Do Carbon Trading Policies Reduce Industrial Carbon Emissions? ——Evidence from China's Pilot ETS

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ABSTRACT

Given the trend toward increased globalization of climate governance, there is an increasing focus on achieving sustainable development through economic growth and low-carbon transition for China. Given that China is the world's biggest carbon emitter, the country must meet the challenge of addressing its international emission reduction targets while facilitating domestic industrial green transition. The industrial sector represents the major contributor of carbon emissions at the national level, implying that low-carbon transition of the industrial sector is essential for reaching dual carbon strategy objectives. The carbon emission trading scheme (ETS) represents a widely used market-based environmental regulation mechanism that has been piloted in various Chinese regions since 2013. After several years of policy experimentations, it becomes necessary to examine the actual impact of ETS policies on industrial decarbonization and their regional differentiation performance. By using balanced panel data of 30 Chinese provinces from 2010 to 2023, the present study uses the DID approach in multiple periods to estimate the impact of ETS pilot policy on the carbon emission intensity of industry. The empirical results show that ETS significantly decreases the carbon emission intensity of industry in pilot provinces, with distinct time-lag effect and accumulation effect. The policy dividend becomes gradually evident in the medium term and becomes even more powerful when market mechanism matures. Distinct heterogeneity effects are found between different regions and institutional environments. In particular, provinces located in the east and with stronger environmental governance capacity have better emission performance under ETS, whereas there is no significant effect of policy in the western region.

Keywords: Carbon Emissions Trading; Industrial Carbon Emission Intensity; Multi-period Difference-in-Differences; Regional Heterogeneity

1. INTRODUCTION

The problem of climate change has changed from being an environmental concern for the future to a concrete problem affecting the economic growth of China today. Since China is the largest emitter of carbon in the entire globe, it needs to reconcile two primary objectives of its development process, namely economic growth and mitigation.

To cope with climate change, China put forward its "dual-carbon" targets in 2020 to achieve carbon peak before 2030 and carbon neutralization before 2060. This long-term target is a sign of transition from the traditional way of regulating environment to low-carbon development. Since industries contribute to over 70% of carbon emission in China [1], it is inevitable for China to push for the decarbonization of industries.

One of the mainstream market-based regulatory instruments for environmental protection is Emission Trading System (ETS). As compared to the administrative regulation of pollution, carbon trading can bring down the total cost of emissions control due to the provision of clear carbon prices in the market. Through allocating emission quotas that can be traded among regulated companies, the program encourages them to independently optimize their production and reduce excess emissions.

The development process of China's carbon trading program takes the general pattern from pilot to full-scale promotion. The first ETS pilots were established in seven provincial areas, such as Beijing, Shanghai, and Guangdong in 2011 under the National Development and Reform Commission, and trading activities started in 2013–2014[2]. After almost a decade of trial experience, China introduced the nationwide carbon trading program in July 2021, which is now the largest carbon trading market in the world in terms of emission coverage.

Unlike the absolute cap-and-trade system adopted in the carbon market of the European Union, the pilot carbon markets in China tend to use the performance standard rule based on intensity of carbon emissions in the power industry. It implies an approach focusing more on carbon intensity than on the absolute amount of emissions, and it is very well suited to the stage of development that China has reached at the moment. However, the current literature does not provide enough evidence about its effect.

As China approaches the final phase of the 14th Five-Year Plan and moves towards the shift from managing energy consumption to managing carbon emissions, it is vital to assess the effectiveness of the ETS policies. Hence, the current study employs a multi-period difference-in-difference (DID) method by analyzing panel data at the provincial level to assess the effect of the ETS pilot policy on the carbon emission intensity of industry. In this regard, the study focuses on the dynamic effects and regional variation of the policy.

2. LITERATURE REVIEW

2.1 Research on Carbon Trading Policy Effects

The global empirical research on the effectiveness of ETS is mostly based on the Porter Hypothesis [3], discussing how properly designed environmental regulations could compensate the cost incurred from compliance by using internal technology adjustment within the company. Researchers have achieved consensus in that regulation's effect on firm green innovation varies a lot among industries and different indicators. It is revealed in the study of EU ETS that carbon prices could effectively stimulate low carbon technological innovations without cutting companies' R&D investments in aggregate.

