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The Role of Industrial Structure in the Impact of Environmental Regulation on Carbon Productivity

--Based on Carbon Emission Trading Policy

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Abstract

In the context of global climate change, China has proposed the "Carbon peaking and Carbon neutrality goals" goal of carbon emissions will reach carbon peak by 2030 and carbon neutral by 2060. As a market-based environmental regulation policy to promote greenhouse gas emission reduction, carbon emission trading policy is expected to reduce carbon emissions and improve carbon productivity, among which industrial structure plays a regulatory role in the impact of carbon emission trading policy on carbon productivity. Using the provincial data of China from 2006 to 2019, this paper evaluated the influence of carbon emission trading policy on carbon emission, taking the industrial structure as the regulating variable, studied the industrial structure in the influence of environmental regulation on carbon emission, and tested the regression results of DID model through parallel trend test, placebo test and PSM-DID model regression. After the above research process, the following conclusions are drawn: the carbon emission trading policy has a significant positive promotion effect on carbon emission reduction, and it is further concluded that the industrial structure has a significant negative regulatory effect on carbon productivity under the carbon emission trading policy.

Keywords

Carbon emission trading right policy, industrial structure, carbon productivity.

1. Research background

From the practical point of view, global warming is a severe problem facing mankind today, which has a great impact on human survival and social development. The main cause of global warming is that humans have used a large number of fossil fuels (such as coal and oil) in the past century, and emitted a large amount of greenhouse gases. The increase in carbon dioxide emissions in the atmosphere is the fundamental cause of global warming. According to the International Energy Agency, almost half of the global carbon dioxide emissions are accounted by the United States, China, Russia and Japan. So some measures must be taken for intervention control, or the expected global average temperature at the end of the 21st century will be about 4 degrees Celsius higher than the pre-industrial levels. Once the global average temperature rises above the threshold of 2℃ in the future, human life may face greater risks, so easing global warming is the top priority at present.

Theoretically, the government to environmental regulation of environmental pollution control, mainly has the following two levels: first, the environment has the characteristics of public goods, objectively, the environment has non-exclusive and competitive, namely the ecological environment should be enjoyed by most people, leading to environmental pollution is a bad public goods, because the polluter don't have to pay the corresponding price for the pollution,

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so the environmental pollution will be increasingly serious. Second, environmental pollution has externalities. As a typical negative externality, environmental pollution, the society needs to pay the corresponding cost of pollution control. To sum up, environmental pollution as a bad public goods and the negative externality of environmental pollution make the automatic regulation function of the market mechanism ineffective, so it is necessary to rely on the government's macro-control and public service function to reduce environmental pollution.

Countries around the world have taken different measures to deal with global warming, with the ultimate goal of reducing greenhouse gas emissions and slowing global warming. The international community signed the United Nations Framework Convention on Climate Change in 1992, the Kyoto Protocol in 1997 and the Paris Agreement in 2015, aiming to control greenhouse gas emissions and thus curb global warming. At present, the carbon emissions of various countries in the world can be roughly divided into the following four types: First, the carbon emissions of developed countries such as Britain, France and the United States peaked around the 1980s, and are currently in the decline stage after the peak. Second, China is still in the stage of industrial restructuring and upgrading, and economic growth has entered a new normal, and carbon emissions have gradually entered a stable stage. Third, some emerging countries, represented by India, are still in a period of rising carbon emissions. Fourth, a large number of developing countries, with the rapid economic and social development, their carbon emissions have not been formally included in the measurement.

As the largest developing country, China has long attached great importance to the issue of climate change, and has continuously increased its willingness to participate in global climate change governance. At the same time, with the improvement of its overall national strength, China has actively undertaken the obligation of quantitative emission reduction, adopted a series of effective actions to save energy and reduce emissions, and made a significant contribution to the response to global climate change. On September 22,2020, the Chinese government proposed at the 75th Session of the United Nations General Assembly: " China will increase its state-determined contributions, adopt more effective policies and measures, strive to peak its carbon dioxide emissions by 2030, and strive to achieve carbon neutrality by 2060."Since 2011, Beijing, Tianjin, Shanghai, Hubei and other places have successively carried out the pilot work of carbon emission right trading. At the end of 2017, China began gradually trading carbon emission rights. On July 16,2021, the world's largest carbon emission trading market was officially launched in China, which may become an important means of industrial action to combat global climate change. Under the background of "Carbon peaking and Carbon neutrality goals", how to improve the level of green development of industry formulated by the government and how to affect the green development requirements of the industrial sector to realize the whole field and the whole process are the focus of scholars.

