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Pilot Policy of Carbon Emission Rights Trading and Enterprise Green Innovation

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Abstract. This study explores the impact of China's pilot carbon emission trading scheme (ETS) on corporate green innovation using a difference-in-differences approach, with data from A-share listed companies spanning 2010-2021. It examines whether the policy drives green patent applications and the mediating role of public attention. Results indicate that the pilot ETS significantly promotes corporate green innovation, with a stronger effect on state-controlled enterprises. Public attention partially mediates this relationship, as the policy enhances public scrutiny, which in turn stimulates firms' green innovation. These findings highlight the effectiveness of market-oriented environmental policies and the role of non-market forces in advancing sustainable development. Based on the research findings, it is suggested to promote enterprises to accelerate green transformation, so as to help achieve carbon emission reduction and sustainable development goals.

Keywords: carbon emission trading pilot policy, corporate green innovation, green patents, public attention, state-controlled enterprises

1. Introduction

In the context of escalating global climate change and the urgent need for carbon neutrality, carbon emission trading schemes have emerged as a pivotal market-based tool to mitigate greenhouse gas emissions [1],becoming an important breakthrough for achieving sustainable development [2]. As a critical component of China's environmental governance strategy, the pilot ETS, launched in 2013 across provinces and cities including Beijing, Tianjin, Shanghai, Guangdong, Hubei, and Chongqing, aims to internalize environmental costs and incentivize low-carbon transitions among enterprises. While existing literature has explored the ETS's impact on emission reductions and energy efficiency [3], its influence on firms' green innovation, a core driver of sustainable development remains underexamined, particularly regarding the mechanisms through which policy pressures translate into innovative activities.

Green innovation, encompassing technologies, processes, and products that reduce environmental harm, is integral to balancing economic growth and ecological sustainability. However, green innovation often entails high R&D costs, long gestation periods, and uncertain returns, creating barriers for firms to invest voluntarily. This raises a key question: Can the pilot ETS, by imposing emission constraints and creating market incentives, stimulate enterprises to enhance their green innovation outputs, such as green patents?

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This study seeks to address this gap by investigating the causal relationship between China's pilot ETS and corporate green innovation. Specifically, it employs a difference-in-differences (DID) approach, where the treatment group comprises firms in pilot regions from 2014 onwards, to isolate the policy's effect. The core explanatory variable (DID) captures the interaction between pilot participation (treat) and post-policy periods (year), while green patent applications (ZLZS) serve as the key measure of green innovation.

Furthermore, this research explores potential mechanisms underlying this relationship, with a focus on public attention (HB), operationalized via Baidu Index searches for "environmental pollution." Public scrutiny may amplify the ETS's pressure on firms, pushing them to adopt green innovation as a legitimacy strategy. Additionally, firm-specific factors such as size (SIZE), financial health (LEV, ROA), and governance characteristics (BOS, MF) are incorporated as control variables to account for heterogeneities in innovation capacity.

This study contributes to the literature in two ways: first, it quantifies the pilot ETS's impact on green innovation, offering insights into policy effectiveness; second, it identifies public attention as a critical mediating factor, enriching understanding of non-market forces in shaping corporate behavior. The findings are expected to inform policymakers on optimizing ETS design to foster sustainable innovation and guide firms in navigating the low-carbon transition.

2. Theoretical analysis and research hypotheses

2.1. Definition of variables

Core Explanatory Variable: DID, indicate the carbon emission trading pilot policy with a dummy variable. This variable is constructed as an interaction term of a regional dummy ($treat_i$) and a time dummy ($year_t$). It takes the value of 1 if a firm is located in one of the pilot regions and the observation year is 2014 or later; otherwise, it is 0.

Explained Variable: ZLZS, number of enterprise green patent applications.It is measured by the total number of green patent applications submitted by a firm within a specific period. This indicator directly reflects the output of a firm's green innovation activities, as patent applications represent formal efforts to develop and protect new environmentally friendly technologies or processes.

