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The Impact of Carbon Emission Trading Policy on Corporate ESG Performance

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Abstract. This study regards China's regional carbon trading pilot schemes as a quasi-natural experimental scenario, and adopts the double-difference (DID) estimation model to carry out an in-depth exploration of the impact results, operational paths and differential traits generated by this policy on the sustainable development performance reflected in corporate ESG dimensions. The empirical outcomes of the investigation indicate that the carbon emission trading mechanism can markedly elevate the comprehensive ESG rating levels of enterprise subjects. Its internal logic is realized through a composite mechanism of "external supervision-internal value creation-capital coordination", that is, while the policy strengthens market attention and reputation supervision, it promotes the transformation of ESG from compliance cost to development capital by improving green profitability and alleviating financing constraints. Heterogeneity analysis shows that there are structural differences in policy effects, which are particularly significant in non-capital-intensive, non-heavy-polluting enterprises and those with CEO duality separation, reflecting the moderating role of resource flexibility and governance efficiency. From the perspective of transmission mechanism and heterogeneity, this study reveals the internal process of market-oriented environmental regulation reshaping the resource and incentive structure of enterprises, and provides empirical evidence for improving carbon market design and implementing differentiated ESG strategies.

Keywords: Carbon Emission Trading, Corporate ESG Performance, External Monitoring, Internal Resources

1. Introduction

Against the backdrop of global low-carbon transition, refining the institutional system of carbon emission trading scheme (ETS) stands as the pivotal link to realize the "Dual Carbon" strategic goals (i.e., carbon peaking and carbon neutrality) and establish a market-led environmental governance system. Since 2013, China has launched pilot projects of carbon emission trading, which internalize the external costs of environmental damage through price-based mechanisms. Such policy practice plays a positive role in monitoring and restricting industrial pollution emissions, guiding capital inflow into low-carbon fields and boosting the effectiveness of resource allocation. By adopting the difference-in-differences (DID) econometric model, this paper conducts an in-depth investigation into how carbon trading policies affect the integrated environmental, social and governance (ESG)

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performance of micro enterprises, and identifies the mediating transmission channels from the perspectives of analyst attention, corporate profitability and financing constraints. The core purpose of this research is to provide micro empirical support for assessing the implementation effects of carbon emission trading policies.

Drawing on extant academic research, this paper takes the ETS pilot program as a quasi-natural experiment to examine its influence on firms' holistic ESG performance. The marginal contributions and innovations of this study are embodied in three dimensions: First, broadening the scope of research samples. Unlike prior studies that concentrate on high-pollution manufacturing sectors like electric power and iron and steel, this paper centers on non-manufacturing enterprises. This analytical angle helps verify the general applicability of market-based environmental regulation across diverse industrial segments and explore the ESG response tactics adopted by non-manufacturing industries. Second, enriching the research dimension. Most current studies pay attention to carbon abatement effects or green technology innovation, while rare literature integrates the comprehensive driving effect on ESG into a unified analytical framework. This research supplements and optimizes the evaluation system for the micro performance of carbon trading policies, and systematically measures the synergistic influence of such policies on the environmental, social and governance pillars of non-manufacturing firms. Third, further advancing the mechanism analysis and empirical validation. This paper builds a multi-channel transmission mechanism model, empirically tests the three mediating paths including external attention, corporate profitability and financing constraints, and adopts robustness test methods such as PSM-DID to ensure the credibility and stability of empirical results. Moreover, heterogeneity analysis is implemented to detect the differential policy effects caused by industrial characteristics and corporate governance heterogeneity. The empirical results reveal that refining and extending market-based environmental regulation tools can effectively drive a wide range of enterprises (including non-manufacturing entities) to upgrade their overall ESG performance, which delivers critical policy implications for boosting the green transformation and high-quality development of the national economy.

The structural arrangement of this paper is as follows: Section 2 focuses on theoretical deduction and research hypothesis development; Section 3 expounds the research design and empirical strategies; Section 4 presents the detailed analysis of empirical outcomes; Section 5 further explores the impact mechanism and heterogeneous effects; Section 6 concludes the main findings and proposes targeted policy suggestions.

