their trading rules and distribution methods, and analyzing the risk sources of the carbon financial market. In research, scholars generally divide the risks existing in the carbon financial market into three categories: policy risk, market risk, and investment risk [1].

In the measurement of carbon financial market risk, the GARCH model and the VAR model are the two most frequently used methods by scholars. Du Li, Wang Li, Zhang Yun, and other scholars mainly focus on different types of risks in the carbon financial market, analyze the transaction risks of carbon finance, and also analyze the asymmetry faced by carbon financial transactions and their related. In this basis, it compares and summarizes the advantages and disadvantages of different measurement models based on the four categories of risks: credit risk, operational risk, transaction risk and liquidity risk. Research and discussion, based on the above research results, and finally put forward countermeasures and suggestions for the risk prevention in the carbon financial market [2]. In the research of Zhang Chen, Yang Yu, Zhang Tao and other scholars, the theories related to financial risk management are first reviewed, and commonly used methods and common perspectives are proposed. The analysis is carried out, and the problem that the carbon price yield has the general characteristics of time series is put forward. Monte Carlo) simulation calculation method, referring to the time series data of the CER futures price and the exchange rate price of EUR/RMB in the United States from 2009 to 2012, the data is analyzed and researched, and the commercial bank's role in carbon finance is analyzed and studied. The market risk is comprehensively measured, and based on the research results, some common risk issues in the carbon financial market are proposed [3]. Based on the research on the risk measurement of carbon finance, scholars have also put forward certain suggestions on the management methods of risks in the carbon financial market: for example, financial innovation should be reasonable and appropriate, not blindly; in the development process of the carbon financial market Pay attention to the balance between risk and return, so as not to blindly pursue high returns and lead to the accumulation of risks. In addition, with the financial innovation in the carbon financial market, carbon financial derivatives will inevitably emerge as the times require. Some scholars have put forward certain views on this aspect. For example, scholars such as Wang Liuzhi and Song Yang proposed that carbon financial derivatives are a To be a double-edged sword, the use of derivatives related to carbon finance requires that enterprises should, under the premise of paying attention to the management and control of risks, rationally use carbon financial derivatives to raise funds, thereby bringing benefits to the enterprise [4]. Therefore, enterprises should have a correct attitude towards carbon financial derivatives, and it is very important to use them rationally. In this regard, enterprises should also pay attention to the cultivation of talents, and the training and quality education of relevant practitioners. Scholars such as Cheng Kai and Xu Chuanhua compared and summarized the experience of the UK, the US and the EU in carbon financial market risk management on the basis of determining the risk classification of carbon financial market, and put forward suggestions for the risk management approach of carbon financial market in China [5].

Many foreign scholars have also conducted research and analysis on carbon trading risks in the international market from different perspectives. Scholars such as Yang Chao take CER futures as the main research object, and mainly focus on the measurement of dynamic risks of carbon finance-related derivatives. The dynamic risk of various types of futures products is measured and compared, which introduces Markov fluctuation transfer into VAR calculation, and combines EPT to measure the risk in the international carbon trading market. Based on the research results, relevant suggestions are put forward for the further development and construction of my country's CDM project market [6]; scholars such as Tian Yuan constructed a GARCH-EVT-VAR model to measure international carbon emissions based on the theory of value at risk, conditional variance theory and extreme value theory. The expected risk of trading spot and futures markets under normal volatility and extreme conditions [7]. In terms of risk management, scholars such as Jiang Jingjing focused on the "capacity control and allowance trading" market established by the EU ETS, taking EUA and CER as research products, and measuring variance on the basis of the VAR measurement framework The GARCH-EVT-VAR model is established to quantify the risk of price fluctuations in the carbon market, and an empirical study on the EU Emissions Trading Market (EUETS) is carried out, and the risk management of the domestic carbon financial market is also based on relevant research results. The problem puts forward a new view [8].

1.2 theoretical analysis

As an environmental regulation tool, the market is a tool to regulate the behavior of polluting the public environment for the purpose of protecting the environment; it has a certain emission reduction mechanism; according to the research of scholars, this mechanism can be from the following three from the perspective of different effects.