Control Variables: In this paper, SIZE(enterprise size), CF(current ratio), LEV(asset-liability ratio), ROA(return on total assets), TAT(total asset turnover), EM(equity multiplier), NPR(property right nature), BOS(board size), AGE(enterprise listing years) are selected as control variables. A set of firm-specific characteristics are included to account for potential confounding factors.

Mediating Variable: HB, public attention. It is proxied by the search volume of the keyword "environmental pollution" in Baidu Index. This variable captures the level of public concern about environmental issues, which may act as an external pressure mechanism influencing firms' green innovation decisions under the carbon trading policy.

This paper selects patent data of A-share listed companies in China's Shanghai and Shenzhen stock exchanges from 2010 to 2021, as well as corresponding economic data of the related enterprises and provinces. The data are derived from CNRDS, CSMAR databases, the China Statistical Yearbook over the years, and other sources. In addition, this paper excludes samples of enterprises labeled as ST, ST*, etc., as well as samples with serious missing or abnormal values of major research variables, and finally obtains 320,259 observations.

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2.2. Theoretical analysis and research hypotheses

2.2.1. The impact of carbon emission trading pilot policy on corporate green innovation

The carbon emission trading pilot policy introduces a market mechanism that internalizes environmental costs by allocating carbon emission permits, thereby creating both pressure and incentives for enterprises to reduce emissions. From the perspective of institutional theory, such policies establish mandatory norms that force firms to adjust their production and operation strategies to comply with emission constraints [4]. For enterprises in pilot regions, exceeding the allocated emission quotas incurs additional costs, while underutilizing quotas allows for profit through trading. This cost-benefit dynamic motivates firms to invest in green innovation as a strategic response to reduce long-term emission costs [5].

From a resource-based view, green innovation, represented by green patents, is a key intangible asset that enhances firms' competitive advantage in a low-carbon economy. The carbon trading policy increases the marginal value of low-carbon technologies, as enterprises with more green patents can achieve emission reductions at lower costs, thereby gaining advantages in quota trading or avoiding penalties [6].Additionally, signal theory suggests that green patent applications can signal a firm's commitment to sustainability, improving its reputation among stakeholders and attracting more resources, which in turn reinforces innovation incentives [7].

Existing empirical studies have shown that environmental regulations can stimulate "innovation offsets" [8], where the costs of compliance are offset by gains from technological advancements. The carbon emission trading pilot policy, as a flexible market-based regulation, is more likely to trigger such offsets compared to command-and-control policies, as it allows firms to choose the most cost-effective emission reduction paths—often through green innovation [9]. Thus, we propose:

Hypothesis 1 (H1):The DID has a positive impact on ZLZS, i.e., enterprises in pilot regions exhibit a significant increase in green patent applications after the policy implementation.

2.2.2. The mediating role of public attention

Public attention (HB), measured by Baidu Index searches for "environmental pollution," acts as a non-market mechanism that amplifies the effects of environmental policies [10]. According to stakeholder theory, enterprises are not only accountable to shareholders but also to the public, who increasingly demand transparency and responsibility in environmental performance [11].High public attention to environmental issues intensifies the social pressure on firms, especially those under the carbon trading policy, to demonstrate their commitment to emission reduction [12].

On one hand, public scrutiny enhances the policy's deterrence effect. When the public is highly concerned about environmental pollution, enterprises violating emission regulations or lagging in green innovation face greater reputational risks. To avoid such risks, firms are more likely to accelerate green innovation activities as a legitimacy strategy, using green patents to signal their environmental responsibility. On the other hand, public attention can drive policy enforcement. High search volumes for environmental issues may prompt local governments to strictly implement the carbon trading policy, reducing the possibility of regulatory capture and ensuring that firms bear the actual costs of non-compliance, thereby strengthening the incentive to innovate [13].Thus, we propose:

Hypothesis 2 (H2): HB plays a mediating role in the impact of the DID on ZLZS, i.e., the policy increases public attention to enterprises' environmental behavior, which in turn promotes green

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patent applications.

