

Article

Does Market-Based Environmental Regulatory Policy Improve Corporate Environmental Performance? Evidence from Carbon Emission Trading in China

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Abstract: The carbon emissions trading (CET) policy is a crucial market-based environmental regulatory policy for managing corporate carbon emissions, thereby assisting China in achieving its carbon peak and carbon neutrality goals. This study examines whether such a policy can boost corporate environmental performance. Based on China's CET pilot as a quasi-natural experiment, this paper employs the difference-in-differences method and difference-in-difference-in-differences method to analyze the data of listed companies in the pilot regions from 2010 to 2020. Findings show that the policy of CET has a significant positive influence on firms' environmental performance. Notably, while high-pollution companies benefit substantially, the effect is relatively weaker compared to others. Mechanism analysis shows that the policy drives improvements through enhanced environmental management and green innovation, and government environmental subsidies promote the effect of CET on environmental performance. In addition, the impact is more pronounced in state-owned, large-scale, and power industry companies; companies in regions with strong environmental regulations; and with high executive green awareness. These findings provide some insights for refining China's CET framework and enhancing environmental outcomes.

Keywords: environmental performance; carbon emission trading; environmental management; green innovation; government environmental subsidy



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1. Introduction

The pervasive impact of climate change resulting from greenhouse gas emissions is profoundly affecting every individual and community. An increasing number of researchers consider the main contributor to climate change to be carbon emissions [1]. Addressing this issue requires a global effort. In 2015, 197 countries signed the Paris Agreement, which is a major step toward reducing global greenhouse gas emissions and is key to improving sustainability in different regions [2]. At the UN Climate Change Conference in 2009, China pledged to reduce CO₂ emissions by 40–45% by 2020. Additionally, China's 2016–2020 Five-Year Development Plan set a goal of an 18% reduction in CO₂ emissions by 2020 compared to 2015. In response, China has introduced a number of energy-saving and environmental protection policies, laws, and regulations aimed at emission reduction [3]. During the 75th session of the UN General Assembly in 2020, the objective of “carbon peaking and carbon neutrality” was introduced. This entails China bolstering its nationally defined contributions, implementing stronger laws and regulations, aiming to peak CO₂

emissions by 2030, and attaining carbon neutrality by 2060. This goal is in line with global efforts toward environmental protection and sustainable development.

The carbon emission trading (CET) system is considered one of the most effective and flexible ways to reduce carbon emissions and improve air quality [4]. Under this system, companies are allocated specific carbon quotas while also having the option to buy or sell carbon quotas among other participating companies according to their carbon emission levels, thus utilizing the market's capacity to reallocate emission rights. Prior to the implementation of CET, China's environmental regulations were largely mandatory, such as all kinds of environmental laws. Compared to mandated environmental regulations, market-based environmental regulations, such as the CET, allow companies to choose appropriate emission reduction methods according to their own cost-benefit analysis, providing companies with greater flexibility. In addition, market-based environmental regulations restrain companies' emission behavior through market mechanisms, reducing the cost of government supervision. Market-based environmental policy is a relatively preferable choice for carbon emission management.

In 2011, the Chinese government proposed setting up a CET system. Between 2013 and 2014, pilot programs were launched in Beijing, Tianjin, Guangdong, Hubei, Shanghai, Tianjin, and Chongqing, with Fujian joining in 2016. Table 1 shows the industries included in China's carbon market, mainly high energy consumption. As of 14 June 2023, the cumulative trading volume has reached 237.69 million tons, as illustrated in Figure 1. The CET policy is essential to lowering carbon emissions and enhancing environmental quality. It incentivizes enterprises to adopt innovative practices, shift to greener operations, and achieve a dual benefit of economic growth and environmental sustainability. By the end of 2020, China had successfully decreased carbon dioxide emissions per GDP unit by approximately 48.4% compared to the levels recorded in 2005, surpassing its original 40–45% target. Additionally, the average PM2.5 concentration in key cities had decreased by over 40% from 2013 levels. Most scholars believe that the regulations of carbon emissions have significantly helped cut carbon emission reduction in the pilot regions, boosting emission efficiency and promoting green development in these areas [5,6].

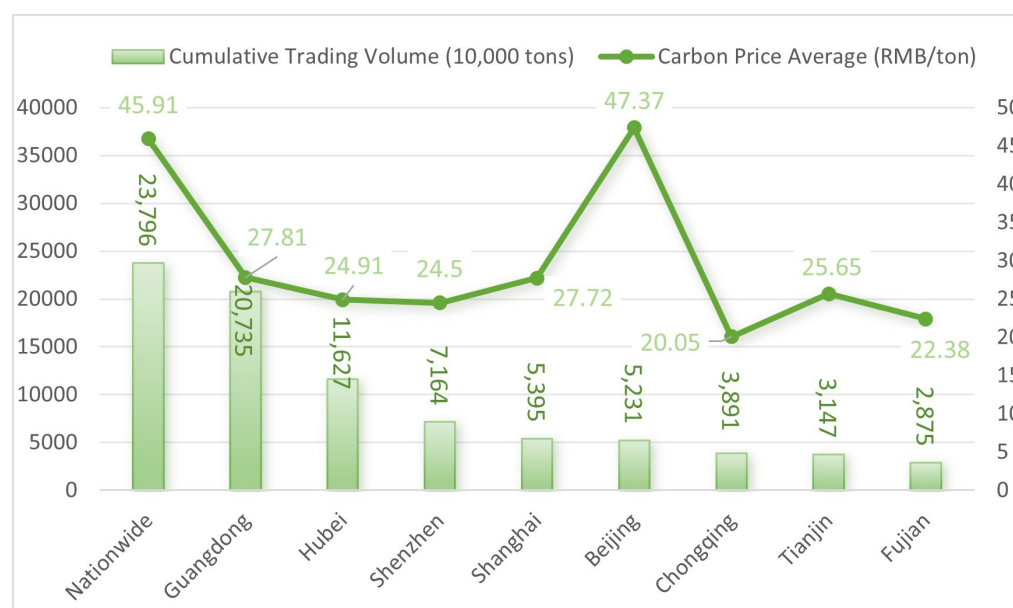


Figure 1. Overview of China's Carbon Market Cumulative Trading (as of 14 June 2023). Notes: Data source: <http://www.tanjiaoyi.com/> (accessed on 10 September 2024).

Table 1. Industries included in China’s carbon market.

Included Industries		Beijing	Tianjin	Shanghai	Chongqing	Hubei	Guangdong	Shenzhen	Fujian
Eight high energy-consuming industries	Power industry	•							•
	Iron and steel industry		•	•	•	•	•	•	•
	Construction material industry	•	•	•	•	•	•	•	
	Petrochemical industry	•	•	•	•	•	•		•
	Chemical industry		•	•	•	•		•	•
	Non-ferrous metal industry		•	•	•	•		•	•
	Papermaking industry				•	•	•	•	•
	Civil aviation industry	•	•	•			•		•
	Transportation	•		•				•	
	Construction			•					
	Other industries	•	•	•	•	•		•	•
	Waste management				•			•	
	Food and Beverages		•		•	•			
	Services	•		•				•	

Notes: Data source: <http://www.tanjiaoyi.com/> (accessed on 10 September 2024). • indicates that the industry in its corresponding province has participated in the carbon trading pilot.

As governments and the public increasingly prioritize environmental concerns, environmental performance has become increasingly important to investors assessing a company’s prospects. Firms with higher environmental efficiency tend to attract external financing more readily [7]. Environmental policies and environmental performance are often closely related [8]. Most literature on the environmental impact of CET focuses on the macro level and pays less attention to the micro level of enterprises [5,6], so a key question arises: Can CET also boost a company’s environmental performance? Research suggests that this policy encourages green technological innovation of enterprises [9], increases green investment of companies in chemical and non-ferrous metal industries [10], and even improves profitability for listed companies [11]. Yet, research into the policy’s impact on companies’ environmental performance remains relatively scarce. Only by evaluating the change in enterprises’ environment-related indicators can we further assess the effectiveness of this policy in improving enterprises’ environmental performance. External rating agencies provide a comprehensive evaluation of a company’s energy management, governance related to the environment, pollutant emissions, and commitment to sustainable development, among other factors. Compared to looking at just a single metric, these ratings offer a more holistic view, helping investors find relevant information and strengthening the connection between companies and investors. Therefore, by using these rating agencies’ environmental scores in our analysis, we can capture the overall changes businesses make in response to the CET policy, offering crucial insights for corporate development.

