The Impact of Carbon Emissions Trading Policy on Green Technology Innovation: Evidence from China's A-Share Listed Firms

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Abstract. By setting against China's carbon neutrality goal, this paper examines if carbon emissions trading policy (ETS) promotes green technology innovation among regulated firms, and investigates underlying mechanisms. Using an unbalanced panel of 4,965 firms and 46,744 firm-year data points drawn from listed A-share companies in China during 2010–2024, we manually identify firms subject to carbon allowance management and employ a multi-period difference-in-differences approach to estimate policy effect. The results show that ETS significantly promotes firms' green technology innovation. Further analysis shows that this effect is mainly caused by substantive green technology innovation, as reflected in applications for green invention patents; for strategic green technology innovation, captured by applications for green utility model patents, the estimated effect does not reach statistical significance. Robustness checks based on event-study analysis, placebo tests, PSM-DID, alternative measures, and alternative estimation specifications support the baseline findings. Mechanism discussion suggests that carbon emissions trading stimulates green technology innovation by raising research and development R&D intensity and easing financial pressure. These findings suggest that a well-designed carbon market generates both environmental and technological benefits with micro evidence for strengthening carbon market development and innovation-oriented environmental regulation in China.

Keywords: ETS, Green technology innovation, Regulated firms, DID

1 Introduction

Under the background of China's carbon neutrality goal, ETS serves as an environmental policy tool that relies on the functioning of the market. Whether it can encourage green technology innovation among regulated firms and by which mechanisms remains an unresolved empirical project. Current research has paid relatively limited attention to regulated firms, the direct micro-level targets of emissions trading policies, and have rarely distinguished between firms' strategic responses and substantive responses to such policies. Moreover, the mechanisms through which emissions trading stimulates green technology innovation among regulated firms remain insufficiently understood. Against this background, this paper

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focuses on regulated firms covered by China's emissions trading system. By manually identifying companies involved in ETS to construct treatment and control groups (Guo et al., 2025), using a multi-period DID approach, this paper examines the effect of ETS on green technology innovation among regulated firms, and investigates the roles played by research and development intensity and funding limitations as potential transmission channels.

This paper makes 3 main contributions. First, it examines whether market-based environmental regulation can simultaneously promote environmental protection and technology innovation in China, thereby extending the understanding of applicability of the Porter Hypothesis in China's context. Second, by focusing on regulated firms—the key micro-level compliance entities under the emissions trading system—the paper offers a more precise assessment of the microeconomic influences of emissions trading. Third, it sheds light on the underlying mechanisms through which emissions trading affects firms' green technology innovation, thereby enriching the literature on how market-based environmental regulation influences firms' green innovation.

2 Theoretical Analysis and Research Hypotheses

2.1 ETS and Green Technology Innovation of Regulated Firms

The ETS internalizes external costs of carbon emissions and uses carbon allowance price signals to guide firms in balancing the costs of emission reduction against the costs of purchasing allowances. Its incentive effects operate mainly through two channels. First, compliance cost pressure: firms can lower expenses through green technology innovation and generate revenues by selling surplus allowances, thereby encouraging the reallocation of resources toward low-carbon R&D. Second, carbon price signals: the price mechanism formed in the carbon market provides firms with incentives to reduce emissions (Huang et al., 2024). Meanwhile, the financial asset characteristics of carbon allowances enhance the market recognition of green innovation, prompting companies to embed green innovation within their long-term business plan. Carbon emissions trading can assist firms' green innovation with high environmental regulations and improving resource allocation efficiency (Liu et al., 2025).

Compared with strategic green innovation, ETS is expected to exert a stronger incentive effect on substantive green innovation. For one thing, substantive innovation generally generates more stable and persistent emission reductions and offers greater long-term economic returns. For another, under sustained carbon constraints, strategic innovation alone cannot achieve a substantial reduction in overall carbon emissions, leaving firms subject to considerable allowance settlement costs. To secure long-term competitive edges, regulated firms therefore have stronger incentives to allocate their core resources toward substantive green technology innovation capable of achieving a deeper decarbonization (Zhang & Qi, 2025). Accordingly, we put forward the following hypothesis:

H1: Substantive green innovation among regulated firms is significantly boosted by ETS, whereas strategic green innovation does not show a statistically meaningful response.

2.2 Mediating Mechanisms

ETS can improve firms' expectations regarding the future returns from emission reductions, enabling them to incorporate the potential benefits of future carbon abatement more fully into their R&D decisions. This reduces the uncertainty associated with R&D activities and encourages enterprises to engage in green research and development. The establishment of a carbon market also endows carbon allowances with distinct financial asset characteristics. Regulated firms can obtain direct cash flows by selling surplus allowances and can further broaden their financing channels through allowance-backed pledges. Further evidence suggests that the financing environment of high-emission companies appears to benefit from carbon emissions trading policies, and ETS also alleviates funding limitations through innovation incentives (He & Zhang, 2024). Accordingly, we put forward the following hypotheses:

H2: ETS enhances green technology innovation among regulated firms by increasing their investment in R&D intensity.