2. Literature review and theoretical hypotheses

Against the backdrop of in-depth global climate governance practices, the carbon emission trading system (ETS)—as a market-oriented environmental regulation instrument—has become the key approach to resolving the balance between ecological conservation and economic growth. Since China launched its carbon trading pilot projects back in 2013, this system has internalized external environmental costs through price signaling mechanisms, thus driving enterprises to take initiative in advancing their green transformation and upgrading [1]. Meanwhile, the ESG rating—regarded as the core metric for assessing enterprises' sustainable development capabilities—shares a high level of logical consistency with the ETS policy framework [2,3]. Identifying the impact effects and operational mechanisms of the ETS policy on corporate ESG performance can provide theoretical references for optimizing the carbon market system and formulating enterprise sustainable development strategies.

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2.1. The impact of carbon trading policy on corporate ESG

Carbon emission trading regulation boosts the all-round improvement of enterprises' ESG development levels through emission quota constraints and market-oriented incentive mechanisms. Previous relevant studies have confirmed that the pilot carbon trading policy can notably elevate the overall ESG evaluation ratings of covered enterprises [4]. The intrinsic mechanism underlying this policy effect can be summarized into three facets: For the environmental pillar, the emission cap imposed by the policy forces enterprises to increase investment in eco-friendly initiatives and low-carbon technological R&D, which directly elevates firms' environmental performance levels [5]; For the social pillar, the scaling effect derived from carbon trading regulation facilitates the advancement of substantial green innovation, relieves enterprises' funding constraints, and further offers financial support for firms to fulfill their social obligations [6]; For the governance pillar, the carbon trading system transmits green certification signals to draw in eco-conscious investment, thus laying a foundation for enterprises' sustainable governance practices [7]. In light of the aforementioned theoretical deduction and analysis, this paper proposes the following research hypothesis:

Hypothesis 1: The carbon trading policy exerts a notably positive impact on the ESG ratings of enterprises in pilot regions.

2.2. Heterogeneous characteristics of the impact of carbon trading policy on corporate ESG scores

The impact of the carbon trading policy exhibits distinct heterogeneous traits, which are closely associated with enterprises' industrial attributes and internal governance mechanisms. From the perspective of capital intensity, enterprises with high capital intensity tend to show a sluggish response to carbon emission trading regulations and gain limited policy dividends. This is mainly due to their high asset specificity, and they often prioritize other sustainable development strategies over low-carbon transformation [8,9]. In terms of industrial pollution characteristics, non-heavily polluting industries bear relatively low pressure of carbon emission reduction, can obtain economic returns by selling surplus emission quotas, and thus have a stronger motivation to promote low-carbon transition; on the contrary, heavily polluting industries are confronted with enormous costs of emission control and environmental governance, which makes the policy's promoting effect on their ESG performance relatively limited [10]. Regarding internal corporate governance, enterprises that implement the separation of chairman and general manager positions (i.e., the non-duality of CEO and chairman) are able to achieve more scientific resource allocation, balance the interests among economic benefits, social responsibility and environmental protection, and thus display a more proactive ESG response to the carbon trading policy [11]. Based on the above heterogeneous analysis and discussion, this paper puts forward the following research hypothesis:

Hypothesis 2: The promoting effect of the carbon trading policy on corporate ESG performance is heterogeneous; this positive effect is more prominent in non-capital-intensive, non-heavily polluting enterprises and those that separate the positions of chairman and general manager.

2.3. The mechanism of the impact of carbon trading policy on corporate ESG scores

The carbon emission trading regime exerts its regulatory effect through diverse intermediary transmission channels. For the external monitoring channel: Strict environmental governance rules raise the level of market attention received by regulated enterprises, and such external binding pressure pushes firms to strengthen non-financial information disclosure and elevate their

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comprehensive ESG performance ratings [12]. For the profit support channel: The carbon trading mechanism opens up new profit growth space for corporate entities, and the market performance of enterprises with low carbon intensity is significantly more favorable [13]. The improvement of operating profit capacity allows enterprises to expand their investment in environmental protection, forming a virtuous cycle of "policy-driven profit growth and profit-supported green investment" [14]. For the financing facilitation channel: The policy reshapes the credit assessment logic of financial institutions, and provides stable financial support for the improvement of corporate ESG by easing financing restrictions, lowering capital costs and enhancing corporate transparency [15]. Based on the above theoretical analysis and logical deduction, this paper puts forward the following research hypothesis:

Hypothesis 3: The carbon trading policy can indirectly promote the improvement of enterprises' ESG ratings by increasing analyst research attention, enhancing corporate profitability and easing financing constraints.