This research examines the influence of the CET system on firms’ environmental outcomes, specifically questioning whether its effects differ between high-polluting firms and other pilot companies. Additionally, it investigates the processes by which the system exerts its influence and whether these effects vary among diverse companies. We manually collected a list of pilot companies from websites of provincial and municipal governments in charge of carbon trading, designating A-share listed companies among them as the study’s treatment group. On the contrary, A-share listed companies within the pilot regions that were not included in the pilot program were selected as the control group. Environmental performance data comes from the Bloomberg Environmental Score. Company financial and non-financial data is from CSMAR and Wind databases. Employing CET pilot as quasi-natural experiments, our analysis applies the difference-in-differences (DID) as well as difference-in-difference-in-differences (DDD) approaches to assess the impact of the policy on environmental outcomes, particularly focusing on those with high pollution levels. Furthermore, three potential channels—enhanced environmental management,

green innovation, and government environmental subsidy—are examined as pathways for these effects. Finally, we account for the heterogeneity of firms in ownership, scale, industry, environmental regulations, and executive green awareness. This study enriches the related literature, offering significant implications for policymakers on enhancing corporate environmental governance and improving environmental performance.

The marginal contributions of this paper are as follows. First, this paper enhances the understanding of the micro-level impacts of CET policies. It addresses a gap in existing research, which has largely focused on macro-level effects such as regional carbon reduction, environmental impacts [5], corporate innovation [12,13], and financial performance [14]. Unlike prior studies that often focus on singular environmental metrics such as emission levels or environmental investments, this paper examines firms' overall environmental scores, as rated by an independent agency, to capture a more comprehensive picture of how CET policies affect corporate environmental performance. Second, the study expands the discussion on the determinants of environmental performance by exploring the influence of regulatory policy, including environmental regulations [15], financial regulations [16], and anti-corruption regulations [17]. Because carbon trading is a market-incentive environmental policy, it offers more flexibility than traditional command-and-control approaches. This allows for the examination of the role of market-driven environmental policies as a novel external factor that impacts corporate behavior. Third, the paper identifies and discusses the mechanisms through which carbon trading policy enhances environmental performance, specifically through the improvement of environmental management as well as the encouragement of green innovation. Moreover, government environmental subsidy plays a promoting role. This perspective encourages companies to recognize the constraints and opportunities of environmental policy, motivating them to proactively engage with these policies to improve environmental performance.

The paper is organized as follows: Section 2 offers a thorough literature analysis and the creation of hypotheses; Section 3 outlines the research design and the data; Section 4 presents the findings from the empirical study, encompassing baseline regression, robustness assessment, mechanism investigation, and heterogeneity evaluation; Section 5 proposes the discussion, and Section 6 provides a summary of the findings.

2. Literature Review and Research Hypotheses

2.1. Literature Review

There are two main categories of relevant literature for this paper. The first category pertains to factors influencing environmental performance, which refers to a firm's environmental impact during its production and operational activities over a given period [18]. It encompasses a range of environmental actions, such as lowering gas emissions of the greenhouse, improving resource and energy efficiency, managing waste, preventing pollution, conserving biodiversity, and adopting environmentally friendly practices and technologies. Researchers examine the factors that impact environmental performance from the aspects of internal operational management and external policy influence. Internally, factors such as green bond issuance [19], digital development [20], and ownership structure [21] can shape a firm's environmental outcomes. Externally, firms are subject to various government mandates, policies, and regulations—especially those related to the environment—which also play a key role in determining environmental performance. For example, Li et al. (2024) find that low-carbon city pilot programs significantly improve environmental performance [15]. Regarding financial policies, Chen et al. (2023) suggest deregulatory action against banks significantly improves environmental outcomes [16]. Xiao and Shen (2022) demonstrate that firms losing political connections due to Regulation 18, forbidding public servants from holding corporate roles, experienced increases in environmental performance [17].

Given the constraining effect of environmental policies and regulations on firms, this paper incorporates the CET pilot, which is a market-driven environmental regulation in China, into the study of environmental performance.

The second category of literature revolves around the economic consequences of CET programs. At the macro level, the pilot programs promote regional carbon emission reduction [5,22] and regional green development [6]. At the micro level, this system has significant impacts on corporate financial performance, the environment, and sustainable development. For example, the implementation enhances the profitability of state-owned listed businesses in China [21]. Cui et al. (2021) provide unambiguous evidence that regional CET pilots effectively reduce firm emissions [23]. Yu et al. (2022) reveal that the financial results of covered companies improve with the adoption of the policy [24]. The EU's carbon emission trading system was established earlier than China's, and the research on the EU's emission system provides an international comparison. Mandaroux et al. (2023) summarize by literature review that the EU emissions trading system has stimulated low-carbon technology but not enough to achieve carbon neutrality [25]. The EU's emission system also improves the company's stock returns [26].

Currently, only a handful of studies have explored the effects of CET on environmental outcomes. Yu et al. (2022) emphasize that there is a threshold impact on environmental performance based on the level of perfection of carbon market policy [24]. Zheng et al. (2023) also find that CET pilot programs enhance environmental performance, but firms achieve environmental enhancement by lowering production levels [27]. A firm's environmental performance encompasses not only its performance in various environmental indices, but also operational costs associated with various environmental investments and activities. Among these, environmental investment—a key component of environmental performance—has also received attention, but there is no consensus on its relationship with CET pilots. For instance, Yang et al. (2023) suggest the opposite, stating that pilot programs negatively affect corporate environmental investment [28], whereas Lv et al. (2023) consider that the implementation of the programs has boosted corporate environmental investment [29]. Overall, the literature has explored the impact of CET on corporate environmental activities to some extent. However, because carbon trading involves some key industries [30], there is still an incomplete understanding of the mechanism and heterogeneity. Under the CET system, what efforts have pilot enterprises made to improve environmental performance to meet carbon emission requirements? Have government support policies had an impact during this process? Does the effect of the policy on environmental performance vary by industry? These gaps are not covered in the existing literature but will be explored in this paper.

2.2. Research Hypotheses

As presented in the literature review earlier, the CET system is an important market-based environmental regulatory framework. It provides companies with emission reduction opportunities based on clear price signals. This encourages businesses to achieve their carbon management goals in a cost-effective manner while aligning with their long-term interests. Currently, the Chinese carbon market primarily adopts a system of free allocation of carbon quotas based on corporate carbon emissions. Companies meeting emission standards can generate cash flow by selling carbon quotas, while those facing a quota shortfall may reduce production to meet the emission targets [27] or purchase additional emission quotas from the carbon emission market. Under quota management, regardless of whether firms have a quota shortfall or not, they have a strong incentive to reduce carbon emissions and improve environmental performance to meet regulatory standards. In the short term, pilot companies will be subject to stricter carbon inspections, reporting, and other

regulations. This increases their emission reduction costs, including carbon trading and compliance costs. As a result, pilot enterprises will prioritize environmental governance, fulfill emission reduction responsibilities, and raise environmental efficiency [23]. In the long run, firms increase their expenditure on environmental preservation initiatives and engage in low-carbon innovations. They also work to reduce their exposure to carbon risks to mitigate capital losses and avoid a negative corporate image. These efforts help them address issues such as fines, production restrictions, and other environmental penalties. This strategy is adopted not only to circumvent penalties but also to facilitate green transformation and long-term development. Based on the Porter hypothesis [31], innovation will increase productivity and offset environmental protection costs, thus enhancing environmental performance. Building on this theoretical foundation and the analysis above, Hypothesis 1 is put forward:

H1: *Carbon emissions trading system can improve environmental performance.*

High-polluting companies are the focus of the CET policy, subject to stronger environmental regulations and greater pressure on emission reduction [32]. Due to institutional constraints and incentive effects, high-polluting companies must make significant carbon emission reduction achievements to meet regulatory requirements [33]. The supervision and inspection of high polluters' carbon emissions is more stringent, encouraging them to actively disclose environmental information and improve environmental performance [34,35]. Under the constraint of carbon quota management, the environmental cost has increased significantly, prompting high polluters to consider investment in emission reduction technology, optimization of production, and adjustment of energy structure [36]. Compared with other industries, high-polluting companies are more motivated to carry out green innovation [37], transform to low-energy and low-emission industries, and improve environmental performance [38]. Based on the analysis of high-polluting companies, we propose Hypothesis 2:

H2: *The CET system can improve the environmental performance of highly polluting companies.*

A company's environmental management not only reflects its awareness of environmental responsibility but also signifies the company's long-term strategy towards environmental friendliness. More efficient environmental management can help assuage stakeholders' concerns regarding a company's exposure to climate risks [39]. Following the introduction of the carbon trading system, pilot companies face increased pressure of emission reduction and environmental regulation. Failure to comply with these regulations or to improve environmental protection measures will be seen by stakeholders as irresponsible environmental behavior. In line with institutional and stakeholder theory, environmental management is viewed as a proactive approach to meeting environmental obligations and reducing carbon hazards [40]. This perspective underscores the incentive for companies to strengthen internal environmental management by adopting stricter environmental policies and measures. Although strict environmental management may increase costs, it can also yield economic benefits for companies in various ways. For example, companies may realize cost savings by avoiding penalties and legal expenses associated with environmental violations. Additionally, improved environmental practices can improve brand reputation, loyalty, and overall corporate value [41]. After strengthening environmental management, a company's production operations will adhere to higher standards. The company will improve energy efficiency, reduce pollutant emissions, and minimize environmental incidents and penalties, ultimately enhancing its overall environmental performance. Evidence from Kenya illustrates that substantial improvements in environmental performance, especially

in developing economies, are associated with the adoption of the worldwide system of environmental management [42]. Furthermore, the adoption of ISO 14001 significantly boosts the environmental outcomes of small and medium-sized businesses [43]. Moreover, standardized environmental management systems help formalize and rationalize firms' green behaviors, resulting in better environmental outcomes [44]. By fostering these structured approaches, environmental management serves as a cornerstone for improving a company's overall environmental performance.

H3: *The CET system enhances environmental performance by promoting better environmental management.*

The carbon trading system sets carbon emission quotas and trading prices through market mechanisms. Based on Porter's hypothesis [31], in order to reduce the cost of purchasing carbon emission quotas, firms are motivated to carry out technological innovation to reduce carbon emissions. These innovations include advancements in machinery, equipment, and production processes to reduce the expense of purchasing additional emission quotas and meet regulatory requirements. In addition to encouraging compliance, the CET policy creates an incentive effect for companies that already meet the standards. These companies are motivated to carry out green innovations to reduce the consumption of carbon quotas and benefit from selling surplus quotas. From the perspective of factor endowment theory, as carbon emission rights have become a scarce resource under the carbon trading system, companies pay more attention to the control of carbon emissions and the efficient use of resources. Faced with the cost pressure brought by carbon trading, enterprises have the incentive to carry out technological innovation, such as developing clean energy and improving energy utilization efficiency, in order to reduce carbon emissions. Furthermore, the carbon trading market provides enterprises with a variety of financial derivatives and expands the source of capital that supports green innovation more effectively. Previous research confirms that CET policy boosts green patent numbers for businesses while also enhancing the effectiveness of green innovation [45–47]. Technological innovation is a key way for companies to improve their environmental performance. By adopting new technologies, companies can manage their resource and energy use more effectively, reduce waste and pollutant emissions, and improve environmental performance. Studies on the relationship between green innovation and environmental performance generally concur that there is a positive promotional relationship. Existing research shows that industries with more advanced green technology exhibit superior environmental efficiency [48]. It is also discovered that green innovation enhances the performance of the economy and the environment [38,49]. Through green innovation, pilot companies achieve green transformation by increasing green innovation, offering more green products or services, offsetting environmental costs, reducing resource waste, conserving energy, and improving resource efficiency [50], thereby reducing negative environmental impacts and enhancing environmental performance [51]. Based on the above discussion, the following hypothesis is proposed:

H4: *The CET system enhances environmental performance by stimulating green innovation.*

The CET policy encourages companies to reduce carbon emissions through the market mechanism, but some companies may find it difficult to achieve the emission reduction target immediately due to the restrictions of technology or capital. Government environmental subsidies are important external environmental capital for companies, which can be a powerful supplement to environmental policies. It reduces the cost of emission reduction and helps companies overcome the difficulties in emission reduction [52]. On the one hand,

environmental subsidies can directly provide financial support for companies to purchase environmental protection equipment, develop more efficient pollution control measures, and low-carbon production technologies [53]. With new equipment and technologies, companies adopt cleaner production processes, effectively improve resource utilization efficiency, reduce carbon emissions and environmental pollution [54], and finally improve environmental performance. On the other hand, companies that receive environmental subsidies are often seen as outstanding in environmental protection, which helps to enhance the brand image and social reputation. Under the background of CET, enterprises with good brand images are more competitive in the market and can attract more consumers and investors [55], creating favorable conditions for sustainable development and further encouraging companies to improve environmental performance. Based on the above discussion, we propose the following Hypothesis:

H5: *Government environmental subsidies can strengthen the role of the CET system on corporate environmental performance.*

3. Research Design

3.1. Sample Selection and Data Sources

This study includes all A-share listed businesses across seven pilot provinces and cities during 2011–2020 as the preliminary sample. The A-share market is the largest and most representative stock trading market in mainland China. A-share listed companies follow a relatively standardized information disclosure system, which facilitates the acquisition of reliable and systematic financial and non-financial data. The carbon trading regulatory authorities in pilot areas have released a list of companies participating in the carbon trading pilot. The A-share listed companies appearing on the list serve as the treatment group, while companies within the pilot regions that do not appear on the list are the control group. The selection process involved excluding companies under special treatment (ST and * ST) and in the financial sectors. For the missing values of variables, we select other variables that have a relatively high correlation with the variable as references and use the linear interpolation method to fill in the missing values. The observation is deleted if it misses too many variables. To mitigate the impact of extreme values, the variables are winsorized at the upper and lower 1% levels. Additionally, companies with Bloomberg ESG ratings were selected, resulting in a final dataset of 324 companies. DID and DDD econometric models are used in this paper. The mediating model and moderating effect model are employed for mechanism testing. Stata 17 is used to run the models. The treatment group of companies is obtained by reviewing the pertinent documents issued by the Development and Reform Commission and the Department of Ecology and Environment of the seven pilot areas when the carbon market launched. The treatment group contains 147 enterprises, while the control group has 177, with 3054 valid observations overall. Two databases were used to retrieve the data: China Stock Market and Accounting Research (CSMAR) and Wind.

3.2. Variable Definition

3.2.1. Dependent Variable

The dependent variable is environmental performance (EP), which is represented by diverse proxy variables in various studies. In this paper, it is depicted through the environmental subcomponent of Bloomberg's ESG rating. Bloomberg's environmental score includes the following aspects: air quality, ecological impact, climate exposure, environmental supply chain management, energy management, sustainable products, GHG emissions management, waste management, and water management. Compared with the single environmental performance variable in previous literature, this metric offers

a comprehensive portrayal of firms' advancements in environment-related production and operation. In the robustness test, the corporate environmental investment (*EI*) is used as a substitute, quantifying the extent of a firm's investments in environmental protection.

3.2.2. Explanatory Variable

Given that CET policy is a typical quasi-natural experiment, the DID model proves instrumental in assessing its impact on environmental performance. The variable *Treat* indicates whether the company is in the treatment group, and *Post* indicates whether the CET pilot has been implemented. Since the initial launching of the carbon trading in seven pilot cities and provinces is concentrated in the latter half of 2013 and the first half of 2014, and there is a time lag effect of the policy's execution, 2014 is considered as the first year of the shock of policy. To study the situation of high-pollution industry, variable *HP* is incorporated into the DDD model to make interactive terms. If a company is in a highly polluting industry, the value of *HP* is 1; otherwise, it is 0.