2. Literature review

At present, the environmental regulation tools adopted in the field of carbon emission in China are mainly Market-Based Incentive (MBI), that is, to set a mechanism similar to the market price for pollution emission through regulatory policies, so as to achieve the effect of promoting the emission reduction of polluting enterprises. In the field of carbon emissions is mainly divided into price regulation and quantity regulation, including price regulation based on price mechanism of carbon tax, lu book and Bai Yanfeng (2021) research carbon tax international practice and its to our country 2030 years ago to achieve "carbon peak" enlightenment, to explore how to build a carbon tax system for 2030 years ago "carbon peak" goal and high quality economic development is of great significance [1]. Quantitative regulation includes carbon emission trading based on total control. Li Ping and Rao Zewei (2021) studied the development status of the world and China's carbon market, explored the significance of relevant research for China to achieve the goal of carbon peak and carbon neutral "Carbon peaking and Carbon neutrality goals", and further demonstrated the necessity of building China's carbon market [2]. At present, China's carbon market regulation policy includes the pilot "double credits" policy in the field of new energy vehicles and the pilot "carbon emission quota" policy in the power, steel and other fields. The "carbon quota" is essentially converting unlimited emission rights into scarce quotas through intervention control, by setting emissions caps. Wei Qi, Pan Yu and Li Linjing (2021), based on the general equilibrium model of the duopoly, studied the impact of carbon quota policy and subsidy policy on enterprises and social welfare, and concluded that the carbon quota policy is more conducive to improving the overall social welfare [3].[1][1][3]

2.1. A Study on the impact of environmental regulations on carbon emissions

[4] From the existing theoretical studies on the impact of environmental regulations on carbon emissions, Sinn (2008) is the first concept, Strict environmental regulations to address climate degradation, In order to curb carbon emissions, And the measures will become stricter in the future, But actual market feedback did not meet the government expected when it made plans, Fossil fuel suppliers will remain pessimistic about the future, And put a lot of fossil fuels today, A flood of oil and other fossil fuels entering the market can lead to a surge in supply, Prices are bound to fall, Ultimately leading to increased consumption, This goes against policy-making expectations for the [4]. Gerlagh (2011) according to a series of literature through modeling analysis discusses the possibility of "green paradox" policy situation, Gerlagh "green paradox" is divided into weak green paradox and strong green paradox, including weak green paradox is short-term analysis, the theory that strict emissions reduction policy will lead to the future scarcity of resources, resulting in scarce rent, fossil fuel resource owners for their own interests maximization will accelerate the exploitation of fossil fuels, leading to short-term carbon dioxide emissions increase, but for long-term consideration is not big. The strong green paradox is analyzed from the long-term welfare. The theory holds that policies subsidizing alternative energy so that the owners of fossil fuels will accelerate the exploitation of fossil fuels, causing cumulative loss and current costs, leading to a decline in long-term green welfare [5]. Van der Ploeg F and Withagen C (2012) According to the concept of "green paradox" proposed by predecessors, the policy types were further distinguished, and believed that the increasing carbon tax policies, policies with time lag and subsidies for alternative energy will lead to the [6] of "green paradox".[5][6]

[7][8]From the existing empirical studies on the impact of environmental regulations on carbon emissions, Zhang Hua and Wei Xiaoping (2014) theoretically put forward four indirect transmission mechanisms for the impact of environmental regulation on carbon emissions, Then from the empirical analysis of Chinese provincial data, Found that the impact of environmental regulation on carbon emissions presents an inverted U-shaped curve, That is to say, with the increasing intensity of environmental regulation, Take a certain value, the threshold value as the dividing line, Before reaching a certain intensity threshold, The influence effect of environmental regulation on carbon emissions is the "green paradox" effect, After reaching a certain intensity threshold, The impact effect of environmental regulation on carbon emissions has changed to the "forced emission reduction" effect [7]. At the same time, Zhang Xianfeng and Han Xue (2014) also studied the impact of environmental regulations on carbon emissions, and conducted theoretical analysis and empirical test on the "forcing effect" and "regressive effect". The research results show that the theoretical and empirical analysis of environmental regulation on economic growth show an inverted U curve, with the increasing strength of the environmental intensity, the environmental regulation will produce the "backward effect" [8]. Zhou Xiaoxiao (2015) based on direct and indirect two perspective discussion of environmental regulation on fossil energy consumption path and results, and based on the provincial panel data, the study found that the influence of environmental

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regulation on fossil energy consumption presents a inverted U curve relationship, namely in the environmental regulation strength is lower than a certain level, in line with the "green paradox" effect, only the strength of the environmental regulation beyond a certain level, to show the environmental regulation of energy saving utility [9].[9]

2.2. Research on the influence of environmental regulation on industrial structure

[10]In the existing research on the impact of environmental regulation on industrial structure, Lu Jing (2007) believes that the government can strategically encourage and subsidize the technological progress and technological innovation of domestic enterprises, so as to achieve the purpose of promoting traditional industries to "force" industrial upgrading [10]. Tan Juan and Chen Xiaochun (2011), based on the analysis of the impact of government environmental regulation on low-carbon economy from the perspective of industrial structure, believe that government environmental regulation is the reason for the change in the carbon emissions of unit GDP of the secondary and tertiary industries, and the optimization of environmental structure is conducive to the construction of low-carbon industrial structure [11]. Li Qiang (2013) studied the impact of environmental regulation on industrial structure adjustment based on the Baumol model, and made empirical analysis with provincial data. The results showed that environmental regulation will increase the proportion of service industry relative to industry, so as to optimize the [12] of industrial structure adjustment. Zhong Maochu, meng-jie li and Du Weijian (2015) based on theoretical analysis and empirical analysis of the provincial data studied the environmental regulation of pollution industry transfer and structure upgrade, the results show that the relationship between environmental regulation and industrial structure is a U curve, only environmental regulation strength over a certain level to achieve the effect of promoting industrial upgrading, and further to reversed transmission industrial structure adjustment of the most effective environmental regulation to explore [13].[11][11][13]

