The impact of carbon emission trading system on energy intensity

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Abstract. From 2008 to 2019, the panel data of 30 provinces and cities in China were selected to study the impact of carbon emission trading system on energy intensity using a two-way fixed-effect dual-difference model. The research shows that the carbon emission trading system is beneficial to the reduction of energy intensity, and the degree of reduction is 4.65%. In addition, the level of technological innovation, economic development, energy structure, urbanization, expenditure on energy conservation and environmental protection and energy price can inhibit the impact of energy intensity, while the increase of energy consumption and the total population can bring about the improvement of energy intensity. Therefore, in order to improve the efficiency of energy utilization and achieve green development, it is necessary to promote the reform of market mechanism, enhance the marketization level of all regions, and establish a unified national carbon emission rights trading market.

Keywords: carbon emission trading system, Energy intensity, Double difference.

1. The introduction and literature review

Since reform and opening up, prosperity in China's economic development, industrialization, increasing demand for energy consumption in the process of urbanization, but also exposed the traditional pattern of industrial growth brought about by the increasing energy consumption level, low energy efficiency problems such as difficult to adapt to the needs of the development of economy, high quality, Therefore, it is urgent to reduce energy intensity to promote industrial green transformation. In September 2020, China clearly put forward the goal of "carbon peak" in 2030 and "carbon neutrality" in 2060.In October 2011, the National Development and Reform Commission issued the Notice on Carrying out the Pilot Work of Carbon Emission Trading, and approved seven provinces and cities, including Beijing, Shanghai, Tianjin, Chongqing, Hubei, Guangdong and Shenzhen, to carry out the pilot work of carbon trading. China's efforts to save energy and cut emissions are getting tougher. This paper analyzes the relationship between the pilot system of carbon emission trading and energy intensity, which will contribute to the formulation of energy efficiency policies, which can balance the contradiction between economic development and energy consumption to a certain extent.

In the research field of carbon emission trading system, there are a large number of literatures concerned about the impact on carbon emission reduction effect and carbon intensity, and the system has a positive effect on the reduction of carbon dioxide emissions. Such as chuan-ming liu [1] by using Chinese provincial panel data and USES the synthesis control effect to reduce emissions of carbon trading pilot, found pilot carbon emissions trading policy can reduce carbon dioxide emissions, but because of the economic development, industrial structure, as well as differences, lead to the heterogeneity of carbon reduction effect of pilot provinces epistle Zhiguo [2] found that carbon trading pilot policies could not only play an effective role in curbing carbon emissions in pilot areas, but also restrain carbon emissions in neighboring areas through policy spillover effects. At the same time, the emission reduction effect has a long cycle, and the direct emission reduction effect is much stronger than the indirect emission reduction effect. Technological progress will become the key to the effective development of the potential emission reduction effect of carbon trading policies. Wang Huiying [3] pilot carbon emission trading policies have effectively promoted carbon emission reduction in pilot areas, but their role in promoting economic development is not significant. And further through the mediation effect test analysis, the policy through the total energy consumption and change of energy consumption structure to achieve carbon emission reduction. Fan Dan [4] from the perspective of both for the environment economic dividends and bonus inspection mechanism of carbon emission trading right pilot in China whether can promote the transformation of low carbon economy in our country, found the means to reduce emissions compared with other provinces pilot province lack of flexibility, policy to a certain extent, reduce carbon emissions, but did not improve the industrial total factor productivity of pilot provinces.