3.2.3. Control Variables

Environmental performance can also be influenced by various factors such as firms' financial situations and the local economic environment. With reference to the current literature [14,16], we introduce the control variables: *Size*, *Lev*, *ROE*, *Top1*, *Cashflow*, *Growth*, *SOE*, *lnGDP*, and *GDP2*. Table 2 provides comprehensive definitions of all dependent, explanatory, and control variables.

Table 2. Variable definitions.

Variable Type	Variable Name	Symbols	Variable Definitions
Dependent variables	Environmental performance	<i>EP</i>	Environmental subcomponent of Bloomberg's ESG rating
	Environmental investment	<i>EI</i>	Amount of investment by each firm in environmental protection (million yuan)
Explanatory variables	Pilot enterprises	<i>Treat</i>	It equals 1 if the firm is on the pilot list, otherwise, it is 0.
	Pilot time	<i>Post</i>	It is 1 when the year is greater than or equal to 2014; otherwise, it is 0.
	Highly polluting industries	<i>HP</i>	It is 1 if the firm is in highly polluting industries; otherwise, it is 0.
Control variables	Firm size	<i>Size</i>	Natural logarithm of total assets
	Financial leverage	<i>Lev</i>	Total liabilities/total assets
	Return on net assets	<i>ROE</i>	Net profit/equity
	Holding ratio of the largest shareholder	<i>Top1</i>	Number of shares held by the largest shareholder/total number of shares
	Cash flow ratio	<i>Cashflow</i>	Net cash flows from operating activities/total assets
	Firm's growth rate	<i>Growth</i>	Current year's operating income/previous year's operating income—1
	Enterprise ownership	<i>SOE</i>	It is 1 for state-owned enterprises; otherwise, it is 0.
	Regional GDP	<i>lnGDP</i>	Natural logarithm of total GDP
	Proportion of secondary industry GDP	<i>GDP2</i>	Secondary industry GDP/total GDP

3.3. Model Design

3.3.1. DID Model

To test Hypothesis 1, we leverage the quasi-natural experiment provided by the CET pilot policy and employ a DID model to assess its impact on the environmental performance of enterprises. The following is an outline of the model.

$$EP_{it} = \beta_0 + \beta_1 Treat_i \times Post_t + \delta X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (1)$$

In Equation (1), EP_{it} stands for the environmental performance of firm i in year t . The core explanatory variable is $Treat_i \times Post_t$ (i.e., DID), where $Treat_i$ represents whether it is a pilot firm in the pilot areas and equals 1 if it is and 0 otherwise. If $t \geq 2014$, $Post_t$ equals 1, and 0 otherwise. X_{it} are control variables related to the environmental performance of the firm, λ_i is firm fixed effects, μ_t is time fixed effects, and ε_{it} is the model error term. The term DID is the most concerned variable, and its coefficient β_1 reflects the impact of CET policy on environmental performance.

3.3.2. DDD Model

To explore the influence of CET policy on the environmental performance of high-pollution industries, reflecting Hypothesis 2, a DDD model is developed by incorporating a dummy variable for the degree of industry pollution into the DID model. High-polluting enterprises are selected according to the Guidelines for Industry Classification of Listed Companies. The model is established as follows:

$$EP_{ijt} = \beta_0 + \beta_1 Treat_i \times Post_t \times HP_j + \delta X_{it} + \lambda_i + \mu_t + \varepsilon_{ijt} \quad (2)$$

In Equation (2), the explanatory variable HP_j denotes the degree of industry pollution, with enterprises belonging to high-polluting industries taking the value of 1 and enterprises in other industries taking the value of 0. The interaction term $Treat_i \times Post_t \times HP_j$ (i.e., DDD) is the core explanatory variable, with the coefficient β_1 representing the net impacts of the CET policy on the environmental performance of the pilot enterprises in high-polluting industries, and the λ_i and μ_t are the firm fixed effects and the year fixed effects.

3.3.3. Models of Mediating Effects

The mechanism analysis for Hypotheses 3 and 4 indicates that the CET policy improves environmental performance by upgrading environmental management capacity and fostering green innovation capacity. So these two capacities are taken as mediating variables to test the channels of influence of the CET policy on environmental performance, and the model is established as follows.

$$M_{it} = \alpha_0 + \alpha_1 Treat_i \times Post_t + \delta X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (3)$$

$$EP_{it} = \gamma_0 + \gamma_1 Treat_i \times Post_t + \gamma_2 M_{it} + \delta X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (4)$$

where M_{it} denotes the mediating variables, specifically focusing on aspects of the environmental management capacity, which includes two variables, environmental quality certification ($EM1$) and environmental management system ($EM2$); the green innovation capacity includes green invention patents ($GI1$) and green utility model patents ($GI2$).

If the mechanism of influence proposed in Hypotheses 3 or 4 holds, then α_1 , γ_1 , and γ_2 should be positive and statistically significant.

3.3.4. Model of Moderating Effects

The mechanism analysis for Hypothesis 5 means government environmental subsidies play a moderating role in the impact of CET on environmental performance. We built a moderating effect model to test H5.

$$EP_{it} = \theta_0 + \theta_1 Treat_i \times Post_t + \theta_2 GES_{it} + \theta_3 Treat_i \times Post_t \times GES_{it} + \delta X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (5)$$

where GES_{it} denotes the moderating variables of government environmental subsidy, which includes two variables, the natural logarithm of government environmental subsidy plus 1 ($GES1$) and government environmental subsidy divided by total assets ($GES2$).

If the mechanism of influence proposed in Hypothesis 5 holds, then θ_3 should be positive and statistically significant.

4. Empirical Results

4.1. Descriptive Statistics

Table 3 shows the description of the primary variables' statistics. The dependent variable *EP* shows a significant distribution gap, with 65.625 as the maximum value and only 1.550 as the minimum. The large distribution span of *EP* means that the data contains more variability and information, which provides a prerequisite for the regression model to explore the influencing factors. The proportion of the sample that received the treatment stands at 18.8%, and the sample of high-polluting enterprises accounts for 19.2%. The proportion of the treatment group is suitable, and the estimation bias caused by too few observations of the treatment group is avoided.

The correlation coefficients of each variable are shown in Table A1. The correlation coefficient between the environmental performance (*EP*) and the dummy variable (*DID*) of the CET policy is 0.159, and it is significant at the 5% level, indicating a relatively high correlation between companies' participation in *CET* and *EP*. The correlation coefficient between *EP* and *DDD* is 0.080, which is significant at the 5% level, suggesting that there is also a relatively high correlation between high-pollution firms' participation in *CET* and *EP*. There are significant correlation relationships between *EP* and most of the control variables. The correlation coefficients among the main variables are relatively low, indicating no serious multicollinearity problem in the model. This provides a prerequisite for the regression analysis in the subsequent part.

Table 3. Descriptive statistics.