2.3. Research on the impact of industrial structure on carbon emissions

In the existing research on the relationship between industrial structure and carbon emissions, Li Jian and Zhou Hui (2012) conducted an empirical analysis of the correlation between China's carbon emission intensity and industrial structure, and concluded that the secondary industry is the main factor affecting the regional carbon emission intensity, and proposed that the carbon emission intensity can be affected by controlling industrial development [14]. Zhang Hua and Wei Xiaoping (2014) believe that environmental regulation promotes the upgrading of industrial structure, stimulates technological innovation, and reverses the direction of the impact of industrial structure and technological innovation on carbon emissions [7].[14][7]

2.4. Study on the relationship between carbon emissions and carbon productivity

Carbon productivity refers to the level of GDP output per unit of carbon dioxide, which reflects the economic benefits generated per unit of carbon dioxide emissions. It is a concept that combines the two low-carbon economic goals of inhibiting carbon dioxide emissions (low carbon) and promoting economic growth (economy).

He Jiankun and Su Mingshan (2009) conducted theoretical and empirical analysis of the growth rate of carbon productivity in various countries, and concluded that the annual growth rate of carbon productivity can be used as an important measurement indicator [15] when measuring the degree and final effect of a country's response to climate change. Chen Wei, Zhu Dajian and Bai Zhulan (2010) using the index of carbon productivity, with Shanghai as the research object, study the relationship between the total carbon emissions and carbon productivity, the

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conclusion shows that the reduction of carbon emissions contributes to the growth of carbon productivity, and the growth rate of carbon emissions is mutual [16].[15][16]

Fan Qiufang and Zhang Yuanyuan (2021) study carbon emissions trading policy affect carbon productivity, based on the provincial data and double difference model and mediation effect model empirical analysis, and further concluded that carbon emissions trading policy can significantly affect carbon productivity, in the mediation effect analysis can further reduce energy intensity, promote technological innovation and advanced industrial structure further improve carbon productivity, namely the three factors in carbon emissions trading policy on carbon productivity mediation [17]. Liu Chuanjiang, Hu Wei and Wu Hanhan (2015), based on provincial data, calculated the environmental regulation intensity index and carbon productivity in each province, focusing on the regional differences in carbon productivity, and conducted an empirical analysis of the impact of environmental regulation and economic growth on carbon productivity. The study found that although there are regional differences in the impact of environmental regulation on carbon productivity, there is a U-shaped curve relationship, which further verified the Kuznets curve hypothesis of carbon productivity [19]. Ren Xiaosong, ma, Liu Yujia and guo-hao zhao (2021) using double difference, dynamic effect test and triple difference method, examines the carbon trading policy on industrial carbon productivity effect and heterogeneity, at the same time using the multiple mediation effect model, analytical carbon trading of industrial carbon productivity mechanism, the results show that carbon trading policy significantly improved the industrial carbon productivity, implements the "carbon reduction to promote the" effect, and the effect keep rising trend year by year [18].[17][15][18]

2.5. This article is innovative

Existing research in the literature is more environmental regulation analyzes the direct effect of carbon emissions, and ignore other factors in environmental regulation on carbon productivity, and various factors in the influence mechanism, especially for the adjustment of industrial structure as one of the main influence object of environmental regulation, industrial structure in the influence of environmental regulation on carbon productivity plays a regulatory role. In this paper under the background of "Carbon peaking and Carbon neutrality goals" , based on the pilot to nationwide promotion of carbon emissions trading policy, explore the influence of environmental regulation, industrial structure on carbon productivity, using the 2006-2019 provincial panel data, using the double difference model policy evaluation, and the robustness test to ensure the effectiveness of the analysis results.

3. Model design

3.1. Hypothesize

Generally speaking, the government to achieve the purpose of reducing carbon emissions and protecting the environment has formulated corresponding environmental regulations. Therefore, the expected impact of environmental regulations on carbon emissions should be positive emission reduction, that is, environmental regulation will have an inhibitory effect on carbon emissions. According to the existing literature research, the impact of environmental regulation on carbon emissions can be understood from the perspectives of the demand side and the supply side of fossil energy. From the point of fossil energy supply side, limit the implementation of the policy measures of climate change, will lead to the phenomenon of fossil energy development accelerated, increase the supply of fossil energy, further lead to fossil energy prices lower, stimulate rising demand, thus accelerating the accumulation of greenhouse gases in the atmosphere, the consequences of environmental deterioration, namely the aforementioned "green paradox" concept. From the perspective of fossil energy demand, the

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government collects the carbon tax and energy tax to raise the cost of fossil energy producers and users, and at the same time to subsidize clean energy, thus forcing the demand for fossil energy to decline and reduce carbon dioxide emissions, that is, "forcing emission reduction".

The influence of environmental regulation on carbon emissions is restricted by many factors. According to the existing research, it is mainly divided into energy consumption structure, industrial structure, technological innovation and FDI. This paper focuses on the regulating factors of the impact of environmental regulations on carbon emissions on industrial structure. According to the existing research, it believes that strict environmental regulations can not only inhibit the development of pollution-intensive industries, but also facilitate the development of service industry and promote the upgrading of industrial structure, so as to reduce carbon emissions and improve carbon productivity. The reasons are analyzed: first, environmental regulation will increase the cost of pollution-intensive industries, making enterprises with high energy consumption and high carbon emission have to transform to seek the survival and development space; second, service industries are less affected by environmental regulation, and consumers prefer green products conducive to environmental protection. Under the strict environmental regulations, the service-oriented industry can have a better space for survival and development.