3. Research design

3.1. Institutional background and research objects

In the context of the global carbon neutrality strategic objective, market-oriented environmental governance instruments have become the core approach to striking a balance between economic advancement and ecological conservation. China launched its carbon emission trading pilot initiatives in 2013, with the first batch covering seven provincial-level administrative regions including Beijing, Shanghai and Guangdong, and established a complete regulatory framework that integrates overall emission cap, allowance allocation, compliance oversight and settlement administration. By 2020, the total cumulative trading quantity of the pilot carbon markets had hit 430 million tons, with the overall transaction value exceeding 10 billion RMB. These pilot markets cover energy-intensive sectors such as electric power, iron and steel as well as chemical engineering, and have grown into one of the largest regional carbon trading platforms across the world.

This study investigates and tests the impact of carbon trading pilot policies on enterprises' ESG performance and its inherent action mechanism. Given that the launch time of each carbon trading pilot differs, the policy effect exhibits time-varying characteristics; for this reason, this study adopts the time-varying difference-in-differences (DID) econometric method to carry out empirical research and analysis. To ensure the reliability and robustness of the research findings, this study defines enterprises located in pilot areas from 2013 to 2020 as the experimental group (with a total of 2,369 sample observations) and enterprises in non-pilot areas during the same period as the control group (with 2,850 sample observations). The relatively balanced sample sizes of the two groups lay a solid empirical foundation for the subsequent research and analysis.

3.2. Difference-in-differences model setting

Given that China's carbon emission trading policy presents the typical attributes of a quasi-experimental setting, this paper adopts the double-difference (DID) estimation approach as its core empirical identification framework. This methodological design can effectively separate policy-driven shocks from other confounding factors by building a comparative structure between the experimental group and the control group. Concretely, this study compares the variations in dependent variables between the two groups both before and after the launch of the carbon trading policy, so as to precisely capture the net causal effect of the policy intervention. Meanwhile, by

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incorporating control variables, firm-level fixed effects and year fixed effects, the econometric model can effectively rule out the disturbances brought by macroeconomic fluctuations and unobserved enterprise-specific inherent characteristics.

Based on the theoretical framework constructed earlier and combined with previous relevant research findings, the benchmark regression specification established in this study is set out as follows:

$$\mathrm{lnESG}_{it} = \alpha_1 + \beta_1 \mathrm{DID}_{it} + \gamma_x \mathrm{X} + \delta_i + \delta_t + \epsilon_{it} \tag{1}$$

Among them, lnESG_{it} represents the natural logarithm of the comprehensive ESG performance score of the i -th enterprise in the t -th year. In this paper, the Huazheng ESG score with more comprehensive data is used; DID_{it} is a 0-1 dummy variable, which takes the value of 1 if the region where enterprise i is located implements the carbon trading pilot policy in year t, otherwise 0; δ_i is the enterprise-level fixed effect to control the impact of the inherent characteristics of enterprises that do not change with time on ESG performance; δ_t is the year fixed effect to control the impact of time-level common shocks such as macroeconomic environment and industry overall trends; ϵ_{it} is the random disturbance term, which follows the independent and identically distributed assumption.

X represents the set of relevant control variables further integrated into the empirical analysis. This study introduces two categories of control indicators: ① Firm-year financial trait control variables, including financial leverage (Lev), enterprise scale (Size) measured by the natural logarithm of year-end total assets, asset turnover ratio (Turnover) calculated as operating revenue divided by average total assets, operating income (log-processed, lnRevenue), revenue growth rate (Growth) computed via (current-year operating revenue less previous-year operating revenue) divided by previous-year operating revenue, capital occupation by major shareholders (Occupy) defined as the net value of other receivables divided by total assets, and return on assets (ROA) measured as net profit divided by the average balance of total assets. ② Firm-year corporate governance trait control variables, covering the proportion of independent directors (Indep) calculated as the number of independent directors divided by the total board members, enterprise listing years (ListAg) computed as the current year minus the listing year, ownership attribute (State) assigned 1 for state-owned enterprises and 0 for non-state-owned ones, board size (Board) determined by the total number of board directors, and whether audited by the Big Four international accounting firms (Big4) coded 1 for firms audited by PwC, Deloitte, KPMG or EY, and 0 otherwise. The descriptive statistical results of all variables are exhibited in Table 1.