	Obs	Mean	SD	Max	Min
<i>EP</i>	3054	12.725	9.349	65.625	1.550
<i>Treat</i>	3054	0.188	0.391	1.000	0.000
<i>Post</i>	3054	0.730	0.444	1.000	0.000
<i>HP</i>	3054	0.192	0.394	1.000	0.000
<i>EI</i>	1057	16.979	2.776	23.994	8.700
<i>Size</i>	3054	23.914	2.044	30.688	20.084
<i>Lev</i>	3054	0.537	0.213	0.950	0.048
<i>ROE</i>	3054	0.086	0.124	0.429	−0.855
<i>Top1</i>	3054	0.385	0.169	0.807	0.058
<i>Cashflow</i>	3054	0.048	0.068	0.264	−0.218
<i>Growth</i>	3054	0.134	0.349	2.673	−0.661
<i>SOE</i>	3054	0.650	0.477	1.000	0.000
<i>lnGDP</i>	3054	7.502	0.741	8.261	4.552
<i>GDP2</i>	3054	0.331	0.122	0.625	0.158

4.2. Baseline Regression Results

In this study, we investigate the impact of the CET system on the environmental performance of companies using the DID model. We also examine how the CET system affects companies in highly polluting industries using the DDD model. The DID model assumes that without CET intervention, the environmental performance trends of the treatment group and the control group are similar. The coefficient of the interaction term *DID* represents the net effect of policy intervention on the treatment group relative to the control group, that is, the additional or reduced effect of the treatment group relative to the control group after policy intervention. The coefficient of the triple difference interaction term in the DDD model represents the net effect of policies on the environmental performance of high-polluting companies relative to other companies. Table 4 presents

the regression results. The outcomes of the DID model are shown in columns (1) and (2), without and with control variables, respectively. At the 1% significance level, the *DID* term's coefficients are significant and positive regardless of the addition of control variables. The coefficient of the *DID* term is 2.113, indicating that after participating in the carbon trading pilot, firms' average environmental performance score increases by 2.113 points. Compared to the average value, this represents an improvement of 16.6% ($=2.113/12.725$). The results suggest that the CET system significantly improves the environmental performance of companies. The outcomes of the DDD model are displayed in columns (3) and (4). At the 10% significance level, the *DDD* term's coefficients are significant and positive, irrespective of the inclusion of control variables, demonstrating that the CET system considerably enhances the environmental outcomes of high-polluting firms. The *DDD* coefficient of 1.540 implies that after enterprises in high-pollution industries participate in the carbon trading pilot, their average environmental performance score increases by 1.540 points. Relative to the average score of high-pollution industries, this amounts to an improvement of 10.9% ($1.540/14.092$). Although this is also a substantial improvement, compared to the full sample, the percentage increase is much smaller. Therefore, the effect of the carbon emissions trading industry on improving the environmental performance of high-pollution industries is relatively smaller compared to that of all pilot enterprises. Although existing research has also considered high-polluting companies [24], this paper uses the DDD model to directly compare the regression coefficients of high-polluting companies with those of all companies, which can more intuitively demonstrate the impact of CET on the environmental performance of high-polluting companies.

Table 4. Regression results of the effect of CET on environmental performance.

Variables	(1) EP	(2) EP	(3) EP	(4) EP
<i>DID</i>	1.808 *** (3.412)	2.113 *** (3.979)		
<i>DDD</i>			1.529 * (1.658)	1.540 * (1.678)
<i>Size</i>		0.380 (1.116)		0.353 (1.035)
<i>Lev</i>		0.731 (0.564)		0.435 (0.336)
<i>ROE</i>		3.871 *** (3.830)		3.824 *** (3.775)
<i>Top1</i>		9.473 *** (5.093)		9.070 *** (4.872)
<i>Cashflow</i>		1.286 (0.701)		1.257 (0.683)
<i>Growth</i>		−0.321 (−1.080)		−0.311 (−1.045)
<i>SOE</i>		−0.442 (−0.483)		−0.357 (−0.390)
<i>lnGDP</i>		−1.224 (−0.853)		−1.117 (−0.777)
<i>GDP2</i>		−6.979 (−1.371)		−6.270 (−1.230)
<i>Constant</i>	9.222 *** (27.303)	7.563 (0.618)	9.218 *** (27.249)	7.424 (0.605)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3054	3054	3054	3054
R ²	0.245	0.259	0.243	0.255

Notes: * and *** indicate significance at the 0.1 and 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.3. Robustness Tests

4.3.1. Parallel Trend Test

One of the important conditions necessary for applying the DID model is meeting the parallel trend assumption. We establish the following dynamic treatment effects model to test parallel trends.

$$EP_{it} = \eta_0 + \sum_{s=1}^2 \eta_{pre_s} Treat_{pre_s} \times Post_{pre_s} + \eta_{current} Treat_{current} \times Post_{current} + \sum_{s=1}^6 \eta_{post_s} Treat_{post_s} \times Post_{post_s} + \eta_2 X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (6)$$

where *pre_s*, *current*, and *post_s* mean *s* years before, the year, and *s* years after the policy is implemented, respectively. We obtain coefficient estimates by establishing a dynamic treatment effects model and generate a graph for the parallel trends test (Figure 2). From Figure 2, it is evident that the confidence interval of the *DID* term includes 0 in the pre-policy period, indicating insignificant coefficients. Hence, before policy implementation, there is no significant difference between the treatment and the control groups, validating the parallel trends assumption. After the policy implementation, the coefficients and confidence intervals show an increasing trend. From the third year onwards, the confidence intervals are significant, showing that the CET policy has a significant effect on the treatment group, but the effect has a certain time lag.

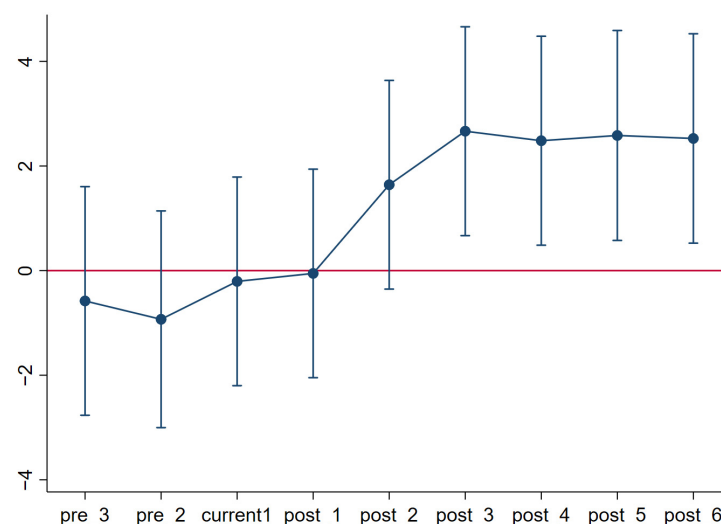


Figure 2. Parallel trend test.

4.3.2. Placebo Test

Environmental performance for companies is influenced by CET policies as well as other unobservable random factors. In the placebo test, this paper uses self-sampling to randomly select the treatment group (147 firms from all firms) and the control group (other firms). We constructed 500 random samples, replicated the baseline regression, and calculated the 500 regression models' estimated coefficients and corresponding *p*-values, as displayed in Figure 3. The solid blue line shows the kernel density curve of the term *DID* coefficients through 500 virtual regressions. The blue empty circles indicate the *p*-values associated with the coefficients of the core explanatory variable. The red vertical line shows the coefficient of baseline regression stated in column (2) of Table 4. The estimated coefficients clustered around 0, as seen in Figure 3., and their *p*-values are mostly above the *p* = 0.1 reference line. To sum up, the influence of CET on environmental performance does not exhibit significant correlation with other unobservable factors.

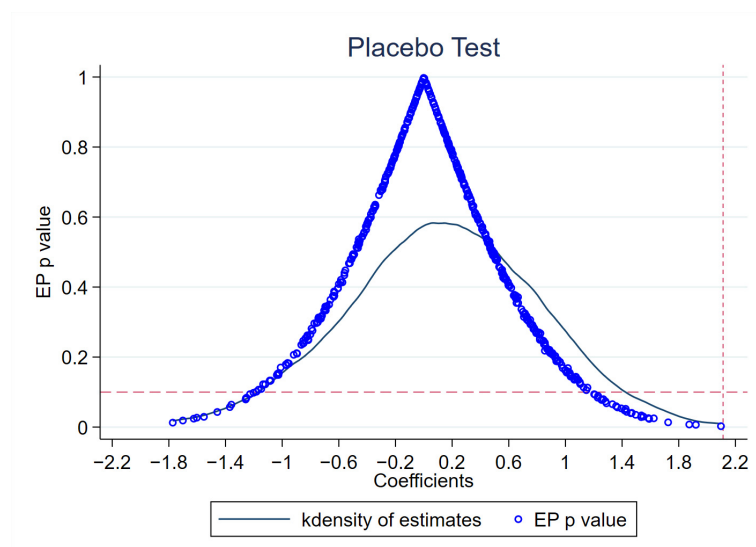


Figure 3. Placebo test.