The first effect is called the structure effect, because it can have a certain impact on the market structure by changing the market access threshold [9], and then it will have an impact on the industrial structure. The second is the technological effect, which is based on the "Porter Hypothesis" - reasonable environmental control can effectively promote technological innovation of high-polluting enterprises, thereby reducing the emission of pollutants such as harmful gases; and can take the lead in technological innovation. Enterprises with the highest level of competitiveness can improve their competitiveness and thus occupy a certain market advantage, which is called the “innovation compensation effect” of enterprises [10]. The third is the allocation effect. Based on the research of Costantini and other scholars [11], from the macro level, strict regulatory policies will help the region to attract the advantages of resources such as capital and labor, and improve the efficiency of regional resource allocation.

2. Data sources and model settings

2.1 Data sources

The data of the experimental group are derived from the actual carbon emission data and carbon intensity data of Beijing, Shanghai, Tianjin, Hubei, Chongqing and Guangdong from 2001 to 2019 (since Shenzhen belongs to Guangdong Province in the pilot city, the data of Guangdong Province is used instead here.); the data of the control group comes from the actual carbon emission data and carbon intensity data of other non-pilot regions. In order to ensure the authenticity and integrity of the experimental data and the accuracy of the experiment, the whole country is excluded from Hong Kong, Macao and Taiwan (with missing data) and Qinghai, Tibet , Hainan Province (CO2 emissions are always far lower than the national average, avoiding the impact of extreme data) and Fujian Province (beginning in 2016 as the eighth national carbon trading pilot area.) data Excluded; the actual carbon emission data used in the experiment is calculated based on the IPCC calculation method, and all kinds of date are from the "China Statistical Yearbook".

2.2 Variable definitions

2.2.1. Carbon Trading Policy Variables

The research in this paper is based on the comparison of carbon emissions and carbon intensity in pilot areas and non-pilot areas. In order to obtain preliminary conclusions, a longitudinal comparative analysis of carbon intensity and carbon emissions in pilot areas is firstly conducted. At the same time, non-pilot areas were introduced and calculate the change trend of carbon intensity and carbon emissions in non-pilot areas, analyze the differences between the two, and preliminarily determine whether the carbon trading market had an impact. After the preliminary conclusions are obtained, the experimental results are tested. In order to analyze the net effect of the policy, the double-difference (DID) method is used for the test. This method needs to ensure that both the experimental group and the control group exist and the time can be divided into two parts-before and after policy implementation. In order to obtain the net effect of the carbon trading policy, the method adopted here is to introduce two dummy variables—whether the carbon trading policy is implemented, that is, “1” for pilot cities, and “0” for non-pilot cities; After the time is divided, it is recorded as "0" before the policy is implemented, and "1" after the policy is officially implemented. The double-difference model is used to conduct an empirical test to examine the net effect of the policy, to judge the impact of the carbon trading policy on the actual carbon dioxide emissions and carbon intensity of various regions, and to evaluate the actual benefits brought by the policy.

2.2.2. Other Control Variables

Considering that there are certain differences in many aspects between cities, in order to constrain these differences so that they will not have a significant impact on the research results, it is necessary to use the method of controlling variables. Here, the following variables are selected as control variables:

(1) The level of economic development Expressed by the actual GDP of the region, it represents the economic development level of each region and the impact of economic growth factors on carbon emissions; the per capita GDP can better reflect the economic development of a region than the actual GDP; however, due to my country's per capita GDP It is still relatively low and cannot play a decisive role in the prime minister of carbon emissions. Therefore, in the model, when the actual carbon emission (CDE) is used as the dependent variable, the real GDP is selected as the control variable, and when the carbon intensity (CDEI) is used as the dependent variable, the per capita GDP is selected as the control variable.

(2) Industrial structure It represents the impact of industrial structural factors on carbon emissions.

(3) Energy consumption It represents the impact of energy consumption on carbon emissions.

(4) Total population It represents the impact of exhaled carbon dioxide on carbon emissions.