Building on the aforementioned DID benchmark model, this study adopts the following econometric specification for in-depth analysis, with the goals of testing the parallel trend assumption and exploring the dynamic impact of the carbon trading pilot policy on corporate ESG performance:

$$\mathrm{lnESG}_{it} = \alpha + \beta_v \sum_{v=-4}^{5} \mathrm{DID}_{v_{it}} + \gamma_x \mathrm{X} + \delta_i + \delta_t + \epsilon_{it} \tag{2}$$

Where $\mathrm{DID}_{v_{it}}$ represents the dual-difference interactive dummy variable corresponding to the v-th period. Concretely speaking, this dummy variable is coded as 1 if enterprise i is in the v-th year prior to or subsequent to the launch of the carbon trading pilot policy, and 0 in all other cases. All the remaining control indicators and fixed-effect settings are fully consistent with those adopted in the benchmark regression specification (1).

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To further dig into the transmission channel through which the carbon emission trading policy functions, this paper implements econometric regression estimation in the mechanism examination section, with the mechanism variables acting as the dependent variables:

$$M_{it} = \alpha_1 + \beta_1 DID_{it} + \gamma_x X + \delta_i + \delta_t + \epsilon_{it} \tag{3}$$

In formula (3), M_{it} is the mechanism variable, and other control variables and fixed effects are consistent with those in the baseline regression equation (1).

3.3. Data description

The data sample utilized in this research covers three core categories: enterprises' ESG performance metrics, relevant information of carbon emission trading policies, as well as corporate financial and governance data. Micro-enterprise level data are obtained from the CSMAR and Wind professional academic databases; policy-associated information is compiled from official announcements and related documents issued by the Development and Reform Commission and Ecology and Environment Department of each pilot region, including key details such as the policy launch year and carbon emission quota allocation rules. The research objects of this paper are China's A-share listed companies in non-manufacturing industries during the period from 2010 to 2020. This research carries out the following screening and preprocessing procedures on the samples: retaining enterprises that maintained continuous operation and owned complete data throughout the policy implementation stage; excluding ST/*ST firms (specially treated enterprises) and those with abnormal financial conditions; eliminating companies belonging to the financial industry. Ultimately, a total of 5,219 valid observation samples are acquired.

4. Empirical results and analysis

In line with the theoretical deductions and research expectations proposed in the theoretical analysis system of this study, this part employs the time-varying difference-in-differences econometric model to carry out empirical estimation and quantitative analysis, so as to test and validate the causal impact generated by the introduction and enforcement of the carbon emission trading pilot scheme on the ESG performance of micro enterprises, and further assess the stability and credibility of the empirical findings.

4.1. Baseline regression results

Table 1 reports the empirical results regarding the impact of the carbon trading policy on the ESG performance of non-manufacturing enterprises. Column (1) only includes the core interaction term DID while controlling for both firm and year fixed effects, with standard errors clustered at the enterprise level. The results show that the coefficient of DID is 0.013 and statistically significant at the 1% level, which provides preliminary evidence that the carbon trading policy exerts a positive effect on corporate ESG performance. Column (2) incorporates control variables reflecting firms' financial characteristics. The coefficient of leverage ratio (Lev) is significantly negative, indicating that high debt pressure inhibits enterprises' investment in ESG-related initiatives; the coefficient of firm size (Size) is significantly positive, reflecting that the scale effect enhances enterprises' capacity for resource integration and social responsibility fulfillment. In this specification, the coefficient of DID increases to 0.015 and remains significant at the 1% level. Column (3) further adds corporate governance-related variables. The coefficient of major shareholders' fund occupation (Occupy) is

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significantly negative, suggesting that the second type of agency problem crowds out resources allocated to ESG development; the proportion of independent directors (Indep) is significantly positive, confirming that a sound supervision mechanism contributes to the improvement of non-financial performance; listing age (ListAg) is significantly negative, implying that long-term listed enterprises may suffer from reform inertia; the coefficient of ownership property (State) is significantly positive, indicating that state-owned enterprises respond more prominently to the policy's incentive effects. In this column, the DID coefficient rises to 0.016 and remains statistically significant. Column (4) includes additional control variables such as operating income (lnRevenue) and board size (Board). Operating income is significantly positive, as it provides stable financial support for ESG improvement; the coefficient of Big Four audit (Big4) is significantly negative, which may be due to the fact that rigorous external auditing eliminates the inflated components in ESG scores. In this full specification, the DID coefficient stabilizes at 0.015 and maintains the 1% significance level.

In summary, the DID coefficients across all four regression columns are consistently positive and statistically significant, ranging from 0.013 to 0.016. With the gradual inclusion of control variables, the positive direction of the policy effect remains stable and robust, thus fully validating Hypothesis 1. This finding demonstrates that the carbon trading policy, as a market-oriented environmental regulation tool, can effectively incentivize enterprises to strengthen environmental management practices, fulfill social responsibilities, and optimize their corporate governance mechanisms.