4.3.3. Propensity Score Matching-DID

We adopt the propensity score matching-DID (PSM-DID) method to avoid estimation errors caused by sample selection bias. Specifically, taking all the control variables as covariates, we match using the kernel and radius matching approaches, and then we estimate DID regression. Following propensity score matching, as indicated in Table 5, the DID term coefficients are 2.106 and 1.761, respectively, which are statistically significant at the 1% level. This is in line with the findings of the baseline regression and verifies the validity of Hypothesis 1, which states that the implementation of the CET policy helps to improve firms' environmental performance.

Table 5. PSM-DID regression results.

Variable	(1) EP-Radius Matching	(2) EP-Kernel Matching
<i>DID</i>	2.106 *** (3.969)	1.761 *** (2.888)
Controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
Observations	3043	2058
R ²	0.258	0.288

Notes: *** indicate significance at the 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.3.4. Dependent Variable Substitution

Replacing the dependent variable with the amount of corporate environmental protection investment (*EI*) and the environmental score (*EP1*) of the ESG Rating Database from Chinese Research Data Services. The specific environmental sub-score is measured by four secondary indicators: climate change, pollution control, circular economy, and environmental risk. The results are displayed in Table 6. The first two columns show that the *DID* and *DDD* terms are all significant in the regressions for *EI*. Unlike the results in Table 4, the coefficient of *DDD* for *EI* in column (2) is larger and more significant than that of *DID* in column (1), demonstrating that CET has a greater effect on the enhancement of environmental protection investment of high-polluting firms. This implies that high-polluting enterprises escalate their environmental protection investments after participating in the CET pilot program, but the enhancement of the environmental scores is relatively slower compared to the increase in environmental protection investment. Columns (3) and (4)

display the regression results for *EP1*. The DID and DDD terms are significant at the 1% level, indicating that CET stimulates the environmental performance. These results are consistent with baseline regression results.

Table 6. Replacement of dependent variables.

Variable	(1) <i>EI</i>	(2) <i>EI</i>	(3) <i>EP1</i>	(4) <i>EP1</i>
<i>DID</i>	0.645 ** (2.521)		2.628 *** (3.457)	
<i>DDD</i>		1.486 *** (4.181)		2.424 *** (3.222)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	1045	1045	3041	3041
R ²	0.093	0.104	0.057	0.054

Notes: ** and *** indicate significance at the 0.05 and 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.3.5. Excluding Other Environmental Policies

We consider the effects of other environmental policies on the results of this paper. First, we consider two national environmental policies: the Air Pollution Prevention and Control Action Plan, implemented in September 2013, and the Environmental Protection Law, implemented in January 2015. The former puts forward a series of specific targets and measures for the prevention and control of air pollution, which may have an impact on the production and management methods of high-emission and high-pollution industries. The latter strengthens the regulatory responsibility of the government and intensifies the punishment for environmental violations, thus bringing about changes in the environmental behaviors of enterprises. Therefore, we excluded the samples from 2014 and 2015 and reconducted baseline regression. The result is shown in column (1) of Table 7, and the results are still significant at the 1% level. In addition, China has implemented three batches of low-carbon city pilot projects in 2010, 2012, and 2017. In order to eliminate the interference of this policy, the variable *LC* is introduced to baseline regression. It equals 1 if the city where the enterprise is located participates in the low-carbon city pilot in the same year and later; otherwise, it is 0. The result is presented in column (2) of Table 7. After adding *LC*, the coefficient of the core explanatory variable *DID* is significant at the 1% level, consistent with the baseline result.

Table 7. Excluding other environmental policies.

	(1)	(2)
Variable	<i>EP</i>	<i>EP</i>
<i>DID</i>	2.873 *** (4.931)	2.093 *** (3.939)
<i>LC</i>		0.629 (0.877)
Firm FE	Yes	Yes
Year FE	Yes	Yes
Observations	2412	3054
R ²	0.157	0.166

Notes: *** indicate significance at the 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.3.6. Substitution of Estimation Method

To address the potential problems of endogeneity and serial correlation, the first-order lag term of the explained variable was added to the benchmark model, and the

Generalized Method of Moments (GMM) was adopted for estimation. The test results are shown in Table 8. Both the AR(1) and AR(2) statistics have passed the significance test, which indicates that the model performs well in eliminating first-order autocorrelation. The coefficient of the first-order lag term of the explained variable is significantly positive. The results of the Sargan test show that there is no over-identification problem with the selected instrumental variables. The regression coefficient of DID remains significantly positive, further verifying the robustness of the benchmark regression results.

Table 8. GMM Estimation results.

	(1)
Variable	EP
L.EP	1.201 *** (0.032)
DID	1.619 ** (0.782)
Controls	YES
Firm FE	YES
Year FE	YES
Observations	2741
AR(1)	0.000
AR(2)	0.205
Sargan	0.104
Hansen	0.476
N	2741

Notes: ** and *** indicate significance at the 0.05 and 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.4. Mechanism Analysis

4.4.1. The Mediating Role of Environmental Management

We use two aspects—environmental quality certification and environmental management system—to characterize environmental management. Environmental quality certification is a crucial method for companies to boost internal environmental management and enhance their external environmental image. The environmental quality certification described in this paper is whether an organization’s environmental management system has passed ISO14001 [56] certification in a given year. Achieving ISO 14001 certification indicates that the organization has met international environmental management standards, ensuring that pollutants, products, and activities are controlled under established requirements. The environmental quality certification variable is represented by *EM1*, which is 1 if the company has achieved ISO14001 certification and 0 otherwise. ISO14001 environmental management system certification helps companies improve environmental management and comply with regulatory requirements. It also reduces environmental incidents, enhances corporate image and reputation, conserves resources, and lowers costs. The environmental management system refers to the completeness of a company’s environmental protection system, including the environmental incident emergency response system, the environmental protection management system, relevant education and training, and the “three synchronizations system” (“Three synchronizations system” refers to the requirement that infrastructure for preventing and controlling pollution in projects of construction should be planned, built, and operationalized concurrently with the main works). The variable *EM2* is defined as 1 if a company discloses any of the multiple systems; otherwise, it is 0. The data is from the CSMAR database.

Table 9 displays the results of the mediation effect model with environmental management as the mediating variable. In Column (1), the coefficient of DID is positive and significant at the 1% significance level, which shows that the CET policy promotes enter-

prises to pass the ISO14001 certification. In Column (2), at the 10% significance level, the coefficient of *DID* is positive and significant, suggesting that the CET policy can encourage companies to establish a comprehensive environmental protection system. Regression results of adding environmental management variables to the baseline model are shown in columns (3) and (4), respectively. The coefficients of *DID* and the environmental management variables *EM1* and *EM2* are all statistically significant and positive, and the absolute value of the coefficients of *DID* is smaller than that in the regression in Table 4, which suggests that the CET policy can promote the environmental performance by facilitating companies to obtain the environmental quality certification and improve the environmental management system.

Table 9. The results of the environmental management mechanism.

Variable	(1) <i>EM1</i>	(2) <i>EM2</i>	(3) <i>EP</i>	(4) <i>EP</i>
<i>DID</i>	0.097 *** (4.472)	0.040 * (1.863)	1.131 ** (2.558)	1.342 *** (3.028)
<i>EM1</i>			3.215 *** (8.743)	
<i>EM2</i>				2.529 *** (6.811)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3054	3054	3054	3054
R ²	0.052	0.049	0.249	0.239

Notes: *, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.4.2. The Mediating Role of Green Innovation

Companies are under certain pressure to reduce pollution after participating in CET pilots. In the short term, they may be able to meet the requirements by reducing production or purchasing carbon emission quotas, but in the long term, they still need to be supported by green innovation. Green innovation is the driving force of green development for enterprises. Through green innovation, companies can manufacture superior green products, mitigate environmental pollution, and enhance environmental performance. We use two variables, *GI1* and *GI2*, to measure green innovation. *GI1* is the logarithm of green invention patent applications plus 1. *GI2* is the logarithm of green utility model patent applications plus 1. The data is from the CSMAR database.