2.3 Description of the main variables

In the process of testing based on the double-difference method, there are some variables that may affect carbon emissions, such as different cities have different population densities and economic bases; five control variables and two explained variables are selected first. The corresponding statistical calculation method and variables are shown in the following table:

Table 1. Description of the main variables

	Variables	name	description method
Explained variable	Carbon dioxide emissions	CDE	Coal emissions + oil emissions + natural gas emissions (calculation method based on IPCC)
	carbon intensity	CDEI	CO2 emissions/real GDP
virtual variable	Policy dummy variables	Policy	The pilot area is recorded as "1", and the non-pilot area is recorded as "0"
	time dummy variable	Time	In 2011 and later, it is recorded as "1", otherwise it is recorded as "0"
cross term	net effect	DID	DID= Policy* Time
control variable	GDP	GDP	Real GDP by Province
	Industrial structure	IS	The proportion of the secondary industry
	total population	TP	The total population of each province at the end of the year
	energy consumption per person	ENERGY	Energy consumption/total population (because China mainly uses coal-fired power generation, the power consumption in each region/total population in each region is used instead)
	GDP per person	GDP_P	Real GDP/Total Population

2.4 Model settings

2.4.1. Carbon Emissions and Carbon Intensity Calculation Model

Calculation Model of Carbon Emissions and Carbon Intensity For the calculation of carbon emissions, this paper uses the carbon emission measurement method of IPCC to calculate the carbon dioxide emissions of each region from 2001 to 2019 (the data after 2019 cannot be accurately calculated), and the calculation formula is as follows:

$$CO_2 = \sum_{i=1}^{3} EC_i * NCV_i * CC_i * COF_i * \frac{44}{12} \tag{1}$$

Among them, CO2 represents the total amount of carbon dioxide emissions; i=1, 2, and 3 represent coal, oil, and natural gas, respectively; EC_i represents the consumption of various energy sources; NCV_i epresents the average low-level calorific value; CC_i indicates the carbon content, which refers to the carbon content per unit of heat; COF_i refers to the oxidation factor, which refers to the carbon oxidation rate during energy combustion; 44/12 is the ratio of the molecular weight of carbon dioxide to carbon. For the calculation of carbon strength, the formula is as follows:

$$\text{CDEI} = \text{CDE/GDP} \tag{2}$$

Among them, CDEI is the carbon intensity, CDE is the carbon dioxide emissions of each region, and GDP is the gross domestic product of each region. This indicator is used to examine the amount of greenhouse gas emissions caused by bringing a unit of GDP.

2.4.2. Double difference model

In order to obtain the net effect of the policy, the method of double difference is used to introduce two dummy variables of "time" and "whether the pilot area is not" to construct a model and conduct an empirical test. The double-difference (DID) method is used to test the results of the policy, and the model based on it is as follows:

$$\begin{aligned} y_{it} &= \beta_0 + \beta_1 Polocy_{it} + \beta_2 Time_{it} + \beta_3 policy_{it} * Time_{it} \\ &+ \sum \delta X_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

$$\ln CDE_{it} = \beta_0 + \beta_1 Policy_{it} + \beta_2 Time_{it} + \beta_3 policy_{it} * Time_{it} + \beta_4 \ln GDP_{it} + \beta_5 TP_{it} + \beta_6 IS_{it} + \beta_7 ENERGY_{it} \tag{4}$$

$$\ln CDEI_{it} = \beta_0 + \beta_1 Policy_{it} + \beta_2 Time_{it} + \beta_3 policy_{it} * Time_{it} + \beta_4 \ln GDP\_P_{it} + \beta_5 TP_{it} + \beta_6 IS_{it} + \beta_7 ENERGY_{it} \tag{5}$$

Among them, i represents the six pilot areas and six non-pilot areas selected above, t represents the time from 2001 to 2019, Y_{it} represents the explained variable, and the explained variable here examines carbon emissions and carbon intensity; $Policy_{it}$ and $Time_{it}$ are two dummy variables. It is considered that $Policy_{it} = 1$ is the treatment group, that is, the carbon trading policy is implemented, and $Policy_{it} = 0$ is the control group, that is, the carbon trading policy is not implemented; according to Divide the time into two groups before and after the policy is released, take the time before the policy is released $Time_{it} = 0$, that is, 2001 to 2010, and take the time after the policy is released, which is 2011 to 2019; The relevant control variables, here are GDP, industrial structure, population density, per capita energy consumption and per capita GDP, ε_it is recorded as a random disturbance term.