Many empirical studies have been carried out to confirm the existence of a noticeable time lag component in the carbon trading strategy. In this case, the effect of ETS mitigation strategy on emissions does not take place instantaneously when it starts. The more the regional carbon markets develop and the trading process gets more systematic, the emission reduction capability of the policy keeps increasing. This means that the mechanism of incentive constraint through carbon trading has become stronger over time in the pilot regions.

Early Chinese domestic academic literature on the country's ETS focused primarily on effectiveness evaluation of basic emissions reduction[4]. Studies conducted during the initial years showed that piloting of carbon trading systems greatly reduces regional industry carbon emission intensities. In more advanced research, it was found that carbon price variability may cause non-linear threshold effects on the behavior of firms toward green innovation[5]. Through the lens of quality economic development, carbon trading leads to industrial upgrading in two ways – efficient production output and selection of high efficiency industrial activity increments.

Recently, research efforts have been changing from direct policy impact to interaction effect and the feature of spatial spillover effect. It is found by new research that the pilots of low-carbon cities, combined with the carbon trading policy, generate synergistic superposition effect, which greatly enhances green total factor productivity of the region [6].

2.2 Literature on Industrial Carbon Emission Intensity

In terms of the global academic landscape on mitigation of carbon intensity of industry, there exist two established streams of research, namely the connection between green finance and development of low-carbon technologies, and institutional analysis of carbon markets across the world.

As to the governance of green finance, many academic works prove that there exists a positive interdependency between green finance and the technological innovation of firms [7]. Empirical evidence shows that effective green finance systems could significantly reduce regional carbon emission intensity [8]. With regard to the institution of carbon market, scholars find that the Tradable Performance Standard (TPS) institution would help improve the efficiency of resource distribution. Nevertheless, this kind of institutional arrangement might increase the productive capacity of enterprises and weaken the competitiveness of the clean energy industry [9,10]. The similar findings have also been verified by empirical research on the American electricity industry.

The domestic research has continuously improved the carbon emission calculation framework, making it more inclusive not only by measuring traditional carbon emissions from fossil fuel combustion but also calculating overall electricity consumption [11]. Current evidence suggests that there is spatial variation in terms of industrial carbon emissions in China, such that the carbon intensity pressure tends to be greater in western provinces than in the east where there is better performance of low-carbon governance [12]. The rapidly developing digital economy has been an essential factor in reducing industrial carbon emissions, which helps reduce carbon intensity through green technology advancement, industrial restructuring, and energy efficiency [12-14]. Besides, the interaction between green finance and R&D plays a very important role in reducing emissionss[15].

In terms of the academic papers on carbon trading policy pilots' influence on industrial carbon intensity, current researches have widely examined such issue by extending the research scope to the policy interaction and cross-region spillovers. Nevertheless, there are still some issues which have not been fully explored so far. For instance, first of all, although the majority of relevant papers have taken the urban sample as the main sample area, few of them have considered the characteristic of cross-provincial diffusion of industrial carbon emission intensity. Secondly, the heterogeneity of such influence remains unexplored from the institutional viewpoint.

3. THEORY AND HYPOTHESES

ETS represents a market-based mechanism of environmental policy regulation which ensures internalization of externalities of carbon emissions via carbon pricing. ETS raises the cost of carbon-intensive manufacturing by setting emission limits and tradable allowances, thereby stimulating companies to enhance their energy efficiency and production processes as well as to develop low-carbon technologies. Moreover, carbon pricing helps redirect resources to cleaner industries and thus drives low-carbon development of industry [16].

Despite the fact that carbon markets might not lead to any immediate reaction from technology on their own, the persisting pressure of regulations and market stimuli can contribute to growing investments into energy saving technologies. This is why the following hypothesis is put forward:

H1: ETS pilot policy lowers industrial carbon emission intensity in pilot provinces.

However, the efficiency of ETS policies could differ regionally because of the difference in economic development level, industrial structure, technological capability, and environmental governance capacity. The eastern regions would have more advanced industrial structure, more innovation capabilities, and more economic resources, and thus, would be able to make effective responses to the carbon price through technological innovation and greening [17]. On the other hand, the central and western regions would rely heavily on the energy-intensive industries and have difficulties in technological and economic capacities, which will lower down the effectiveness of the policies.