3. Model construction

To empirically examine the impact of the carbon emission trading pilot policy on corporate green innovation, this study employs a DID model, leveraging the quasi-natural experiment of the policy's formal implementation starting in 2014. The six pilot provinces and cities for carbon emission trading, namely Beijing, Guangdong, Hubei, Tianjin, Shanghai and Chongqing, are taken as the treatment group, while the other provinces, autonomous regions and municipalities in China are included in the model as the control group for analysis. The model is constructed based on panel data covering the period 2010-2021.

The core model to test the causal effect of the carbon emission trading pilot policy on corporate green innovation is specified as:

$$ZLZS_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \alpha_2 Control_{i,t} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (1)$$

In Equation(1):The subscript i denotes the region; the subscript t denotes the year. $ZLZS_{i,t}$ represents regional carbon emissions or carbon emission intensity. $DID_{i,t}$ is the core explanatory variable, where $DID_{i,t}=treat_i \times post_{i,t}$. Here, $treat_i$ indicates whether the region is in the treatment group, and $post_{i,t}$ indicates the official implementation time of the carbon emission trading pilot policy in pilot regions. $Control_{i,t}$ represents control variables that vary with regions and time and affect carbon emissions or carbon emission intensity. μ_i denotes firm fixed effect, controlling for unobservable time-invariant firm characteristics; φ_t denotes year fixed effect, controlling for macroeconomic shocks or policy changes that affect all firms in the same year; $\varepsilon_{i,t}$ denotes random error term; α_0 denotes constant term;

Based on the test of the mediating effect of HB, a stepwise regression method is adopted to construct the following three models, aiming to analyze the influence path of the DID on the number of ZLZS through public attention:

Model 2: Testing the Impact of the Policy on the Mediating Variable

$$HB_{i,t} = \gamma_0 + \gamma_1 DID_{i,t} + \gamma_2 Control_{i,t} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (2)$$

In this model, $HB_{i,t}$ is the mediating variable (public attention), and the definitions of other variables are the same as those in formula 1. It is used to test whether the carbon emission trading pilot policy has a significant impact on public attention.

Model 3: Testing the Transmission Effect of the Mediating Variable

$$ZLZS_{i,t} = \theta_0 + \theta_1 DID_{i,t} + \theta_2 HB_{i,t} + \theta_3 Control_{i,t} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (3)$$

On the basis of formula 1, the mediating variable $HB_{i,t}$ is introduced. By comparing the changes in the coefficients of α_1 and θ_1, it is judged whether public attention plays a mediating role in the relationship between the policy and corporate green innovation.

DOI: 10.54254/2754-1169/2025.LH25966

4. Empirical results and robustness analysis

4.1. Descriptive statistics of variables

The descriptive statistical results of the variables used in the model and related tests of this study are shown in Table 2.

Table 1. Descriptive statistical results

Variable	N	Mean	SD	Min	p50	Max
DID	20478	0.290	0.450	0	0	1
ZLZS	20478	0.810	5.670	0	0	347
SIZE	20478	22.25	1.270	19	22.05	28.51
CF	20478	3.970	106.6	0	1.780	12070
LEV	20478	0.400	0.240	0	0.390	10.50
ROA	20478	0.0400	0.120	-4.950	0.0400	1.410
TAT	20478	0.630	0.470	0	0.530	11.34
EM	20478	3.870	199.6	-339.2	1.620	26070
NPR	20478	0.280	0.450	0	0	1
BOS	20478	8.530	1.670	0	9	18
AGE	20478	8.690	7.310	0	7	31

4.2. Baseline Regression Results

Baseline Regression Results Table 3 reports the baseline regression results regarding the impact of the carbon emission trading pilot policy on corporate green innovation. The coefficient of DID is 1.123, which is significantly positive at the 1% level, indicating that the policy significantly promotes enterprises' green patent applications. This supports Hypothesis1, confirming that market-oriented environmental regulations can effectively drive corporate green innovation.