3. Empirical Results Analysis

3.1 Empirical Results Analysis

Empirical Results Analysis In order to analyze and judge the impact of the carbon trading pilot policy on the actual carbon dioxide emissions in each region, we firstly conducted a vertical comparison of the six pilot regions, and obtained the results as shown in the following figure:

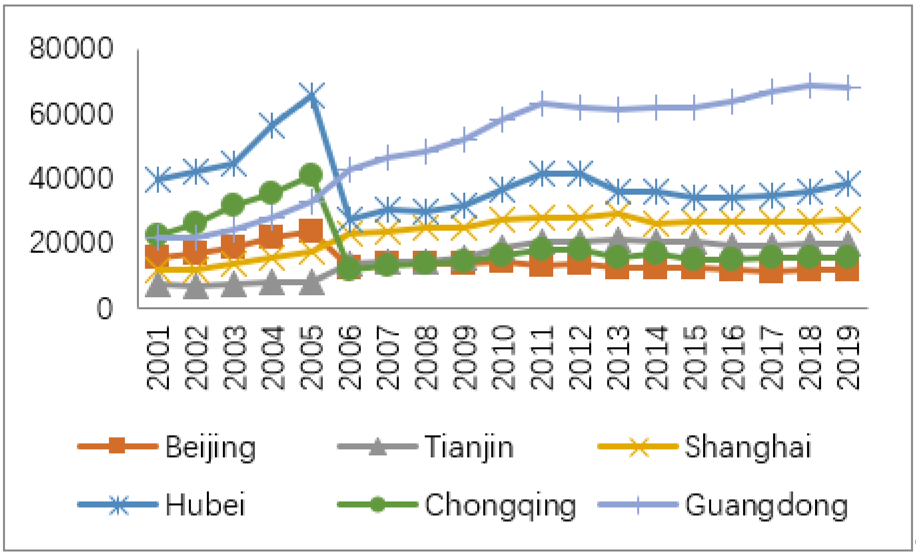

Fig. 1 Carbon dioxide emissions in each pilot region from 2001 to 2019

It can be seen from the experimental results that with the development of industrialization, the annual increase of carbon dioxide emissions is an inevitable and undeniable trend. Emissions all showed an upward trend. Among them, Hubei, Chongqing and Beijing showed a significant decline in carbon emissions from 2005 to 2006, and then entered a new growth stage; however, it can be observed that from 2011 to 2011 the rate of increase in 2017 decreased, and the overall upward trend stabilized, especially in the four regions of Beijing, Chongqing, Tianjin and Shanghai, whose CO2 emissions remained basically unchanged from 2011 to 2019.

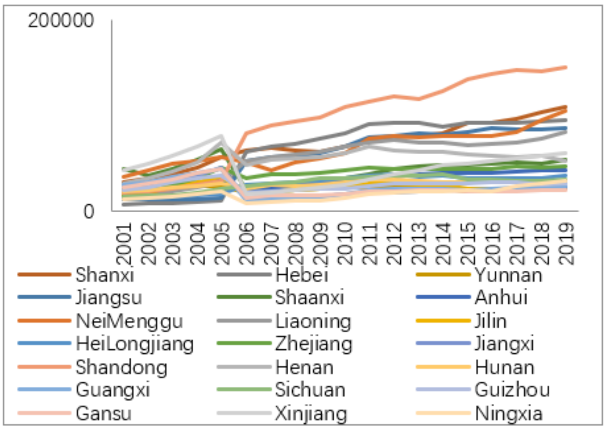

Fig. 2 Carbon dioxide emissions in non-pilot regions from 2001 to 2019

From the above results, it can be seen that for these non-pilot regions, from 2001 to 2019, the overall trend from 2001 to 2019 shows that although some regions have flattened the changes in carbon emission data from 2011 to 2019, there are still many provinces. Showing a relatively obvious upward trend, in order to make a horizontal comparison of the overall carbon dioxide emissions in the pilot areas and non-pilot areas, the average of the two groups of data from 2001 to 2019 was calculated; the six pilot areas were the experimental group, and the remaining provinces were the control group. The result is as follows:

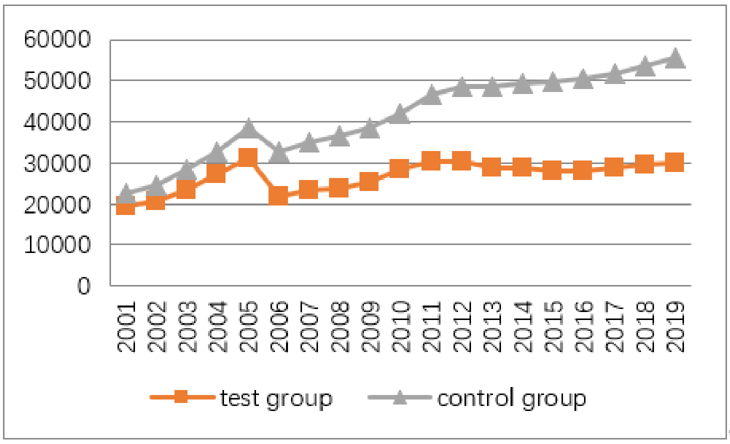

Fig. 3 Statistical comparison of the average carbon emissions between the experimental group and the control group from 2001 to 2019