H3: ETS promotes green technology innovation among regulated firms by easing their funding restrictions.

3 Research Design

3.1 Source of Research Data

The initial sample consists of all firms listed on the A-share markets in Shanghai and Shenzhen and we construct an unbalanced panel dataset covering 2010–2024. Firms that were included in the carbon allowance management system are classified as treated firms, while firms not subject to the carbon allowance management system act as control group. After data cleaning, final sample comprises 4,965 publicly listed companies and 46,744 firm-year samples. Firm-level annual inclusion in the carbon market compliance list is manually identified and matched using publicly available carbon market information and relevant documents issued by the ecological and environmental authorities of pilot regions. Financial data are drawn from the China Stock Market & Accounting Research Database (CSMAR) and WIND, while green patent records are retrieved from China Research Data Services (CNRDS).

3.2 Definition of Variables

Dependent Variable. Firms' green technology innovation is captured by the count of applications for green patents. To further analyze innovation quality, green technology innovation is decomposed into essential innovation, captured by applications for

green invention patent, and strategic innovation, proxied by green practicality patent applications.

Independent Variable. The ETS shock is captured by the interaction term between the policy indicator and the time indicator. Specifically, the indicator is set equal to 1 if company i is included in the carbon allowance management system in year t, and 0 otherwise.

Mechanism Variable. We quantify R&D intensity by dividing a firm's yearly R&D spending by its revenue from operations.

Funding limitations. Firms' funding limitations are gauged with the SA index.

$$SA = -0.737 \times Size + 0.043 \times Size^2 - 0.040 \times Age \quad (1)$$

Firm size is proxied by Size, with the value computed as the natural log of total assets at fiscal year-end(in millions of yuan), and Age denotes firm age. The SA index is generally negative, and its larger absolute magnitude reflects greater funding limitations. Table 1 reports main indicators definition.

Table 1. Definition of variables.

Variable type	Variable	Symbol
Dependent Variables	Green Technology Innovation	GTI_1
	Essential Green Technological Innovation	GTI_2
	Strategic Green Technological Innovation	GTI_3
Core Explanatory Variable	Carbon Emissions Trading Policy	CETP
Mediating Variables	R&D Intensity	RDI
	Funding limitations	SA

3.3 Model Specification

Baseline Regression Model. Exploiting the natural experiment created by the heterogeneous policy shocks associated with pilot carbon emissions trading programs across different provinces, cities, and firms, we construct the following multi-period DID model. β_1 measures the mean policy effect of ETS on firms' green technology innovation:

$$GTI_{it} = \beta_0 + \beta_1 DID_{it} + \beta_2 Controls_{it} + \mu_i + \eta_t + \varepsilon_{it} \quad (2)$$

Mechanism Test Model. Given that the conventional stepwise regression approach may yield biased estimates in the presence of endogeneity in the mediating variables, we adopt a "preceding-effect verification–logical reasoning" framework. Specifically, we examine only the influence of policy variables on mechanism variables and assess the validity of the mediation pathways based on theoretical reasoning. The corresponding empirical model is specified as follows:

$$RDI_{it} = \beta_0 + \beta_1 DID_{it} + \beta_2 Controls_{it} + \mu_i + \eta_t + \varepsilon_{it} \quad (3)$$

$$SA_{it} = \gamma_0 + \gamma_1 DID_{it} + \gamma_2 Controls_{it} + \mu_i + \eta_t + \varepsilon_{it} \quad (4)$$

It is noteworthy that the construction of SA index already incorporates firm size. To avoid multicollinearity, it is therefore excluded from the SA regression, while all other control variables remain the same as those in the previous main regression.

4 Empirical Results and Analyses

4.1 Descriptive Analysis

Table 2 summarizes the descriptive analysis for the key variables.

Table 2. Descriptive analysis

Variable	N	Mean	Std. Dev.	Min	Median	Max
GTI_1	46,744	0.426	0.870	0	0	7.062
GTI_2	46,744	0.306	0.732	0	0	6.901
GTI_3	46,744	0.235	0.609	0	0	6.080
CETP	46,744	0.031	0.172	0	0	1
RDI	46,744	0.053	0.059	0.0002	0.038	0.352
SA	46,744	-3.854	0.273	-4.557	-3.851	-3.171

4.2 Regression Results

Table 3 presents the primary regression results. The level of regulated firms' green technology innovation rises significantly under the impact of ETS (β=0.127, p<0.01). Further analysis shows that the policy significantly enhances applications for green invention patents (β=0.110, p<0.01), showing that ETS pushes forward substantive green technology innovation. In contrast, its effect on green utility model patent applications is statistically insignificant (β=0.020, p>0.1), thus supporting H1.