Moreover, local environmental governance capacity can affect the efficiency of the carbon markets. The regions that have strong environmental governance capacity and more investments on environmental protection would have better conditions for regulating through the market and upgrading their industries. However, the weak environmental governance capacity could hinder the effectiveness of ETS policies. Therefore, the second hypothesis would be:

H2: The emission reduction effects of ETS pilots vary significantly across different regions. The policy effect on carbon emission intensity of industries is more pronounced in eastern regions and regions with higher governance level of local environment protection.

4. RESEARCH DESIGN

4.1 Empirical Model Specification

For the quantitative measurement of the net causality effect of China's ETS trial reform on the industrial carbon emission intensity of provinces, the traditional method of multivariate difference-in-difference is employed to conduct the empirical estimation. The regression equation is set up as below:

$$\mathrm{cei}_{it} = \beta_0 + \beta_1 \mathrm{DID}_{it} + \gamma \mathrm{Controls}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{1}$$

Let cei_{it} represent the industrial carbon emission intensity of province i in year t. It will be set up as the dependent variable in this research. The main independent variable is the interaction variable of treatment group indicator and year dummy, namely treat×year. Meanwhile, the control variables will include per capita GDP, industry structure, population density, environmental protection investment intensity, R&D expenditure intensity, share of coal consumption, and trade openness. The province fixed effect will be included to control for the unobserved time-invariant province heterogeneity, and year fixed effect is also introduced to control for the unobserved common trend effect.

4.2 Variable Definitions and Measurement

4.2.1 Dependent Variable: Industrial Carbon Emission Intensity

Industrial carbon emissions intensity (cei) is chosen as the key dependent variable in order to measure the degree of low-carbon development of industry in each province. In contrast to carbon emissions per se, this ratio measures the efficiency of reducing carbon emissions through comparing the amount of carbon emissions with that of economic benefits, which can be a more appropriate indicator for evaluating the efficiency of industrial transformation towards low-carbon.

$$C_T = C_F + C_E \tag{2}$$

$$\text{cei} = \frac{C}{GDP} \tag{3}$$

where cei is the industrial carbon emission intensity of province i in year t, expressed in tons of CO2 emissions per 10,000 yuan of industrial value added; C_T is the total industrial carbon emissions, which consists of the carbon emissions due to burning of fossil fuels (C_F) and the carbon emissions due to electricity (C_E); and GDP is the industrial value added, measured in constant 2010 prices.

The calculations of fossil fuel-related industrial carbon emissions follow the reference approach recommended by the Intergovernmental Panel on Climate Change (IPCC), as shown in Equation (4).

$$C_F = \sum_{i=1}^{12} C_i = \sum_{i=1}^{12} E_i \times SCF_i \times CEF_i \tag{4}$$

where E_i represents the physical consumption of fossil fuel type i; SCF_i denotes the standard coal conversion coefficient of energy type i; and CEF_i represents the corresponding carbon emission coefficient. The fossil fuel sources include 12 categories of energy consumption, such as coal, crude oil, and natural gas.

Considering that there is variation in energy structures and conditions of electricity production among Chinese provinces, electricity emission factors vary geographically and temporally. It means that time-varying province-specific electricity emission factors are used to calculate indirect carbon emissions from industrial electricity consumption.

$$C_E = \sum_{j=1}^{30} C_{E_j} = \sum_{j=1}^{30} E_j \times CE_j \tag{5}$$

where j represents province j (j=1,2, ...,30); E_j denotes industrial electricity consumption in province j, measured in kWh; and CE_j represents the corresponding provincial grid electricity emission factor. Given China's large differences between provinces in terms of power generation and energy resource situation, there is no way for the national average emission factor of electricity to characterize accurately the emission situation in different regions. Thus, time varying provincial electricity emission factors are adopted according to the "Guidelines for Provincial Greenhouse Gas Inventories." The emission factors of electricity are estimated from the grid emission factors from the official greenhouse gas inventory guidelines.

4.2.2 Core Explanatory Variable

The staggered difference-in-differences model is used to accommodate the irregular rollout of the carbon trading pilot reform in China. Treat×Year interaction is chosen as the key policy variable that represents the pure treatment effect of the ETS reform on industrial carbon emission intensity.