Based on the above analysis, this paper makes the following assumptions:

H1a: The effect of environmental regulation on carbon productivity is a positive promotion.

H1b: Industrial structure plays a regulatory role in the impact of environmental regulation on carbon productivity.

3.2. Research technique

This paper adopts DID dual difference model (Differences-in-Differences), by controlling the group difference between experiment and control group analysis policy effect, is an effective policy quantitative assessment research tools, and carbon emissions trading policy pilot promotion in batches, conform to the characteristics of "natural experiment", meet the application conditions of the dual difference model.

3.3. Sample selection

The seven pilot areas for carbon emission trading designated in 2011 include Beijing, Shanghai, Tianjin, Guangdong, Shenzhen, Hubei and Chongqing, All pilot carbon markets take direct and indirect emission sources as control targets, All covered such as electricity (thermal) force, steel (metallurgy), petrochemical, cement and other secondary industries in the high energy consumption, high emission industries, Greenhouse gas coverage varies widely across the pilot areas, The specific coverage is closely related to the level of economic development, industrial structure, energy consumption and emissions of the pilot areas, The inclusion thresholds are mainly based on regional energy consumption intensity reduction targets and carbon dioxide emission intensity reduction targets, And combined with the historical greenhouse gas emission data of enterprises and institutions.

This paper selected 31 provinces and cities as the research object (considering the availability of data, Hong Kong, Macao and Taiwan in China are not included in the scope of this study). The experimental group includes 7 provinces and cities including Beijing, Shanghai, Guangdong, because Shenzhen is located in Guangdong Province, the experimental group will include 6 provinces and cities; the control group includes other provinces and cities except Beijing, and considering the complete availability of the data, the control group does not include Tibet.

3.4. Data selection and source

This paper takes 30 provinces and cities as the research objects, and sets the year 2006-2019 as the research range. The required relevant data are from China Energy Statistics Yearbook,

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China Industrial Economic Statistics Yearbook and China Environmental Statistics Yearbook, and some of the data are from CSMR database and China's economic and social big data research platform.

3.5. Model construction and variable description

The model for the influence of environmental regulation and industrial structure on carbon productivity is as follows:

model I:

$$Carbon_{it} = \alpha_0 + \alpha_1 treated_{it} + \alpha_2 time_{it} + \alpha_3 did_{it} + \delta_{it} + \varepsilon_{it}.$$

model Ⅱ:

$$Carbon_{it} = \alpha_0 + \alpha_1 treated_{it} + \alpha_2 time_{it} + \alpha_3 did_{it} + \alpha_4 time * treated * \sec ondary\, industry + \delta_{it} + \varepsilon_{it}$$

model Ⅲ:

$$Carbon_{it} = \alpha_0 + \alpha_1 treated_{it} + \alpha_2 time_{it} + \alpha_3 did_{it} + \alpha_4 time * treated * \sec ondary\, industry_{it} + \alpha_5 controls_{it} + \delta_{it} + \varepsilon_{it}$$

Where, $Carbon_{it}$ is the carbon productivity, $treated_{it}$ is the grouping variable, 1 is the experimental group, 0 is the control group; $time_{it}$ is the time grouping variable, when 1 is after the policy impact (2011-2019), when 0 is before the policy impact (2006-2010); did_{it} is the interaction term of DID, that is, the net effect of the policy studied in this paper; $time * treated * \sec ondary\, industry_{it}$ is the three cross terms of industrial structure $\sec ondary\, industry_{it}$, $treated_{it}$ and $time_{it}$; $controls_{it}$ is the control variable; δ_{it} is the fixed effect of control; ε_{it} is the random disturbance term.

The specific variables are described as follows:

Table 1. Variable description

type of variable	Variable name	Variable description and calculation formula
explained variable	Carbon productivity (Carbon)	Total regional GDP / regional carbon dioxide emissions are (%)
explanatory variable	Policy effect of carbon emission right trading (d idit)	The interaction term representing sample and time; is "control group"; is "experimental group"; is, before the policy impact studied in this article; is after the policy impact studied in this article. $i=0$ $i=1$ $t=0$ $t=1$
regulated variable	Industrial Structure (secondary industry)	The output value of the secondary industry accounts for (%) of GDP
controlled variable （controls)	Population size (Resident population)	Permanent resident population at the end of the year (ten thousand people)
	R & D Funding (R & D expenditure)	R & D expenditure (RMB 100 million)

Interpreted variable: regional carbon productivity is selected to measure the carbon emission of the region, and the specific index is selected as carbon productivity = regional GDP (100 million yuan) / regional total carbon dioxide emission (100,000 tons) 100%.

Explanatory variable: did_{it} carbon emission trading policy effect is selected as explanatory variable to represent the interaction term between the sample and time; The value of i is 0 or 1, where $i=0$ is "control group" and $i=1$ is "experimental group"; The value of t is 0 or 1, and

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$t=0$ is before the influence of the policy studied in this paper; $t=1$ is after the policy impact studied in this paper.