From this figure, it can be clearly seen that the difference in actual carbon emissions between the experimental group and the control group, especially in the later period of 2011 to 2019, the actual carbon emissions of the experimental group tended to be stable, while the actual carbon emissions of the control group still showed an increase trend, the difference between the two groups further widens.

In order to analyze the impact of the carbon trading pilot policy on the carbon intensity of various regions, first of all, a longitudinal comparison of the carbon intensity of the pilot regions, in which the carbon trading pilot policy was released in 2011; since Shenzhen belongs to Guangdong Province, data from Guangdong Province is used instead here; the carbon emission data from 2001 to 2019 in Beijing, Shanghai, Tianjin, Hubei, Chongqing and Guangdong are divided by real GDP pre year to obtain the following carbon intensity statistics:

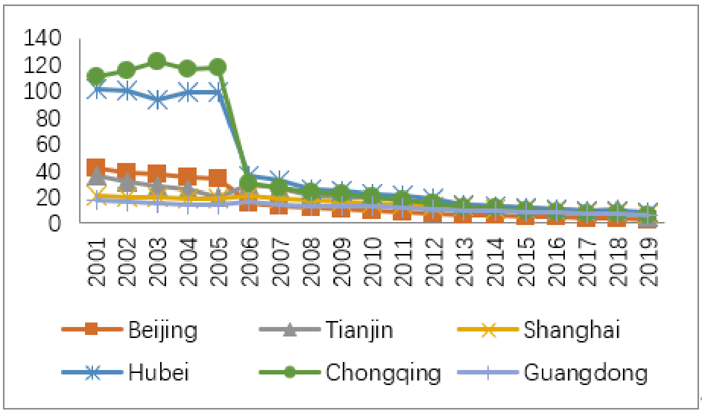

Fig. 4 Comparison of carbon intensity in pilot regions from 2001 to 2019

According to the above pictures, we can see the overall change trend of carbon intensity in the pilot area from 2001 to 2019. In 2006, the carbon intensity of Hubei, Chongqing and Beijing had a significant decrease, while the carbon intensity of Tianjin, Shanghai and Guangdong increased slightly. After 2006, the carbon intensity of the above six provinces gradually tended to be similar and remained stable from 2011 to 2019. This result shows that the carbon dioxide emissions per unit of GDP are getting less and less.

In order to clarify the role of the carbon trading policy, a horizontal comparison of carbon intensity will also be carried out - a comparison between pilot and non-pilot areas. Here we use the whole country except Hong Kong, Macao and Taiwan (with missing data) and Qinghai, Tibet, Hainan Province (CO2 emissions are always far lower than the national average, avoiding the impact of extreme data) and Fujian Province (beginning in 2016 as the eighth country in the country). The carbon trading pilot areas cannot adapt to the time division of the model in this paper. To ensure the accuracy of the empirical evidence, the data of other areas except for the first excluded) are calculated based on their carbon emissions and annual GDP data, and the results are as follows:

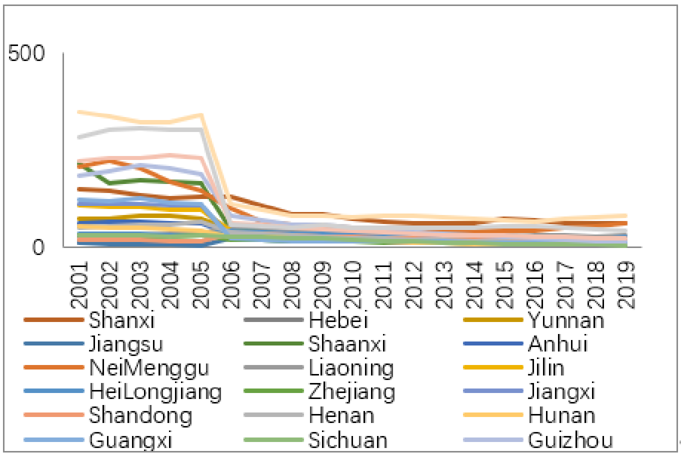

Fig. 5 Changes in carbon intensity in the remaining non-pilot regions from 2001 to 2019