The group dummy (treat) indicates whether each provincial unit belongs to the pilot area or not. Those involved in the carbon trading reform take 1, whereas the rest conventional areas take 0. The year dummy (year) refers to the specific year of the policy penetration, where 1 stands for post-treatment period beginning from the policy penetration date when local carbon trading was officially launched, 0 for the pre-treatment period before any policy penetration.

According to the empirical dimension of provincial level data, the independent pilot project in Shenzhen city has been merged into the province of Guangdong for dimensional consistency. The final pilot regions comprise six provincial-level units: Beijing, Tianjin, Shanghai, Guangdong, Hubei, and Chongqing. The other 24 provincial units form the control group during the entire sample period. It should be pointed out that there exists a staggered rollout of these pilots: Beijing, Tianjin, Shanghai and Guangdong started trading in 2013, and Hubei and Chongqing started their trading in 2014. This kind of variation in the policy shock provides the natural experiment condition for DID estimation.

4.2.3 Control Variables

In order to eliminate biases generated by unobservable characteristics at the provincial level, several sets of control variables are introduced to address issues including economic development, industrial structure, energy intensity, and technological advancement.

Economic development is indexed using per capita GDP (pgdp) as the ratio of provincial economic output to average population size. The industrial structure (IS) index embodies the attributes of industrial upgrading, which is the ratio of the output of secondary industries to that of tertiary industries. Resource pressure is measured using population density (Pinten), which is the year-end population size per land area unit. Institutions and technology indicators include environmental governance investment intensity (invest) as the ratio of industrial pollution control investment to provincial GDP, and R&D intensity (RD), which is the ratio of research and development expenditures to economic output. Energy and openness measures include the share of coal consumption (coal) for measuring the degree of fossil energy reliance, and the trade openness (open) index, which is the ratio of import and export amount to provincial GDP. All continuous variables are logged in the baseline regressions to minimize the effects of data fluctuation except the measure of coal consumption share.

4.3 Data Sources and Sample Description

The balanced sample consists of 30 provincial units on the Chinese mainland from 2010 to 2023 (except for Tibet, Hong Kong, Macau, and Taiwan). The industrial carbon emissions of the provinces are calculated on the basis of the data on energy consumption taken from energy statistics database sources that provide information on the inventory of carbon emissions in each sector of the province. Table 1 shows the summary statistics of the variables used in the empirical analysis.

Table 1. Descriptive Statistics

	Observations	Mean	Std. Dev.	Min	Max
Lncei	420	0.2828	0.6940	-2.4809	2.2060
Did	420	0.1524	0.3598	0.0000	1.0000
Lnpgdp	420	1.6631	0.5012	0.2758	3.0756
Lnrd	420	-13.8869	0.5932	-15.6214	-12.6403
Lnis	420	-0.2530	0.3922	-1.7668	0.6098
Coal	420	0.3713	0.1508	0.0056	0.6868
Lninvest	420	2.4874	1.1151	-3.0449	4.9533
Lnpinten	420	-0.2398	0.6229	-2.0167	1.0087
Lnopen	420	-6.3649	0.9500	-9.5045	-4.2508

Note: This table reports descriptive statistics of main variables.

5. EMPIRICAL ANALYSIS

5.1 Baseline Results

The results from the regression analysis indicate that there is a significantly negative impact of the ETS pilot policy on industrial carbon emission intensity. The DID coefficients are found to be significant at the 1% level in both model specifications. The DID coefficient in Column (1) without control variables is −0.2659, while the DID coefficient in Column (2) with all provincial-level control variables is −0.3201. Thus, the estimated impact of the policy can remain constant even after controlling for other potential determinants of industrial carbon emission intensity.

Given that the dependent variable is log-transformed, the economic magnitude of the coefficient needs to be explained using the exponential transformation. From the fully controlled model specified in Column (2), we can say that the ETS pilot policy leads to a reduction of 27.39% in industrial carbon emission intensity in pilot provinces. Moreover, the 95% confidence interval from the exponential transformation shows the reduction rate between 18.04% and 35.68%.