Adjustment variable: The industrial structure is selected as the adjustment variable to play a regulating role between carbon productivity and policy effect. Considering that the secondary industry is mostly with high energy consumption affected by the carbon emission right trading policy, the specific index is selected as the proportion of the output value of the secondary industry in GDP (%).

Control variables: Population size and R & D funds are selected as control variables, and specific indicators are selected for permanent resident population (one million yuan at the end of the year) and R & D funds and R & D expenditure (100 million yuan).

4. Empirical analysis

4.1. Descriptive statistics

Descriptive statistics results after sample assignment are shown in Table 2 and Table 3:

Table 2.Descriptive statistical results of the control group data

Variable name	number of variates	mean	standard error	least value	crest value
GDP(100 million)	336	18058.68	16676.38	585.15	99631.52
Permanent resident population at the end of the year (one million)	336	4504.735	2634.269	548	10106
R & D expenditure (RMB 100 million)	336	298.0505	411.6118	2.1044	2779.517
The output value of the secondary industry accounts for (%) of GDP	336	44.10671	8.436858	20.7	62
Total carbon dioxide emissions (10,000 tons)	336	40546.8	28902.36	2428.628	149307

Table 3. Descriptive statistics of the experimental group data

Variable name	number of variates	mean	standard error	least value	crest value
GDP(100 million)	84	25100.38	21822.21	3226.47	107986.9
Permanent resident population at the end of the year (one million)	84	4472.592	3239.287	1601	12489
R & D expenditure (RMB 100 million)	84	680.2596	666.3474	36.914	3098.489
The output value of the secondary industry accounts for (%) of GDP	84	40.24768	10.65216	16	53.4
Total carbon dioxide emissions (10,000 tons)	84	28564.31	16209.65	9834.204	71499.16

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As can be seen from the above two tables, Differences in the descriptive statistics of the indicators between the control and experimental groups, The mean and standard deviation of the gross regional product (GDP) and R & D expenditure of the control group were smaller than the corresponding values of the experimental group, In the control group, the average values of the permanent resident population index, the proportion of the output value of the secondary industry in GDP and the total carbon dioxide emissions were higher than the corresponding values of the experimental group, The reason may be that the experimental groups of carbon emission trading policy are mostly first-tier cities or more economically developed cities, The corresponding gross domestic product (GDP) and R & D expenditure are higher than the control region, And the experimental group area has a better industrial structure, The low proportion of the secondary industry, And even less carbon dioxide emissions, The statistical results are also more in line with policy expectations.

4.2. Benchmark regression analysis

In this paper, benchmark regression analysis with DID model, all models adopt fixed effects, among them, did not add other influencing factors in the model I, the model on the basis of the model I introduced industry adjustment variables, model on the basis of the model introduced the population size and R & D funds as a control variable, the regression results are as follows:

Table 4.DID regression results

	Carbon productivity (I)	Carbon productivity of (Ⅱ)	Carbon productivity of (Ⅲ)
time	0.208*** (11.00)	0.208*** (12.84)	0.126*** (7.98)
treated	0.000 (.)	0.000 (.)	0.000 (.)
did	0.303*** (7.18)	1.569*** (13.45)	1.190*** (11.21)
time *treated *secondary industry		-0.032*** (-11.42)	-0.025*** (-9.93)
R&D			0.000*** (10.34)
population size			-0.000 (-0.50)
cons	0.353*** (26.64)	0.353*** (31.09)	0.341*** (3.93)
N	390	390	390
R 2_a	0.412	0.568	0.680

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

From model I, model and model can be seen that carbon emission trading policy has a significant role in promoting carbon productivity, such as in Table 4 model I did_{it} coefficient 0.303 (p <0.01), did_{it} coefficient 1.569 (p <0.01) and did_{it} coefficient 1.190 (p <0.01), we can see that the study of carbon emission trading policy on carbon productivity is significant, and is positive promotion, the conclusion meets the proposed hypothesis H1a:: environmental regulation on carbon productivity for positive promotion.

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It can be seen from the model and the model that it has a significant regulatory role in the industrial structure (the proportion of secondary industry output value to GDP) and the influence of carbon emission right trading policy on carbon productivity. For example, the $time*treated*secondary\ industry_{it}$ coefficient of the three interaction items in Table 4 is-0.032 (p <0.01), and the $time*treated*secondary\ industry_{it}$ coefficient of the three interaction items in the model is-0.025 (p <0.01). Combined with the did_{it} coefficient in the model, the industrial structure studied in this paper has a significant negative effect on carbon productivity under the carbon emission trading policy. This conclusion conforms to the previous hypothesis that H1b: industrial structure plays a regulatory role in the influence of environmental regulation on carbon productivity, and further concluded that the industrial structure plays a negative role in the influence of environmental regulation on carbon productivity.

The model is based on the model of the introduction of the population size and R & D expenditure, the did_{it} coefficient is significant but significantly decreased, in addition to R 2_a model (0.680), the model (0.568) and model I (0.412) are improved, indicating that the model of fit is higher, join the control variables have a better interpretation of the model. Model R & D spending coefficient is small but the numerical performance has a significant effect on carbon productivity, compared by the model and model, the regression results to a certain extent overestimated the carbon emissions trading policy on carbon productivity, more in line with the objective facts of control variables to weaken the carbon emissions trading policy on carbon productivity.