Table 1. Baseline regression results

	(1)	(2)	(3)	(4)
Variables	lnESG	lnESG	lnESG	lnESG
DID	0.013***	0.015***	0.016***	0.015***
	(0.00)	(0.00)	(0.00)	(0.00)
Lev		-0.052***	-0.036**	-0.041***
		(0.01)	(0.02)	(0.02)
Size		0.013***	0.014***	0.003
		(0.00)	(0.00)	(0.01)
Turnover		-0.002	-0.001	-0.012***
		(0.00)	(0.00)	(0.00)
ROA		0.033	0.030	0.020
		(0.03)	(0.03)	(0.03)
Occupy			-0.080*	-0.079*
			(0.04)	(0.04)
Indep			0.001***	0.001**
			(0.00)	(0.00)
ListAg			-0.018**	-0.021**
			(0.01)	(0.01)
State			0.024*	0.024*
			(0.01)	(0.01)
lnIncome				0.014***
				(0.00)
Growth				-0.001
				(0.00)
Board				-0.011
				(0.01)

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Table 1. (continued)

Big4				-0.015*
				(0.01)
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	5199	4978	4933	4933
adj. R^2	0.525	0.546	0.553	0.555

4.2. Parallel trend test

The core precondition for ensuring the validity of the time-varying DID estimation model is that the treatment group and the control group must satisfy the parallel trend hypothesis before the policy launch. To examine this critical identification assumption, this paper adopts the event-based analysis approach to establish a staggered dynamic DID specification, and comprehensively investigates the evolutionary pattern of ESG performance for firms in both the treatment and control groups before and after the rollout of the carbon trading policy. Figure 1 displays the yearly regression coefficients and their associated 95% confidence bands. It can be distinctly seen that the confidence bands of the interaction term coefficients in all pre-policy periods encompass zero, whereas those in each post-policy period all move away from zero and present a persistent upward trend. This outcome confirms the validity of the parallel trend hypothesis, implying that the positive influence of the carbon trading policy on corporate ESG performance revealed in the baseline regression is a real causal effect of policy implementation. It eliminates the risk of spurious regression triggered by the intrinsic heterogeneities between the two groups of enterprises, and lays a solid foundation for the robustness of the follow-up empirical findings.

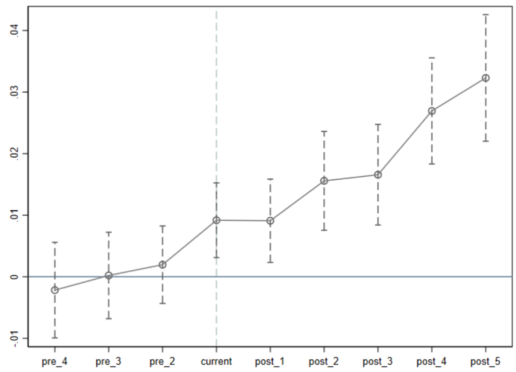

Figure 1. Parallel trend test

4.3. Robustness test

To rule out the disruptive impacts brought by sample selection bias and confounding variables, this study utilizes the subsequent approaches to test and confirm the dependability of the baseline regression findings.

4.3.1. Propensity Score Matching-difference-in-Differences method (PSM-DID)

To tackle and alleviate the issue of sample self-selection bias, this paper adopts the PSM-DID estimation method. The detailed matching process is carried out as follows: taking whether an

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enterprise is situated in a carbon trading pilot region as the binary dependent variable, selecting the control variables as matching covariates, performing 1:1 nearest-neighbor matching with the caliper set to 0.05, and only retaining observation samples within the common support range. The results of the balancing test (pstest) show that after the matching procedure, the standardized bias of all matching covariates is significantly reduced without obvious systematic differences, and the treatment group and the control group achieve effective and stable balance. Based on the matched sample data, this paper conducts regression analysis by controlling for firm fixed effects, year fixed effects and industry-year interaction fixed effects. The empirical outcomes indicate that after gradually adding a series of control variables, the DID coefficient remains stable at 0.017 and is statistically significant at the 1% level. The sign of this coefficient is completely consistent with the baseline regression results, and the adjusted R^2 rises to 0.590, which confirms that after mitigating the endogeneity problem, the positive promoting effect of the carbon trading policy on corporate ESG performance still maintains robustness and credibility.