Other studies on carbon emission trading system include industrial structure upgrading and transformation, total factor energy efficiency, and technological innovation level.Liu Hewang [5] considered the incentive environmental regulation from the perspective of interpretation, and found that the carbon emission trading pilot system forced the transformation and upgrading of Chinese enterprises, and the transmission mechanism affected the transformation and upgrading of enterprises through the path of technological innovation. Moreover, the impact of carbon emission trading pilot on different types and different regions of enterprises is heterogeneous. Sun Zhenqing [6] used PSM-DID model to study the impact of carbon emission trading policies on carbon emissions and carbon emission intensity, and found that the policies could promote coordinated emission reduction in pilot and non-pilot areas. Carbon trading policy has a positive promotion effect on the upgrading of industrial structure, and the effect on the improvement of technological innovation efficiency is relatively obvious, but the effect on the rationalization of industrial structure is not obvious. Therefore, carbon emission reduction is mainly achieved through the upgrading of industrial structure and technological innovation. Ong Jingrong[7] divided environmental regulation into command type, cost type and investment type, and government support behavior into R&D subsidy and low-carbon subsidy. Three different environmental regulation tools and two kinds of government support behaviors were included in the analysis framework. It is found that the effect of command-type regulation and investment-type regulation on green technology innovation shows an inverted U-shaped curve.

Among the influencing factors of energy intensity, technological innovation, energy price, industrial structure, urbanization economic development level and so on. Sun Keliza[8] studied the influence of technological progress of enterprise R&D investment, foreign direct investment and environmental regulation on energy intensity, and found that R&D investment and foreign direct investment had brought about remarkable neutral technological progress and factor saving, which both contributed significantly to the decline of energy intensity. Hang Rui[9] established an econometric model to analyze the influence of energy grid and economic growth on various factors of energy intensity change. The rise of energy prices in China can drive the decline of energy intensity through the share of technological progress effect, economic restructuring or the change of energy consumption structure. And by comparison with OECD and Latin America, China has the strongest share of energy-price-driven technological progress.

Wang Fuzhong[10] found by generalized least squares (GLS) regression that the coefficient of energy price on energy intensity was significantly negative, that is, it had an inhibitory effect, but the lag period was not significant. It shows that the energy price mechanism is effective, and price, as a key factor, can play a due role in regulating energy intensity. I Biao[11] four estimation method of use: FE, IV - FE, IV and GMM and MG, the results show that although in the short term, the urbanization can significantly reduce energy intensity, but because of China's urbanization development path and there is no continue to play its advantage in the aspect of intensive utilization of energy, so that the long-term effects of urbanization on energy intensity is positive. Hang Rui [12] established a dynamic panel data model and found that there is a long-term equilibrium relationship between energy intensity, income, industrialization and urbanization, and urbanization has a significant positive impact on energy intensity. Therefore, it is necessary to pay attention to the internal quality construction of urbanization.

Above all, found that the reduction effect, the study of carbon emissions trading system widely, and there is blank in the field of energy intensity, in order to adapt to save resources to speed up the transformation of energy structure, improve the efficiency of resource utilization, this article explores the carbon emissions trading system market-based environmental regulation can play a role in the field of reducing energy intensity.

2. Construction of Empirical Model

Since the panel data from 2008 to 2019 are selected in this paper, it is an important issue whether the fixed effect model or the random effect model should be used. To this end, it is necessary to test the null hypothesis that the error term is uncorrelated with the individual fixed effects as explanatory variables, that is, "H0: μit is uncorrelated with Xit and εit" (the random effects model is the correct model). If the null hypothesis is true, a random effect model is established; if the null hypothesis is not true, a fixed effect model is established.

Table1. Hausman test

	Statistical magnitude	P value
Hausman test	118. 93	0. 0001

According to the test results, the statistic of Hausman test is 118. 93, and the null hypothesis should be rejected through the 5% confidence interval level, that is, it is considered that the study of carbon emission trading system and energy intensity tends to consider adding individual fixed effects into the model. In addition, from the perspective of before and after the implementation of carbon trading policy, the annual macroeconomic growth trend is contained in the characteristics of the year. In summary, two-way fixed effect model was selected in the re-fixed effect model in this paper, including year fixed effect and individual fixed effect.