4.3. Robustness test

4.3.1. 4.3.1 Parallel trend test

The parallel trend is assumed to be a prerequisite for the use of DID, and the DID model can be used for regression analysis only when the target variables of the treatment and control groups meet the parallel trend hypothesis before the policy occurs. On the other hand, if there is some difference between the treatment group and the control group in advance, then the results made with DID will no longer represent the net effect of the policy, and it is highly likely that other factors will affect the change of carbon productivity of the explained variable. In this paper, the model is tested with parallel trends to ensure the regression results of the DID model:

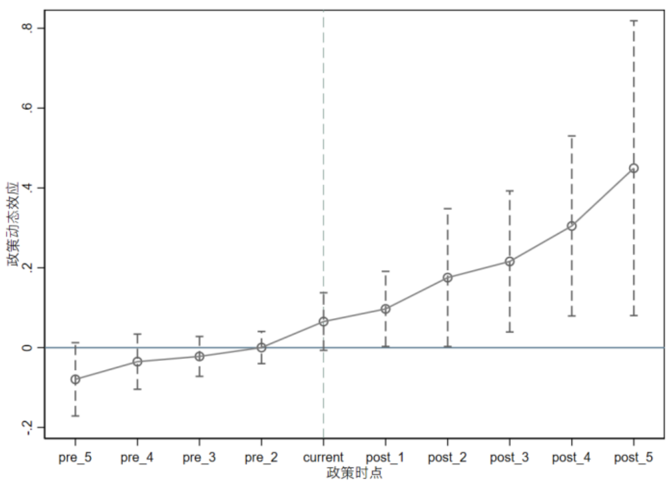

Figure 1. Parallel trend test chart

As shown in Figure 1, Before the implementation of the policy in 2011, The 95% confidence interval of the regression coefficient of carbon emission rights trading policies in almost all years includes the value 0, It can be considered that the impact of carbon emission right trading policy on carbon productivity is insignificant; After the policy was made in 2011, The 95%

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confidence interval of the regression coefficient of the carbon emission right trading policy in most years includes the value 0, The impact of carbon emission trading policy on carbon productivity is considered significant, Among them, the first period after the policy and the second period after the policy can be considered as some slightly insignificant, The reason is that the carbon emission trading policy is slightly different in the pilot areas, The policy was officially implemented in various pilot areas in 2013, Policy effects can be considered to have a slight time lag. In conclusion, it can be concluded that there is no significant difference between the treatment groups and the control groups before the implementation of the carbon emission right trading policy, and the DID model meets the parallel trend test.

4.3.2. 4.3.2 The placebo test

To further examine whether some very important variables or random influencing factors are missed in the DID model, the model will be tested for placebo in this paper. Can take methods to build virtual processing group or virtual policy time regression, if the estimate of regression results, as the benchmark model is significant, then shows that the benchmark model regression results is likely to be inaccurate, there are certain, deviation, can be interpreted as perhaps other policy or random factors affect the explained variable carbon productivity changes. This paper adopts building false processing group to placebo test, specific practice is as follows: randomly selected one percent of the provinces and cities as false experiment group, the rest of the not selected provinces and cities as false control group, using false experiment group and false control group DID regression, and repeat 400 times, draw the regression coefficient of probability distribution is as follows:

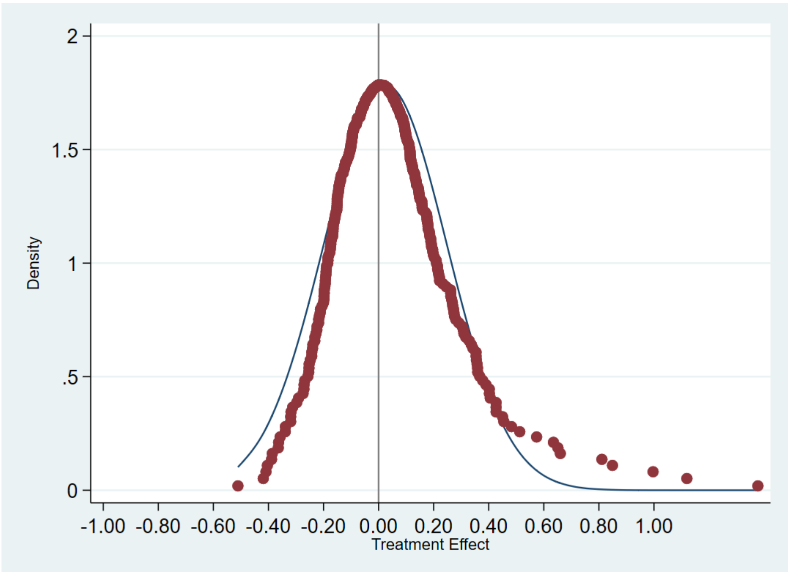

Figure 2. Placebo test chart

According to the analysis of the results of the placebo test, if the regression coefficient of the false policy is evenly distributed around the value 0, it indicates that the DID model does not omit important relevant variables or the immediate influencing factors, thus indicating that the regression results of the DID model are robust; otherwise, if the regression coefficient of the false policy is not evenly distributed around the value 0, it indicates that the DID model is missing important relevant variables or immediately influencing factors, thus indicating that the regression results of the DID model are not robust. The results of the placebo test of the DID model in this paper are shown in Figure 2. The regression coefficient of the false policy is evenly distributed around the value 0, indicating that the DID model does not omit important relevant variables or immediate influencing factors in this paper, and the regression results are robust.