Table 2. Baseline Regression Results

	(1)	(2)
Did	-0.2659***	-0.3201***
	(0.0612)	(0.0618)
Lnpgdp		-1.7799***
		(0.2529)
Lnrd		-0.3523***
		(0.0668)
Lnis		0.3321**
		(0.1478)
Coal		0.0135
		(0.4089)
Lninvest		0.0670
		(0.0411)
Lnpinten		0.1031
		(0.0867)
Lnopen		0.0802
		(0.0601)
_Cons	0.3234***	-1.1532
	(0.0159)	(1.0632)
Province FE	YES	YES
Year FE	YES	YES
Observations	420	420
R^2	0.8667	0.9012

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Standard errors clustered at the provincial level are reported in parentheses. The same applies to subsequent tables.

5.2 Robustness Tests

5.2.1 Parallel Trend Test

For the validity of the estimation using multi-period DID technique, there should be parallel trends for the two groups in terms of their industrial carbon emission intensity in periods preceding policy implementation. Since there is a staggered implementation of carbon trading pilot programs in China, an event study technique is used to test dynamic impacts of policies. One year before policy implementation is chosen as the baseline period. It is shown that coefficients of the pre-policy period are statistically insignificant with the confidence intervals having zero within it, thus supporting the validity of the parallel trend assumption.

Concerning dynamic impacts, the ETS policy shows a significant time-lag impact. Coefficients are negative and insignificant in both the implementation year and the first three years after implementation. However, the emission reduction effect becomes significant from the fourth and fifth years after policy implementation. Dynamic impacts of the policy are shown in Figure 1 below.

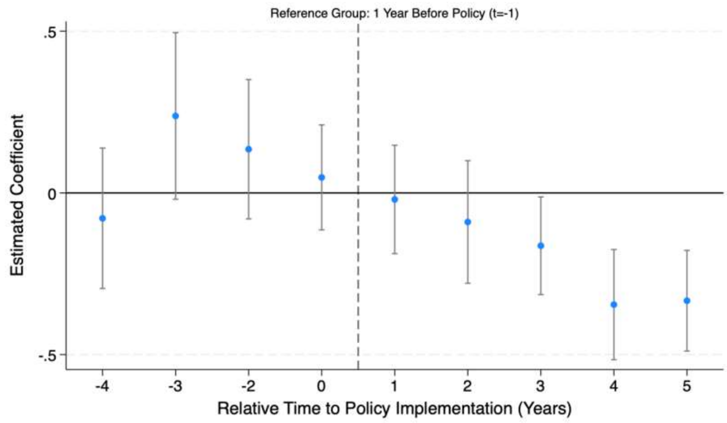

Figure 1. Parallel Trend Test Results

5.2.2 Placebo Test

In order to exclude the possible influence of hidden confounders at the provincial level and any kind of statistical chance, placebo test is applied to test the robustness of the baseline causal relationship between policy and dependent variable. The idea behind this test is creating imaginary shocks that are supposed to have no place in reality at all.

Six provinces are randomly chosen as fictitious treatment provinces from the entire dataset with fictitious dates of policy implementation in order to create artificial ETS policy DID variables that have nothing in common with reality. In order to make the test statistically persuasive, this procedure is replicated 500 times, producing 500 sets of simulated coefficients with their significance distributions. Kernel density of 500 placebo regressions reveals that simulated coefficients are concentrated around zero value and are normally distributed. Moreover, the baseline regression coefficient based on real ETS policy is noticeably deviated from this distribution. This clearly indicates that significant effect of industrial decarbonization obtained in baseline regression is not due to the random statistical variation or omitted variables but is an outcome of real policy effects due to carbon trading pilot reform. Figure 2 displays the kernel density distribution of the simulated coefficients from the placebo tests.