Table 2. Baseline Regression Results

	(1)
	ZLZS
DID	1.123^{***}
	(0.0941)
Controls	YES
Ind FE	YES
Year FE	YES
N	20478
R^2	0.122
adj. R^2	0.109

DOI: 10.54254/2754-1169/2025.LH25966

4.3. Parallel trend test

From the parallel trend test results graph, before the policy implementation, the policy effect coefficients were close to 0 with confidence intervals containing 0, meaning there was no significant difference in trends between the treatment and control groups, fulfilling the parallel trend assumption. At the time of policy implementation, the policy effect coefficient started to increase, showing a difference emerged between the two groups in the outcome variable. After the policy implementation, the coefficients fluctuated but were significantly non-zero,indicating a continuous and significant impact on the treatment group and a persistent difference.

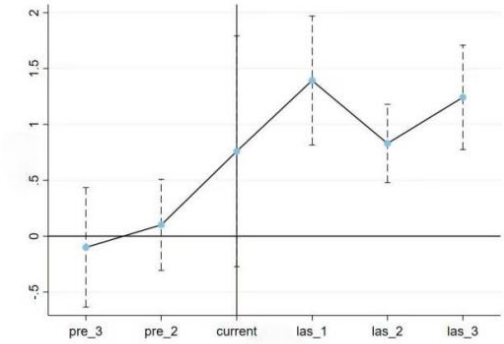

Figure 1. Parallel trend test of the carbon emission trading policy on enterprises' green innovation

4.4. Robustness test

4.4.1. Replace the core dependent variable

To verify the reliability of the baseline results, Table4 (1) replaces the explained variable with ZLHD(the number of green patents obtained by enterprises). The coefficient of DID is 0.544 ($p<0.01$), which is significantly positive, consistent with the baseline conclusion.

Table 3. Robustness test

	(1)	(2)
	ZLHD	ZLZS
DID	0.544***	1.123***
	(0.0547)	(0.0941)
BM		0.0522
		(0.297)
MF		-0.00116
		(0.00440)
Controls	YES	YES
Ind FE	YES	YES
Year FE	YES	YES
N	20478	20478
R^2	0.122	0.122
adj. R^2	0.109	0.109

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4.4.2. Add control variables

Table6 (2) adds two more control variables:BM(book-to-market ratio) and MF(management efficiency). The coefficient of DID remains 1.123 ($p<0.01$),indicating that the baseline results are robust to the inclusion of additional control variables.

4.4.3. Placebo test

Although the previous analysis has validated that the model satisfies the parallel trend assumption, it is still necessary to prevent changes in the post-treatment group and control group from being influenced by other policies or random factors. To avoid systematic biases caused by human factors or variable loss in regression results, this paper further conducts a placebo test to ensure the robustness of research conclusions.

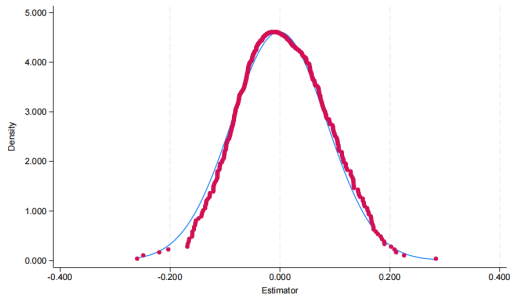

Figure 2. Placebo test results

It can be observed in Figure 2 that the majority of the estimator values are clustered around 0, with the highest density concentrated near the 0 point. This suggests that the placebo effects are centered around 0, indicating that there is no systematic bias or spurious correlation driving the results in the placebo scenarios. Such a distribution strengthens the reliability of the original empirical findings. It implies that the significant effect observed in the actual analysis is unlikely to be due to random chance or unobserved confounding factors, thus supporting the validity of the core conclusion.