A mediation effect model is established with green innovation being the mediating variable, and Table 10 displays the outcomes. The *DID* coefficients in columns (1) and (2) are both significant at the 1% significance level and positive, suggesting that CET policy increases the number of green invention patents and green utility model patents. Columns (3) and (4) show the results of adding the green patent variable to the benchmark regression. The *DID* coefficients and green innovation variables *GI1* and *GI2* are all significant and positive. Furthermore, the smaller absolute values of the coefficients of *DID* compared to those in the benchmark regression imply that the CET policy fosters environmental performance through the encouragement of green innovation within enterprises.

Table 10. The results of the green innovation mechanism.

Variable	(1) <i>GI1</i>	(2) <i>GI2</i>	(3) <i>EP</i>	(4) <i>EP</i>
<i>DID</i>	0.330 *** (5.464)	0.239 *** (4.935)	2.083 *** (3.973)	2.125 *** (4.008)
<i>GI1</i>			0.925 *** (4.548)	
<i>GI2</i>				0.620 *** (2.755)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3054	3054	3054	3054
R ²	0.080	0.083	0.264	0.261

Notes: *** indicate significance at the 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.4.3. The Moderating Role of Government Environmental Subsidy

Government environmental subsidy is an effective way for enterprises to obtain environmental protection funds and increase environmental protection investment. To test Hypothesis 5, we introduce the variable government environmental subsidy and model (5), referring to [57]. The government subsidy data is compiled from the subsidy data of the non-operating income part of the annual report of listed companies, mainly including scientific research subsidies, energy conservation and emission reduction subsidies, and technology improvement subsidies. There are two variables of government environmental subsidy, namely *GES1* and *GES2*. *GES1* is the natural logarithm of government environmental subsidies plus one. *GES2* is the government environmental subsidy divided by total assets.

Table 11 shows that the coefficients of *DID* × *GES1* and *DID* × *GES2* are significantly positive at the significant level of 1%, indicating that government environmental subsidies play a positive moderating role between CET and environmental performance. It verifies the Hypothesis 5. The carbon trading system requires enterprises to pay for their carbon emissions, which increases the operating costs. Government environmental subsidies can partially or completely offset these costs, thereby reducing the emission reduction costs. This makes companies more motivated to adopt environmental protection technologies and measures to reduce carbon emissions and pollutant emissions when facing the pressure of carbon trading, so as to improve their environmental performance.

Table 11. The results of the government environmental subsidy mechanism.

Variable	(1) <i>EP</i>	(2) <i>EP</i>
<i>DID</i>	2.421 *** (4.170)	1.816 *** (3.243)
<i>GES1</i>	0.041 * (1.889)	
<i>DID</i> * × <i>GES1</i>	0.146 *** (3.052)	
<i>GES2</i>		25.149 (0.360)
<i>DID</i> × <i>GES2</i>		0.797 *** (3.117)
Controls	YES	YES
Firm FE	YES	YES
Year FE	YES	YES
Observations	3054	3054
R ²	0.170	0.144

Notes: * and *** indicate significance at the 0.1, and 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.5. Heterogeneity Analysis

4.5.1. Heterogeneity of Corporate Property Rights

In China, state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs) possess distinct property rights attributes. Therefore, the CET policy may have a heterogeneous impact on SOEs and non-SOEs. As seen in Table 12, we separate the entire sample into SOEs and non-SOEs, creating DID models for each group. Column (1) shows that the *DID* coefficient for SOEs is 2.001 and significant at the 1% level of significance, which indicates that the CET policy exerts a significant improvement in the environmental performance of SOEs. Conversely, in column (2), the *DID* coefficient for non-SOEs is 1.567, which is statistically insignificant, indicating that CET has no significant positive effect on the environmental performance of non-SOEs. In contrast to non-SOEs, SOEs exhibit a more proactive and quicker response to relevant policies. Additionally, SOEs often prioritize environmental protection and sustainable resource utilization in their developmental processes. On the other hand, non-SOEs tend to focus more on immediate economic benefits and might not prioritize environmental policies as much, resulting in relatively slower improvements in environmental performance.

Table 12. Heterogeneity of property right, scale, and industry.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Property Right SOE	NSOE	Scale Large	Small	Industry Power	Other
<i>DID</i>	2.001 *** (3.153)	1.567 (1.544)	2.852 *** (3.335)	0.574 (1.089)	8.817 *** (4.686)	2.185 *** (3.556)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1986	1068	1523	1531	189	2223
R ²	0.286	0.246	0.398	0.079	0.376	0.155

Notes: *** indicate significance at the 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.5.2. Heterogeneity of Corporate Size

Different-sized enterprises exhibit substantial differences in development strategies and economic capabilities. Consequently, CET policies might generate heterogeneous effects across enterprises of varying sizes. Employing the median of total assets within the sample as a benchmark, companies exceeding this benchmark are categorized as large enterprises, while those below it are considered small-scale enterprises. Group regression is carried out to investigate the impact of CET policy on environmental performance across various firm sizes, as shown in Table 12. In Column (3), for large-scale enterprises, the *DID* coefficient is 2.852 and significant at a 1% significance level. The *DID* coefficient for small-scale firms in Column (4) is 0.574 but statistically insignificant. When companies are engaged in carbon emission trading, they need to purchase carbon emission quotas, which will increase their operating costs. Meanwhile, companies will increase their investment in environmental protection to reduce future carbon emission expenditures. However, these environmental protection investments often require substantial capital expenditures and occupation of funds, which may lead enterprises into a debt dilemma. With the increase in costs and financing pressure, for the companies with smaller scales and weaker financial strength, it is indeed difficult to reduce carbon emissions in a short period of time. As a result, there has been no significant improvement in environmental performance either. On the contrary, large-scale enterprises possess more funds for technological innovation and use more energy-efficient and environmentally friendly equipment for production. Moreover, larger companies typically shoulder more social responsibilities, leading to more proactive responses to new policies, timely adjustments in business strategies, and

improved environmental performance. Consequently, large-scale businesses are more significantly impacted by the CET system.

4.5.3. Heterogeneity of Industries

Carbon emission trading policy, as a market-oriented environmental regulatory approach, is designed to encourage enterprises to reduce carbon emissions through economic incentives. However, given the significant differences in production processes, energy structures, and other aspects among various industries, the impact of this policy on the environmental performance of different industries may exhibit pronounced heterogeneity. We carry out a heterogeneity analysis of the key carbon emissions trading industries presented in Table 1. It is found in Column (5) of Table 12 that the CET policy has a significant positive impact on the environmental performance of the power industry. Specifically, the coefficient of *DID* for the power industry is 8.817, far greater than the regression coefficient of other industries, which is 2.185. The *p*-value of the Fisher test for differences between group coefficients is 0.030, indicating that the regression coefficients of the two groups are significantly different. This suggests that the policy has a more significant impact on the power industry. The power industry is one of the key sectors in carbon emissions. Its primary production mode, such as thermal power generation, relies on the combustion of fossil fuels, thus presenting high carbon emission intensity. Under the CET system, due to its large volume of carbon emissions, power enterprises need to purchase a substantial number of carbon emission quotas, significantly increasing their production costs. In response to this pressure, power enterprises have a strong incentive to carry out energy-conservation and emission-reduction technological transformations, such as increasing investment in renewable energy power generation. By doing so, they can reduce their carbon emissions and enhance environmental performance. Given that the power industry is one of the high-polluting and high-energy-consuming industries, this result to some extent validates the significant impact of CET policy on the environmental performance of high-polluting industries.