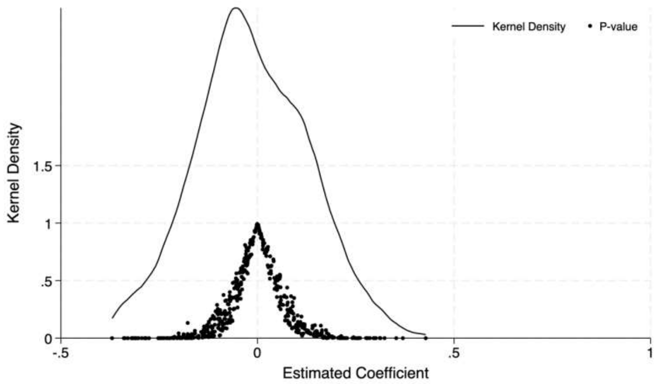

Figure 2. Placebo Test Results

5.2.3 Alternative Dependent Variable

The results of these robustness checks, including the alternative dependent variable specification, are reported in Table 3. To ensure that no empirical findings hinge on the specific measurement of the key indicator, substitution analysis for the dependent variable is carried out. Unlike the industrial carbon emission intensity that captures the efficiency in terms of emissions relative to output, the total industrial carbon emissions depict the overall magnitude of the industrial carbon emissions at the provincial level. Substitution of the key variable with the total industrial carbon emissions will cross-validate the efficacy of the policies aimed at reducing emissions.

The multi-period difference-in-differences regression with the substitution measurement of the key indicator still yields similar results compared with the initial regression analysis results. The key DID regression coefficient still holds statistically significant and negative at the 1% level of significance. This proves that the ETS pilot reform brings about a dual governance effect that enhances the efficiency of low-carbon industry while also limiting industrial carbon emissions growth. In conclusion, the consistent regression results with varied measurement of indicators demonstrate the reliability of findings and immunity to variable selection bias.

Table 3. Robustness Test Results

	(1) Replacement of the dependent variable	(2) 1% winsorization	(3) Excluding the sample from 2021 to 2023
DID	-0.2086***	-0.3050***	-0.2983***
	(0.0448)	(0.0581)	(0.0577)
_cons	8.6348***	-1.8205	-1.6085
	(0.8647)	(1.1096)	(1.1422)
Control Variables	YES	YES	YES
Province FE	YES	YES	YES
Year FE	YES	YES	YES
Obeservations	420	420	330
R^2	0.9717	0.9221	0.9345

5.2.4 Winsorization

Outliers in continuous economic and environmental variables could produce bias in statistical inference and disrupt baseline regression analysis. In order to address any estimation problem that might be created by outliers, a winsorization process of 1% bilaterally is used for both the dependent variable and all continuous control variables, cutting off extreme tails in the 1% and 99% percentiles.

The results from regression using the processed data reveal that after eliminating outlier influence, the key DID coefficient is still highly significant at the 1% level and the size of the coefficient is close to the baseline estimate. Stable regression performance demonstrates that the key inhibition effect exerted by ETS on the industrial carbon intensity does not depend on any extreme individual observations.

5.2.5 Sample Period Adjustment

The formal establishment of China's national carbon trading scheme in July 2021 brings about institutional reforms in carbon governance at the national level. The policy shock to the nation at this national scale might affect incremental effect measurement of provincial pilot policies. In order to exclude any interfering policy effects, the original sample period is restricted to observations within the years 2010 to 2020.

Regression results obtained through the use of restricted time periods show that despite the exclusion of institutional interferences after 2021, the main policy effect is still significantly negative at the 1% level and economically consistent with baseline results using full samples. Therefore, it can be inferred that the incremental reforms of provincial pilot carbon trading policies are the main drivers of industrial decarbonization identified in this research.

5.3 Heterogeneous Treatment Effects

5.3.1 Regional Heterogeneity Analysis

There are significant disparities among the eastern, central, and western regions of China in terms of economic development, industry structure, technology level, and market efficiency. To explore the existence of regional differences, the sample of provinces is split into three sub-samples, and regression models are separately estimated. Table 4 summarizes the regression results for the three regional subsamples.

Table 4. Regional Heterogeneity Analysis

	(1)	(2)	(3)
	Eastern Region	Central Region	Western Region
DID	-0.3511***	-0.2085***	-0.0278
	(0.0792)	(0.0654)	(0.1084)
_cons	1.4124	-3.7557**	-3.7537*
	(2.2808)	(1.6944)	(2.0656)
Control Variables	YES	YES	YES
Province FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	182	84	154
R^2	0.8535	0.9797	0.9576

It can be seen that there are substantial regional differences in the impact of ETS on emission reduction. The DID estimates are significantly negative in both eastern and central regions, but the impact effect is much more prominent in the eastern region. The estimates in western regions, however, are negative but statistically insignificant, implying no significant effect of ETS pilots on emission reduction in western regions.