Furthermore, this paper regards carbon trading policy as a quasi-natural experiment, and establishes a two-way fixed effect difference-difference model to analyze the impact of carbon emission trading system on energy intensity:

$$Eit=\beta0+ \beta1D\_it +\beta2\ Xit+\lambda it+\mu it+\varepsilon it$$

λ_{it} is a time-point fixed effect, μ_{it} is an individual fixed effect, and D_{it}=post*treat, D_{it} is a policy dummy variable. If a city or city implements carbon emission trading policy in year t, then the policy dummy variable D_{it}=1,Otherwise, the value is 0. E_{it} is the energy intensity of each province, X_{it} is the control variable, technological innovation, energy consumption, economic development level, industrial structure, foreign direct investment, energy structure, fixed asset investment, urbanization level, energy conservation and environmental protection intensity, and green credit level.

3. Data Sources and Processing

The research data in this chapter are panel data of 30 provinces from 2008 to 2019. In 2011, China announced plans to set up carbon emission trading markets in seven pilot regions. The pilot areas of the carbon emission trading system include Beijing, Shanghai, Guangdong, Shenzhen, Hubei and Chongqing. As the carbon emission trading system was introduced in different provinces at different times, Beijing, Tianjin, Shanghai and Guangdong provinces started the pilot operation at the end of 2013, and each pilot area started carbon emission trading successively in that year, resulting in trading volume. Chongqing and Hubei started in the first half of 2014. Therefore, the unified time dummy variable in this paper is 2014 to investigate the effect of carbon emission trading pilot policies before and after the official implementation of the policy in 2014.

At the same time, for the sake of data integrity, the sample data of Tibet Autonomous Region, Hong Kong, Macao Special Administrative Region and Taiwan were not included in the study of China, and Shenzhen was incorporated into Guangdong Province to analyze the pilot areas in six provinces. The main economic data come from China Industrial Economy Statistical Yearbook, China Energy Statistical Yearbook, China Science and Technology Statistical Yearbook and the statistical yearbooks of each province. See Table 2 for a detailed description：

Table2 Variables and Expressions

Variable categories	symbol	metrics
Explained variable	EIit	Total energy consumption/total industrial output
Core explanatory variable	D_it=treat*post	For the pilot areas in 2014 and later, it is 1, and the rest are assigned a value of 0
Control variables	perencon	Total energy consumption/total population
	pergdp	Gross Domestic product/total population
	structure	Value added of secondary industry/Gross Domestic product
	fdi	Actual utilized foreign investment is taken as logarithm
	energystructure	Coal consumption/total energy consumption
	capital	Total investment in fixed assets
	urb	Population of the town/total population of the area
	protection	Energy conservation and environmental protection/total industrial output
	energyprice	Fuel, power class purchase price index
	rate	Interest expenditure of six energy-intensive industries/total interest expenditure of industrial industries
	innovation	Take the logarithm of the R&D expenditure level
	constantman	total population

4. Analysis of empirical results

The carbon emission trading pilot launched in 2014 in China was used as a quasi-natural experiment. Panel data from 30 provincial levels from 2008 to 2019 were used as research samples to construct a two-way fixed-effect difference model to empirically study the impact of carbon emission trading on energy intensity. The experimental group included Beijing, Guangdong (Shenzhen merged), Tianjin, Shanghai, Hubei and Chongqing, and the control group included other provinces and autonomous regions in mainland China. The model expression is as follows: $Eit=\beta 0+\beta 1D_{\_it}+\beta 2X_{it}+\mu_{it}+\varepsilon_{it}$

where D_it is the product of the grouped dummy variable and the time dummy variable, and its coefficient β1 measures the net effect of policy implementation where the grouped dummy variable is 1 for the experimental group and 0 for the control group;The time dummy variable, taking 2014 as the year of policy implementation, takes the value as 0 before policy implementation and 1 after policy implementation, and ε it is a random error term. The empirical results are as follows:

Table3 Regression results

Variable	(1) EIit	(2) EIit	(3) EIit
D_it	0. 9070		-0. 0464875**
innovation		-0. 0245***	-0. 0249***
perencon		0. 2437***	0. 2436***
Pergdp		-0. 0446*	-0. 0415*
constantman		1. 2495***	1. 3552***
Structure		-0. 0902	-0. 0606
fdi		0. 0160	0. 0168
energystructure		-0. 2940*	-0. 3116*
capital		0. 0071	0. 0077

urb		-0. 7312***	-0. 8146***
Protect		-0. 1088***	-0. 1033***
price		-0. 2614**	-0. 2639**
rate		-0. 3181**	-0. 3746***
Time fixed effect	control	control	control
Individual fixed effects	control	control	control
N	360	360	360
R^2	0. 6357	0. 8320	0. 9261

It can be seen from the empirical results that the coefficient of the interaction term is positive when the control variables are not added, and the conclusion that the truth is hidden is obtained when the interference variables of the experiment are not controlled. However, with the addition of control variables, the confidence level of 5% indicates that the carbon emission trading system has a significant impact on the inhibition of energy intensity. At the same time, technological innovation, economic development level, improvement of energy structure, improvement of urbanization level, energy price and green credit level through the 10% significance level, indicating that these variables also have a positive impact on the reduction of energy intensity, and the increase of energy consumption and resident population significantly improves energy intensity. In addition, the industrial structure does not pass the significance level, but the negative coefficient is in line with the expectation, indicating that the improvement of the industrial structure level can reduce the energy intensity. The sources of foreign direct investment are mainly in the fields with high energy consumption and high pollution. According to the theory of "pollution paradise", it can bring about the increase of energy intensity. Fixed asset investment also drives the demand for energy-intensive products, which will lead to an increase in energy intensity. But if the investment is focused on high-tech industries, it will help improve energy efficiency and energy intensity will decrease. Therefore, the reason why the coefficient is negative is that the fixed asset investment is more focused on the field of high energy consumption products.

5. Robustness test

5.1 Parallel trend test

In this paper, the policy effect of carbon emission trading system on energy intensity is explored by using the method of differential, an unnatural experiment. The problem to be considered is that if there is a certain difference between the treatment group and the control group before the occurrence of the policy, then the result made by DID can no longer represent the net effect of the policy, and there may be other factors that affect the change of our explained variables. Therefore, in order to test the applicability of the differential method in this paper, it is necessary to verify whether the Settings of the treatment group and the control group meet the parallel trend hypothesis before conducting the differential method. Since it is too rough to simply compare the regional consistency of the parallel trend chart of energy intensity between the treatment group and the control group before and after the implementation of the policy, this paper chooses the event study method for analysis due to the consideration of accuracy. If the reduction of energy intensity before the implementation of carbon emission trading policy is not significant, it indicates that there is a common trend between pilot and non-pilot provinces before the implementation of the policy. It is only convincing if the reduction effect after the policy occurs is significant. This paper selects five years before and after the implementation of the pilot policy to conduct parallel trend tests, and the results are as follows:

Table4 Parallel trend test

point	coefficient	P value
Before_2	-0. 0140	0. 533
Before_1	-0. 0041	0. 816
Current	-0. 0117	0. 160
After_1	-0. 0553**	0. 024
After_2	-0. 0809***	0. 012
After_3	-0. 0866***	0. 005

According to the results of the parallel trend test, it was found that there was no difference between the experimental group and the control group before 2014, but there was a significant difference in the year after the implementation of the policy in 2014, which passed the hypothesis of the parallel trend test.

5.2 Placebo test

Although this paper added control variables and controlled region and time effects to the baseline regression to avoid the interference caused by omitted variables, there may still be unobserved factors. To this end, the placebo effect was used for testing. Six provinces and cities were randomly selected as the treatment group, and the remaining provinces and cities were used as the control group to conduct differential regression. The whole sampling process was repeated for 2000 times, and the kernel density map of regression coefficients was drawn (see Figure 1). The dotted line in the figure is the coefficient size of the core explanatory variable in the benchmark regression. It can be seen that most regression coefficients are concentrated on both sides of 0, and there is a significant difference with the magnitude of the benchmark regression coefficient. It shows that the baseline regression conclusion is not caused by other unobservable factors, which verifies the robustness of the baseline regression conclusion.