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4.4. Two-fold differential model for propensity score matching: the PSM-DID model

In order to solve the problem of selection bias and non-randomization experiment, that is, the selection is not random and cannot reflect the characteristics of the whole, thus bias the estimator, the double difference model of propensity score matching (PSM-DID model) is introduced to test the effect of carbon emission trading policy on carbon productivity when the data characteristics and trends of the experimental group and the control group are basically the same. This paper uses Logit model and 1:1 matching method to make propensity score matching. Control variables in the regression of the benchmark DID model were selected as covariates to estimate propensity scores, and then perform propensity estimation score matching. In the process of matching, in order to improve the quality of matching, only individuals with overlapping propensity scores will be retained, and some sample size will be lost, which gives the common value range of propensity scores in Figure 3 below, and Figure 4 and Figure 5 show the nuclear density distribution map of experimental and control groups before and after propensity scores matching.

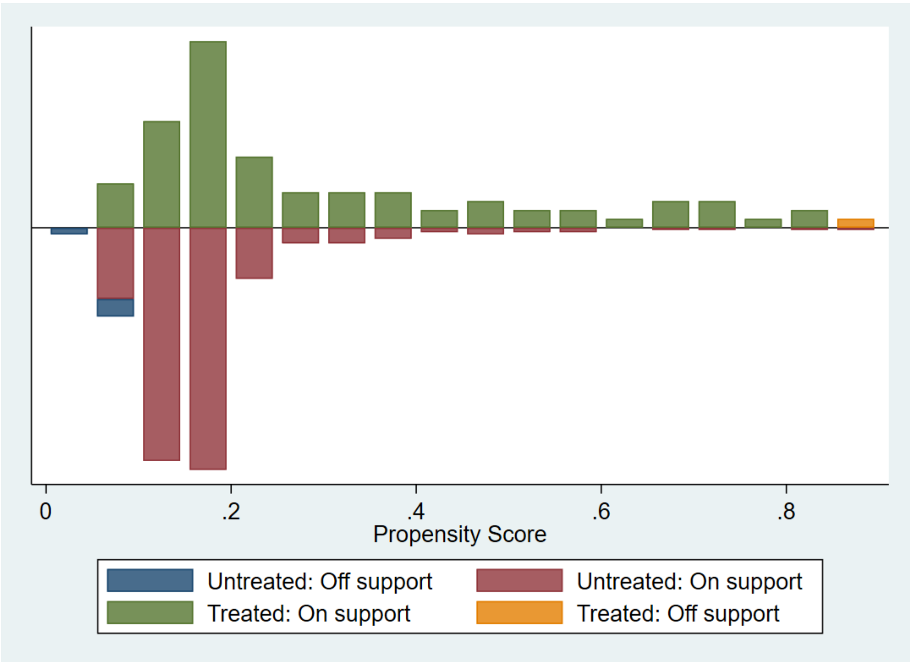

Figure 3.Range of common values for the propensity score

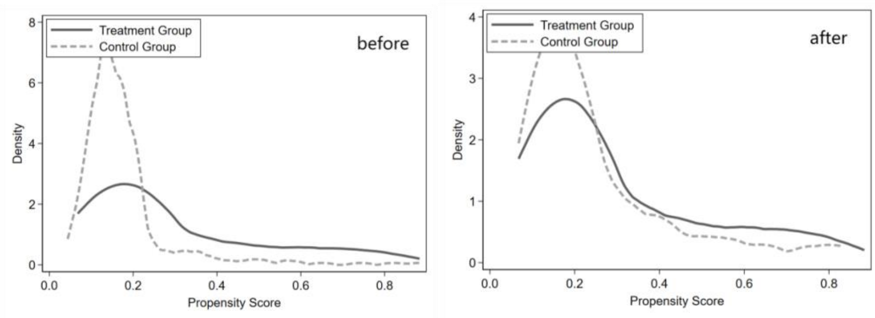

Figure 4. Nuclear density maps before and after propensity matching

As can be observed from Figure 3, after propensity score matching, most of the observed values are included in the common value range (i. e. on support), and only a small number of samples

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are lost, consistent with the assumption test of common support. As can be observed from Figure 4, the gap in nuclear density distribution between the experimental and control groups decreased significantly after performing propensity matching, indicating the effectiveness of the propensity score matching method adopted in this paper.