The aforementioned differences are highly associated with regional development levels. In general, the industry structures of eastern provinces tend to be more advanced and technologies are better, which means that the enterprises in eastern provinces are more likely to respond to carbon market incentives. Central regions, on the other hand, are experiencing industrial upgrading and face certain restrictions in terms of technologies and finances. In western regions, enterprises are less dependent on green industries and innovation capability.

5.3.2 Environmental Governance Heterogeneity

Carbon trading serves as an environmental governance system based on the market, but its full potential of reducing emissions cannot be realized without the complementary role of local administrations' governance policies. The effectiveness of implementing carbon markets largely depends on the strength of local environmental governance. Budget expenditure allocated to pollution management leads the flow of government finance towards environmentally friendly industries and prompts firms to improve their production efficiency and close down polluting industries, together realizing the effects of carbon trading systems. The ratio of expenditures on environmental fiscal affairs in total budget expenditure by local general public is used to indicate the level of local environmental governance. Based on the median value of the sample data as the standard for classification, all the samples are classified into two groups of strong and weak governance and then regression analysis is conducted separately.

Table 5. Heterogeneity Analysis Based on Environmental Governance Intensity

	(1) High environmental stringency	(2) Low environmental stringency
DID	-0.3098***	-0.1963**
	(0.0996)	(0.0899)
_cons	-1.7509	-1.4078
	(1.2810)	(2.2598)
Control Variables	YES	YES
Province FE	YES	YES
Year FE	YES	YES
Observations	209	207
R^2	0.9553	0.8462

The regression results show that the ETS pilots have very strong inhibitory impacts on the carbon intensity in industries for both sub-samples, but there is definitely an inequality with respect to the magnitude of the influence of policies. The basic DID coefficient is statistically significant at the 1 percent level for the sub-sample with good environmental governance inputs.

This comparison demonstrates that carbon trading is able to generate much better decarbonization efficiency in places where there is strong environmental management locally. In those areas where there is more expenditure on environmental fiscal budgeting, there is more emphasis placed on protecting environmental objectives and thus the fiscal and administrative guidelines can help direct social capital towards low-carbon industries. The companies that operate under strict environmental regulation are forced to optimize their production processes and eliminate their old high-emitting capacity. The estimation results based on environmental governance intensity are presented in Table 5.

6. CONCLUSION AND POLICY IMPLICATIONS

6.1 Main Findings

This paper carefully examines the impacts of China's ETS policy pilot reform on the industrial decarbonization process, paying special attention to the features of policy lag and heterogeneity in implementation effects in different provincial industrial conditions. Using a balanced panel database from 30 Chinese provinces for 2010 to 2023, this study uses an empirical approach of multi-period difference-in-difference to investigate the causal impact of ETS policy implementation on industrial carbon emission intensity change.

The results obtained through this research consist of four primary insights. The first one reveals that the ETS policy pilot decreases the industrial carbon emission intensity in pilot provinces, and the conclusion is robust to parallel trends test, placebo test, alternative variable replacement, outliers, and sample window size adjustment. The second insight demonstrates that the impact shows evident characteristics of policy lag and accumulation. The third finding indicates the regional differences in Emission Reduction Efficiency-the largest effect is observed in the East Region, weak but positive in the Central Region, and zero in the West Region, due to industrial structure and transitional costs of industrial decarbonization in the West Region. The fourth insight states that the better governance capacity on environment-indicated by increased fiscal expenditure and more strict regulation-significantly enhances the efficiency of the carbon trading system on emission reduction.

6.2 Policy Implications

In light of the findings from the empirical analysis, we put forward the following five recommendations for the national carbon market in China. First, the scope of the market will need to include steel, cement, and non-ferrous metals, with increased pressure being put on the traditionally high-emitting industries to lower emissions levels and become low-carbon industries. With regard to regional diversity, there is need for differentiated quota and penalty mechanisms for each region, with increased technical and financial aid being extended to central and western provinces due to their structural disadvantages. There needs to be emphasis on the interaction between the carbon market mechanism and administrative oversight in the region, since regions with high levels of expenditures on environment and strict regulations perform better. Therefore, it will be necessary to provide incentives to local government officials, so that they channel their efforts in the right direction towards green industries. Since reduction in emissions takes place only after a long period of market functioning, policy frameworks have to be consistent and not undergo drastic changes due to temporary results.

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