4.5.4. Heterogeneity of Environmental Regulation

The implementation process of the CET policy will be affected by the environmental supervision of local governments. If the local government attaches importance to environmental protection and introduces a variety of environmental regulations, then these policies can ensure the smooth implementation of CET policies. Since the government work report is the outline of law-based administration, referring to Chen et al. (2018) [58], this paper selects the occurrence frequency of environment-related words in provincial government work reports as the proxy variable of regional environmental regulation, which can comprehensively reflect the government's environmental governance intensity. Firstly, we manually collected the provincial government work reports from 2010 to 2020. Secondly, we processed the government work reports using word segmentation with Python 3.8 software. Finally, we counted the frequency of environment-related words in the reports. Environment-related terms include environmental protection, pollution, energy consumption, emission reduction, ecology, green, low-carbon, sulfur dioxide, carbon dioxide, PM10, and PM2.5. Using the median word frequency as a dividing line, the sample is divided into two parts. Table 13 shows the regression results. In Column (1), for the sample with high word frequency, the *DID* coefficient is 3.603, which is significant at the 1% level, and its value and significance are both much greater than the coefficient in Column (2). This shows that CET policies improve environmental performance more significantly in regions with strong environmental regulations. Stronger local environmental regulations reflect more detailed incentives and penalties for environmental protection by local governments

and enhance the motivation of enterprises involved in carbon trading to improve their environmental performance.

Table 13. Heterogeneity of Environmental Regulation and Awareness.

Variable	(1) Environmental Regulation High	(2) Low	(3) Executive Green Awareness High	(4) Low
<i>DID</i>	3.603 *** (3.687)	1.234 * (1.832)	1.923 *** (2.659)	1.308 (1.936)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	1536	1518	1798	892
R ²	0.259	0.280	0.274	0.159

Notes: * and *** indicate significance at the 0.1 and 0.01 levels. The values in parentheses under the coefficients are t statistics.

4.5.5. Heterogeneity of Executive Green Awareness

The executive team is responsible for the business activities and development strategy of the company. Executives often make decisions and take actions based on their knowledge, experience, and perception. Executive green awareness can be defined as the level of concern and awareness of environmental issues by their unique experience, knowledge structure, and values [59]. Executives' green consciousness is reflected in their willingness and ability to integrate environmental protection, resource allocation, green production, and other factors into business decisions. Referring to Chen et al. (2024) [60], we used text analysis to measure the green awareness of executives. We select keywords from the following aspects: green competitive advantage awareness, corporate social responsibility awareness, and external environmental pressure awareness. Then we calculate the frequency of these words' occurrence in the annual reports. The sample is divided into two groups according to the frequency median. The outcomes are displayed in Columns (3) and (4) in Table 13. The *DID* coefficient is significant at the 1% confidence level in the high executive green awareness group, while it is not significant in the low executive green awareness group. This shows that the green awareness of executives plays an important role in promoting the impact of CET policies on corporate environmental performance. Executives with high green awareness can enable enterprises to actively respond to CET policies, solve difficulties in policy implementation, rationally allocate resources, and thus better improve environmental performance.

5. Discussion

This study investigates the impact of China's CET policy on the environmental performance of A-share listed firms in pilot areas, illuminating the micro-level effects of environmental policies on corporate environmental practices, a subject of growing public concern. We find that the policy considerably enhances the environmental performance of A-share listed firms that participate in the pilot program relative to those in pilot regions that do not participate in the pilot program. The sample selection and research design may have limitations, particularly regarding external validity. In order to ensure the effectiveness of the estimated policy effect, the sample of this paper is the listed companies in the pilot provinces, and the companies in the pilot list are taken as the treatment group. There are differences in economic development among different provinces in China, but the overall social system, laws, and regulations are consistent. Therefore, the conclusions of this paper are expected to apply to the whole of China. In 2021, the national unified carbon market was officially launched, and the number of provinces participating in carbon

trading continues to increase. An updated list of national carbon trading pilot companies can be used to examine the impact of carbon trading policies on a national scale.

Previous studies on environmental performance mainly focused on specific environmental indicators, such as emissions charges, SO₂ emissions [24], or pollution environmental protection expenditures [28]. In contrast, this paper utilizes the environmental score from the ESG rating by the external professional organization Bloomberg. The score encompasses diverse aspects of environmental issues, for example, energy management and environmental supply chain management. This indicator offers a more comprehensive evaluation of environmental performance than single indicators, reflecting a company's overall effectiveness in environmental protection and representing the capital market's perspective on a company's environmental efforts. However, the use of the ESG score as an indicator has limitations, as the scoring process and the individual scores of sub-indicators composing the environmental score are not available. Future research could benefit from exploring environmental scores provided by various external organizations and gaining insights into the composition of the scores for a more detailed analysis.

Additionally, in recent years, China has introduced various environmental regulations and enhanced environmental justice, such as implementing new environmental inspection systems and establishing environmental courts. These developments introduce additional external environmental legal factors influencing environmental performance. These dynamics present an opportunity for more comprehensive research to understand their impact fully.

6. Conclusions

Based on panel data of all A-share listed companies in the first seven pilot provinces or cities from 2011 to 2020, the effect of CET policy on corporate environmental performance is examined. First, we find that the policy enhances the environmental outcomes of the pilot companies. Then, it reveals that the positive impact of CET on heavy polluters is significant but relatively smaller compared to less-polluting companies. After several robustness tests, this conclusion is still valid. Mechanism analysis indicates that the policy promotes environmental performance by enhancing companies' environmental management and fostering green innovation capabilities, while the government environmental subsidies play a positive moderating role. Additionally, the heterogeneity analysis suggests that the policy's impact is more pronounced for SOEs, large enterprises, the power industry, regions with strong environmental regulations, and firms with high executive green awareness. Among the key industries in carbon trading, the power industry has the greatest improvement in environmental performance.

Based on our findings, we provide the following suggestions. Firstly, relevant authorities should develop a comprehensive legal and regulatory framework for carbon emissions trading. Considering the significant impact of CET policy on enterprises, it is essential to create an extensive legal system to ensure policy implementation and safeguard the legitimate rights of enterprises. Enhancing regulation in areas such as environmental protection, taxation, and the carbon financial market is crucial, along with the formulation of detailed penalty measures. Secondly, market-oriented environmental incentive policies need to be combined with appropriate government intervention. For companies participating in carbon trading, the government should provide financial support, tax incentives, and technological assistance. All of these would aim to encourage investment in emission reduction technologies, foster green innovations, support companies in obtaining environmental quality certification, and facilitate the implementation of cutting-edge environmental management systems to enhance environmental performance. Thirdly, carbon trading incentives for different types of enterprises should be differentiated. For

state-owned enterprises, incentive measures can be combined with the performance evaluation of enterprise leaders. For example, carbon emission performance is incorporated into the assessment, salary, and promotion of leadership teams. For private and smaller enterprises, incentive mechanisms mainly revolve around market mechanisms and tax incentives. Preferential policies, such as tax reductions, financial subsidies, and priority access to green finance support, should be provided. Finally, strengthening regional environmental regulations and improving executives' green awareness are important factors in promoting the implementation of CET policies.

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Appendix A

Table A1. Correlation coefficients of variables.

	EP	DID	DDD	Size	Lev	ROE	Top1	Cashflow	Growth	SOE	lnGDP	GDP2
EP	1.000											
DID	0.159 *	1.000										
DDD	0.080 *	0.500 *	1.000									
Size	0.433 *	0.183 *	0.035	1.000								
Lev	0.198 *	0.063 *	−0.025	0.661 *	1.000							
ROE	0.024	−0.015	−0.039 *	0.138 *	−0.060 *	1.000						
Top1	0.141 *	0.045 *	0.127 *	0.185 *	0.042 *	0.085 *	1.000					
Cashflow	0.052 *	0.080 *	0.079 *	−0.074 *	−0.246 *	0.235 *	0.078 *	1.000				
Growth	−0.034	−0.024	0.005	−0.015	0.023	0.248 *	−0.035 *	0.032	1.000			
SOE	0.115 *	0.096 *	0.062 *	0.276 *	0.208 *	−0.027	0.359 *	−0.065 *	−0.081 *	1.000		
lnGDP	0.182 *	0.148 *	0.103 *	0.187 *	0.086 *	−0.064 *	0.159 *	−0.117 *	−0.065 *	0.245 *	1.000	
GDP2	−0.133 *	−0.127 *	−0.096 *	−0.245 *	−0.101 *	0.034	−0.249 *	0.032	0.059 *	−0.271 *	−0.633 *	1.000

Notes: * represents significance at 5% level.

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