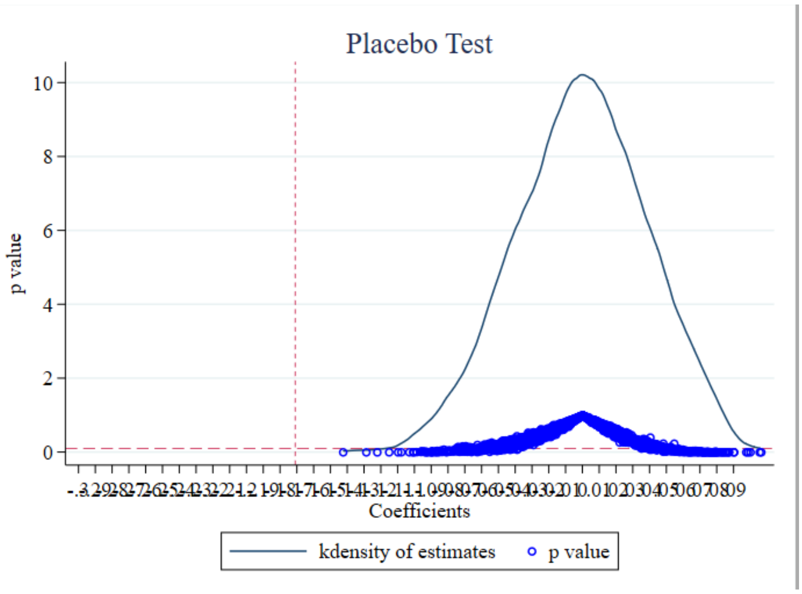

Figure 1 Placebo test

6. Conclusion and suggestions

In recent years, China is faced with the dual challenges of economic growth decline and environmental pollution. The key to solve this problem is to develop green economy and improve energy efficiency. With the continuous economic development, China has encountered structural problems such as overcapacity, resource waste and environmental pollution, and has been seeking to get rid of the extensive development model. However, to achieve the development goal of "not only gold and silver mountains, but also clear water and green mountains", we need to constantly explore effective mechanisms and institutions. Under the constraint of controlling the total carbon emissions, the carbon emission trading system based on the market mechanism regulates the carbon emissions of relevant subjects through the market mechanism, which can effectively allocate resources, promote the social economy to improve the quality and efficiency, and promote green and low-carbon development. Therefore, in this paper, by constructing bidirectional fixed effects of double difference model, get the carbon emissions trading system has inhibition effects on energy intensity, which is in parallel trend under the premise of hypothesis test, the placebo inspection have been the important conclusion, that the market incentive mechanism may bring economic effect and mitigation effect of double benefit.

Based on the research conclusion, the following policy suggestions are put forward to promote the construction of carbon emission trading market and reduce energy intensity:

We will continue to deepen the development of the carbon emission trading market, advance the reform of the market mechanism, improve the market level of all regions, and establish a unified national carbon emission trading market. Carbon emissions trading in 2013 pilot is to establish a unified national carbon emissions trading market of laboratories, the current pilot policy can bring the double benefit of economy and environment, if find a feasible path, relying on the Internet platform to establish a unified national carbon emissions trading market, radiation throughout the country will benefit, with a wider range of dual advantage.

Due to China's vast territory, resource endowment, economic development level, industrial structure and energy structure vary from region to region, and development priorities and goals vary from region to region. Quotas should be specified in accordance with local conditions and actual conditions. The right to development of different regions and different enterprises will be guaranteed. To advocate enterprises, especially those with high energy consumption, to actively integrate into the carbon emission rights trading market can correspondingly increase the construction of relevant training, consultation and third-party certification institutions, provide convenient and authoritative training, consultation and certification reports for all trading subjects, so as to improve energy utilization efficiency and increase the benefits of green economy.

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