The carbon intensity values of the pilot areas and non-pilot areas from 2001 to 2019 were averaged and compared, and the results were as follows:

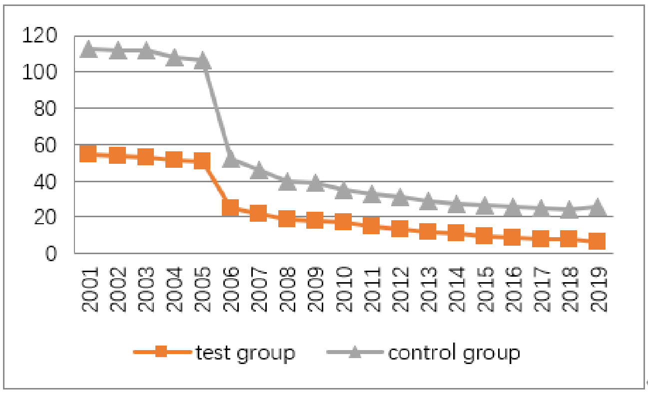

Fig. 6 Comparison of carbon intensity values between experimental and control groups from 2001 to 2019

It can be seen from the above image that the overall trend of carbon intensity value changes in the non-pilot areas is similar to that in the pilot areas, with obvious changes in 2006 and tending to be similar since then. However, from the horizontal comparison of carbon intensity between the experimental group and the control group, it can be seen that the experimental group showed a lower carbon intensity value in any particular year from 2001 to 2019, and the carbon intensity in the carbon trading pilot years was lower. The value of carbon intensity maintained a continuous downward trend, and the decline rate was close to 20%; while the control group also showed a downward trend in carbon intensity, but the decline was more gradual, about 10%.

In order to further verify the above inference results, two explanatory variables CDE and CDEI are introduced, and per capita GDP, real GDP, industrial structure, population density, and per capita energy consumption are introduced as control variables, and the above two Policy and Time are introduced as dummy variables, The double-difference analysis is used, and the following results are obtained:

Table 2. The results of double-difference analysis with CDE and CDEI as explained variables

	(1)	(2)
VARIABLES	Ln CDE	Ln CDEI
TIME	0.131	0.141
	(1.360)	(1.443)
POLICY	-1.029**	-1.619***
	(-2.138)	(-4.206)
DID	-0.413***	-0.485***
	(-5.402)	(-6.424)
TP	0.000***	0.000***
	(7.156)	(5.202)
IS	-0.031***	-0.031***
	(-5.956)	(-5.790)
ENERGY	0.000***	0.000***
	(3.659)	(3.014)
Ln GDP	0.118	
	(0.685)	
Ln GDP_P		-0.846***
		(-4.939)
Constant	9.682***	6.375***
	(8.573)	(23.762)
Observations	513	513
R-squared	0.744	0.877
time fixed effects	Y	Y
individual fixed effects	Y	Y
control variable	Y	Y

Note: All other variables have been controlled; t values are in parentheses; *, **, *** indicate significant at the 10%, 5% and 1% levels, respectively, and the following table is the same as

It can be seen from the above experimental results that when the actual carbon dioxide emission is used as the explained variable, the coefficient of the DID term is -0.413 and shows significance at the 1% level; it can be clearly seen that the implementation of the policy has reduced the actual carbon emissions in the pilot area, which can be considered to have a very good impact on the energy conservation and emission reduction work in the region.

At the same time, when carbon intensity is used as the explained variable, the coefficient of the DID term is -0.485 and it is significant at the 1% level. From the results of the coefficient and the significance level, it can be considered that the implementation of carbon trading policies has also decreased the carbon intensity of the pilot areas. The implementation of carbon trading policies has made outstanding contributions to the green economy work in the area.