4.5. Heterogeneity analysis

According to the results of the heterogeneity analysis in Table 5, with NPR as the classification criterion, there are significant differences between state - controlled enterprises (Column 1) and other enterprises (Column 2) in the impact of DID and control variables on ZLZS.In terms of the impact of DID, both groups show a significant positive effect, but the coefficient of state - controlled enterprises is 1.297, which is larger. This indicates that the policy has a stronger promoting effect on the number of green patents of state - controlled enterprises.The reason may be that state - owned enterprises usually have a stronger policy and system advantage, thus obtaining more government funds and resource allocation, and they also have extensive external financing channels, with a stronger ability to acquire external capital factors [14]. The important role of state-owned enterprises in economic development and their own political responsibilities make them obliged to actively respond to and implement the national environmental policies, and more sensitive to the pilot policy of carbon emission trading [15].

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Table 4. Heterogeneity analysis of property rights nature

	(1)	(2)
	ZLZS	ZLZS
DID	1.297***	1.001***
	(0.191)	(0.106)
Controls	YES	YES
Ind FE	YES	YES
Year FE	YES	YES
N	5796	14682
R^2	0.339	0.055
adj. R^2	0.314	0.038

4.6. Mediation effect analysis

Table 6 tests the mediating role of HB using a stepwise regression method.Column(1) shows that DID has a significantly positive impact on HB, indicating that the policy significantly increases public attention to enterprises' environmental behaviors.Column(2) includes both DID and HB. The coefficient of HB is 0.126, which is significantly positive, while the coefficient of DID remains significant. This confirms that public attention plays a partial mediating role in the relationship between the policy and green innovation, supporting Hypothesis 2.

Table 5. Mediation effect analysis

	(1)	(2)
	HB	ZLZS
DID	0.318***	1.190***
	(0.0188)	(0.121)
HB		0.126**
		(0.0548)
Controls	YES	YES
Ind FE	YES	YES
Year FE	YES	YES
Controls	YES	YES
N	13845	13845
R^2	0.210	0.059
adj. R^2	0.195	0.041

5. Conclusions and recommendations

Based on the micro-data of Chinese listed companies from 2010 to 2021, this paper empirically examines the impact of the pilot carbon emission rights trading policy on corporate green innovation using DID estimation. A systematic analysis is conducted through parallel trend test, robustness test,

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placebo test, heterogeneity test, and transmission mechanism test, and the following conclusions are drawn:

First, the empirical results consistently demonstrate that ETS exerts a significant and positive impact on corporate green innovation. The robustness of this conclusion is reinforced by multiple rigorous tests;Second,from the perspective of heterogeneity analysis, the policy's impact on green innovation varies significantly across firms with different NPR. State-controlled enterprises benefit more strongly from the ETS;Last,from the mediation effect analysis, public attention (HB) emerges as a critical partial mediator in the relationship between the ETS and corporate green innovation.

Based on the above research findings, this paper proposes the following countermeasures and suggestions:

Policy-Making Level: Optimize carbon quota allocation by linking it to green patent output, rewarding high-innovation enterprises. Expand pilot coverage to unify the national market. Combine ETS with green financial support and tax breaks to reduce firms' R&D costs.

Enterprise Level: State-owned enterprises should leverage policy advantages to lead low-carbon tech R&D. All firms need to boost green innovation investment, focus on core patent layout, and use green patents to respond to public concern and enhance reputation.

Government Supervision: Strengthen enforcement of carbon trading rules, prevent regulatory capture, and ensure non-compliant firms bear costs. Use public attention data to monitor corporate environmental behavior and drive policy implementation.

Public Participation: Improve environmental information disclosure to facilitate public supervision. Popularize knowledge of carbon trading and green patents to guide consumer preference for green products, pressuring enterprises to innovate.

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