Table 3. Main Regression Results

	GTI_1	GTI_2	GTI_3	RDI	SA
CETP	0.127^{***}(3.43)	0.110^{***}(2.91)	0.020(0.69)	0.005^{***}(2.79)	0.013^{**}(2.21)
Controls	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
N	46744	46744	46744	46744	46744
Adjusted R^2	0.690	0.678	0.603	0.820	0.956

4.3 Robustness Checks

The results of the robustness checks are shown in Fig. 1 and Fig. 2. According to the event-study findings, none of the pre-treatment coefficients reaches statistical significance, supporting the assumption of parallel trends. The persistently positive and statistically significant post-treatment coefficients further show that the positive impact on ETS among regulated firms is persistent and robust. Furthermore, firms are randomly placed into the treatment group to carry out a placebo test. The placebo results provide further evidence that the observed positive effect cannot plausibly be attributed to random assignment or other spurious correlations.

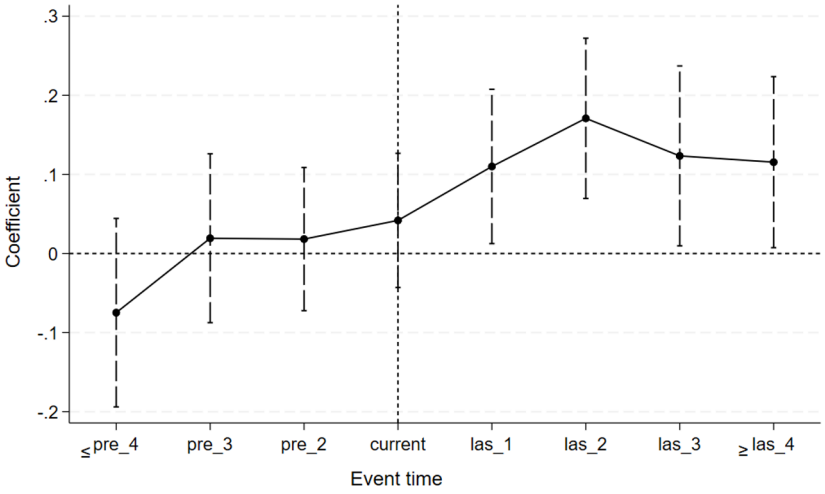


Fig. 1. Parallel Trends Test

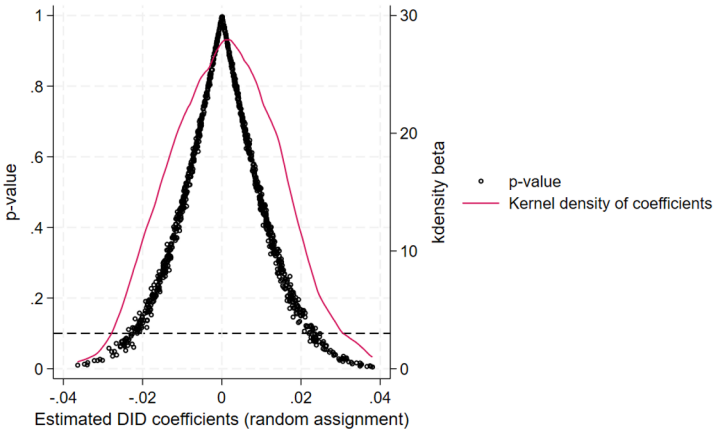


Fig. 2. Placebo Test

Further robustness checks are conducted using PSM-DID, alternative measures of the dependent variable, heterogeneity-robust estimators to address the negative-weight problem in multi-period DID models, and industry-by-year interaction fixed effects. The core findings remain robust across these specifications.

4.4 Mechanism Analysis

Table 3 further shows the evidence obtained from the mechanism tests. ETS significantly increases R&D intensity of regulated firms ($\beta=0.005$, $p<0.01$). It also significantly increases the SA index ($\beta=0.013$, $p<0.05$); given that a higher SA value indicates weaker funding limitations, this result shows that the policy effectively alleviates firms' funding limitations. From the theoretical perspective, existing literature has commonly found that higher R&D intensity significantly promotes green technology innovation among firms, as well as the positive role on alleviating funding limitations. Therefore, ETS promotes green technology innovation by two different paths: increasing the intensity of R&D and easing funding limitations, thus supporting H2 and H3.

5 Conclusions and Research Implications

Our findings show that ETS effectively reinforces green technology innovation among regulated firms, with the effect primarily reflected in improvements in essential green innovation. The mechanism test further indicates that increased R&D intensity and alleviated funding limitations form important channels through which the policy promotes green innovation. This paper provides micro-level evidence that carbon emissions trading can generate both environmental and innovation benefits among regulated firms. The findings highlight the importance of aligning carbon market incentives with high-quality green innovation. Accordingly, we should strive to further strengthen the development of the national carbon market, enhance incentive mechanisms oriented toward substantive emission reductions and high-quality green innovation, and develop carbon finance to improve the financing environment for firms' green R&D.

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Disclosure of Interests. The authors have no competing interests to declare that are related to the content of this paper.

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