After propensity matching score and effectiveness test, after matching PSM-DID regression, all models adopt fixed effects, among them, did not add other influencing factors in the model I, model I model on the basis of the industry mechanism adjustment variables, on the basis of the model introduced the population size and R & D funds as a control variable, the regression results as shown in table 5:

Table 5. PSM-DID regression results

	Carbon productivity (I)	Carbon productivity of (Ⅱ)	Carbon productivity of (Ⅲ)
time	0.197*** (10.84)	0.197*** (12.43)	0.123*** (8.05)
treated	0.000 (.)	0.000 (.)	0.000 (.)
did	0.289*** (7.28)	1.421*** (12.51)	1.089*** (10.58)
t ime *treated *secondary industry		-0.028*** (-10.47)	-0.022*** (-9.24)
R&D			0.000*** (9.87)
population size			-0.000 (-0.13)
cons	0.357*** (27.96)	0.358*** (32.13)	0.315*** (3.92)
N	378	378	378
R 2_a	0.423	0.561	0.672

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

As can be seen from Table 5, in the matching PSM-DID regression, the model, the regression coefficient is significant and positive, indicating that the influence of the carbon emission trading policy on carbon productivity is significantly positive, which is the same as the regression results of the benchmark DID model in Table 4. The triple interaction term $time * treated * secondary\ industry_{it}$ coefficient of the industrial structure as the adjustment variable is significantly negative, which shows that the industrial structure plays a significant negative role in regulating the influence of carbon emission right trading policy on carbon productivity, which is also consistent with the previous results of the benchmark DID model regression. Because this paper is in the DID model of adjusting variables and control variables, so this paper focuses on the model, it can be seen, carbon emission trading policy of carbon productivity model also has a positive effect on carbon productivity, industrial structure plays a significant negative role in the influence of carbon emission trading policy on carbon productivity, add R & D expenditure and population size as the control variables, the R & D spending coefficient is small but positive, indicating that R & D spending also has a significant effect on carbon productivity. Moreover, the regression results of the PSM-DID model in Table 5 and the benchmark DID model in Table 4 show that the regression results of the PSM-DID model in

Table 5 are slightly lower than the corresponding regression results of the DID model in Table 4. The PSM-DID regression results after the matching show that the regression results of the benchmark DID model are robust, and the benchmark DID model overestimated the effect of carbon emission right trading policy on carbon productivity compared with the PSM-DID model.

5. Conclusion and suggestion

5.1. Conclusion Analysis

Under the background of dual carbon, China's carbon emission trading market was officially launched nationwide in 2021, and the impact of environmental regulation on carbon emission is increasingly apparent. The carbon emission quota policy will be piloted in batches, which is in line with the characteristics of "natural experiment" and the conditions of DID natural experiment. Based on the carbon emission trading policy, this paper adopts the DID dual difference method to make an empirical analysis on the role of industrial structure on the effect of environmental regulation on carbon productivity. From the point of policy expectations, carbon emissions trading policy for our country industrial structure optimization adjustment will have certain influence, this paper selects the index of industrial structure for the second industry output accounted for the proportion of GDP, and carbon emissions trading policy by the pilot industry for electricity, such as iron and steel, and carbon emissions trading policy will further affect the carbon productivity. Therefore, the DID model to evaluate the influence of the carbon emission trading policy on carbon productivity, and the industrial structure as a regulatory variable, the industrial structure plays a regulatory role in the influence of environmental regulation on carbon productivity, the robustness of DID model by parallel trend test, placebo test and PSM-DID model regression. The following conclusions are drawn: the previously proposed hypothesis H1a is established, that is, the carbon emission trading policy has a significant positive effect on carbon productivity, and is robust and effective; the previously proposed hypothesis H1b is established, and further concluded that the industrial structure has a significant negative adjustment effect on carbon productivity under the carbon emission trading policy, and is robust and effective.

5.2. Research limitations and perspectives

The study of this paper has certain limitations, first of all, the implementation of carbon emission trading policy pilot area is not completely unified in 2011, regional policy implementation between time successively, such as the actual implementation of the first round of pilot in 2013, so this paper only consider 2011 for all experimental group policy implementation year is not completely practical, can be used in the study of multi-stage DID, considering the actual implementation year of the pilot policy, build a better regression model for further analysis. Second, our country in the electric power, steel and other second industry take environmental regulation for carbon quota policy, namely the government will according to the total carbon emissions through certain calculation method of carbon emissions quotas allocated to the enterprise, the carbon trading market remaining quota or unfinished quota trading, this will inevitably lead to carbon emissions trading policy has a certain lag, this can be seen from parallel trend inspection, subsequent lag can be considered in the model for further analysis and research. In addition, this paper only considers the regulatory role of industrial structure in the impact on carbon productivity under the carbon emission trading policy, and does not test the selection of regulatory variables, and does not analyze and confirm whether other factors have regulatory effects, so more stricter analysis of the selection of regulatory variables in subsequent studies.

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5.3. Policy enlightenment

Carbon peak, carbon neutral requirements nationwide the effective configuration of carbon emissions, in this context, the implementation of carbon emissions trading policy is a long-term trend, so can not only pay attention to an industry of carbon emissions, should consider the whole industry of carbon peak, carbon neutral, in policy should avoid "pollution shelter" problem, avoid due to the severity of environmental regulation pollution to a certain area or a certain industry. Of course, while promoting carbon emission reduction, we should also pay attention to the impact of the policies adopted on enterprises, whether it will cause some negative effects on enterprises, such as increasing the emission reduction cost of enterprises, so that the originally planned for research and development investment and other funds are occupied by emission reduction funds, which is not conducive to the development of enterprises themselves. In addition, China's carbon emission trading market is still in the early stage of construction, and the awareness of carbon emission reduction of industrial enterprises may be weak. Therefore, we can increase the guidance of green transformation of industrial enterprises, improve the participation of enterprises, actively participate in the implementation of carbon emission trading policy, and build a green and sustainable development environment.

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