3.2 Parallel Trend Test

The difference-difference model estimates rely on the parallel trend assumption. The parallel trend assumption means that the time when the trend of the experimental group deviates significantly from the trend of the control group is consistent with the time of the event; if it is not satisfied, it means that the net effect of the policy obtained by the two differences is not entirely the real policy effect, part of which is due to the experimental caused by the differences between the group and the control group itself. For this reason, in order to ensure the reliability of the above research conclusions, this paper will test this hypothesis next. Specifically, the parallel trend test in this paper adopts the following ideas: we still select the data from 2011 to 2019 for processing and regress again, but in this research interval, we assume that the policy occurred in 2015. If the policy does not occur during the year, Policy=0; after that, the policy occurs, that is, Policy=1; at the same time, the provinces and cities that implement the carbon trading policy are randomly reselected. If it is found that the coefficient of DID is not significant at this time, it means that in this paper Parallel trends are assumed to hold, otherwise they are not. The corresponding estimation results are shown in Table 3:

Table 3. Parallel trend test results

	(1)	(2)
VARIABLES	LNCDE	LNCDEI
DID	0.021	0.024
	(0.258)	(0.289)
time fixed effects	Y	Y
individual fixed effects	Y	Y
control variable	Y	Y

Note: other variables have been controlled; t values are in parentheses; *, **, *** indicate significant at the 10%, 5% and 1% levels, respectively

It can be clearly seen from the table that the DID result at this time is not significant. It can be considered that the parallel trend hypothesis is established in the experiment of this paper. Therefore, it is considered that the time when the trend of the experimental group deviates significantly from the trend of the control group is consistent with the time when the policy occurs. The authenticity of the net effect of the policy is verified; such results further demonstrate that the implementation of carbon trading policies is of great significance in reducing the actual carbon emissions and carbon intensity of the region.

4. Conclusions

The research results proves that the implementation of carbon trading policy is a very necessary part of the road to the realization of "dual carbon" goal of China. On July 16, 2021, with the establishment of the national carbon trading market, China has taken another major step in carbon finance. To solve the problem and correct it, which plays a very important role in promoting the carbon trading market to make greater contributions to the establishment of my country's low-carbon economic system in the future.

REFERENCES

[1] Shen Fei, Zheng Zuting. A review of my country's carbon financial risk management research [J]. Economic Outlook on the Bohai Rim, 2019(05): 49-50.

[2] Du Li, Wang Li, Zhang Yun. Carbon financial transaction risk: measurement and prevention [J]. Economic Management, 2014, 36(04): 106-116.

[3] Zhang Chen, Yang Yu, Zhang Tao. Risk integration measurement of commercial bank carbon finance market based on Copula model [J]. China Management Science, 2015, 23(04): 61-69.

[4] Wang Liuzhi, Song Yang. A brief discussion on the financial innovation and risk prevention of carbon trading in my country [J]. Modern Finance-Journal of Tianjin University of Finance and Economics, 2009,29(06):30-34..

[5] Yuan Pu, Han Xiaoya, Zhao Heqin. Literature Review on Risk Management of Carbon Financial Markets [J]. Times Finance, 2020(30): 8-11.

[6] Yang Chao, Li Guoliang, Men Ming. Risk measurement of the international carbon trading market and its enlightenment to my country—a comparative study of VaR based on state transition and extreme value theory [J]. Quantitative Economics, Technical and Economic Research, 2011, 28(04):94-109+123.

[7] Tian Yuan, Chen Wei, Song Weiming. Research on risk measurement of major international carbon emission trading markets based on GARCH-EVT-VaR model [J]. Science and Technology Management Research, 2015, 35(02): 224-231.

[8] Jiang Jingjing, Ye Bin, Ma Xiaoming. An empirical study on carbon market risk measurement based on GARCH-EVT-VaR model [J]. Journal of Peking University (Natural Science Edition), 2015, 51(03): 511-517.

[9] Blair Benjamin F. Hight Diane. The impact of environmental regulations on the industrial structure of landfills [J]. Growth and Change, 2005, 36(4): 529-550.

[10] Zhao Lingdi, Zhang Lei, Xu Le, Hu Mingzhao. The mechanism of human capital, industrial structure adjustment and green development efficiency [J]. China Population, Resources and Environment, 2016, 26(11): 106-114.

[11] Hu Jun, Huang Nan, Shen Hongtao. Can market incentive-based environmental regulation promote technological innovation of enterprises?——A natural experiment based on China's carbon emission trading mechanism [J]. Financial Research, 2020(01):171- 189.