Table 2. PSM-DID regression results

	(1)	(2)	(3)
Variables	lnESG	lnESG	lnESG
DID	0.017***	0.017***	0.017***
	(0.00)	(0.00)	(0.00)
Lev	-0.047***	-0.034**	-0.037**
	(0.01)	(0.02)	(0.02)
Size	0.014***	0.015***	0.005
	(0.00)	(0.00)	(0.01)
Turnover	-0.002	-0.001	-0.009*
	(0.00)	(0.00)	(0.00)
ROA	0.018	0.013	0.002
	(0.03)	(0.03)	(0.03)
Occupy		-0.097**	-0.097**
		(0.04)	(0.04)
Indep		0.001***	0.001*
		(0.00)	(0.00)
ListAg		-0.028***	-0.030***
		(0.01)	(0.01)
State		0.015	0.015
		(0.01)	(0.01)
lnIncome			0.012***
			(0.00)
Growth			-0.001
			(0.00)
Board			-0.014
			(0.01)
Big4			0.000
			(0.01)
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
N	4831	4831	4831
adj. R^2	0.584	0.589	0.590

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4.3.2. Placebo test

To eliminate the confounding impact of unobservable factors, this study verifies the authenticity of the policy effect through a placebo test based on random assignment. A pseudo-treatment group of the same size as the actual treatment group was randomly selected from the full research sample, while keeping the timing of the hypothetical policy shock unchanged. This process was repeated for 500 rounds of regression to generate a distribution of simulated coefficients. The empirical results show that the coefficients obtained from these 500 simulations follow a normal distribution centered at zero, indicating that the fictitious policy shock had no significant effect on corporate ESG performance. In contrast, the actual DID coefficients from the baseline regression (ranging from 0.013 to 0.016) are located in the right tail of this distribution, falling far beyond the bounds of the 95% confidence interval. Two-sided P-value tests confirm that the proportion of placebo coefficients with an absolute value greater than or equal to the real coefficient is less than 5%. This evidence rules out the possibility that the observed policy effect is driven by random chance or time-varying confounding factors, confirming it as the genuine net effect of the carbon trading policy implementation. In conclusion, after mitigating sample self-selection bias and excluding the interference of unobservable variables, the core conclusion—that the carbon trading policy significantly improves corporate ESG performance—remains robust. Hypothesis 1 is thus fully validated.

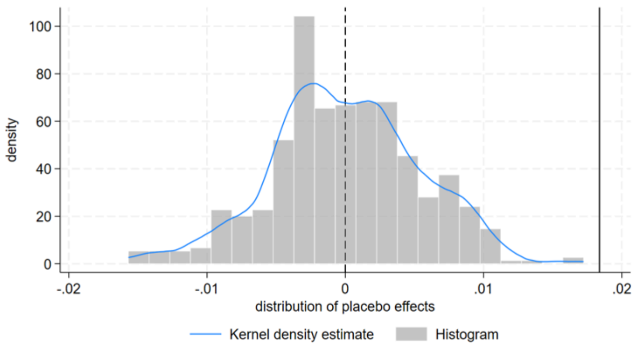

Figure 2. Placebo effect distribution

5. Further analysis: mediating effect and heterogeneity

5.1. Mediating effect test

Building on the empirical confirmation that the carbon trading policy improves enterprises' ESG performance, this study employs the stepwise regression method to empirically examine its transmission mechanisms. From the perspectives of resource allocation and external institutional environment, the policy exerts its influence mainly through three channels: external monitoring, resource accumulation and financing environment improvement. First and foremost, the implementation of the policy strengthens enterprises' environmental compliance awareness, creates external supervision pressure by attracting attention from analysts and the media, and forces enterprises to optimize their ESG performance to maintain corporate reputation and market image. As shown in Column (1) of Table 3, the regression coefficient of the policy variable is 3.890 and statistically significant, which confirms that the policy effectively increases the research attention received by enterprises. Second, the carbon trading mechanism pushes enterprises to carry out green innovation and production process optimization, cuts down environmental compliance costs, and

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enhances corporate profitability through green premiums and policy subsidies, thereby providing stable financial support for the advancement of ESG construction. The statistically significant coefficient of 0.098 in Column (2) corroborates this profitability improvement channel. Third, the policy sends positive sustainable development signals to the market, eases financing constraints by reducing information asymmetry, and solves the capital bottleneck for the long-term implementation of ESG strategies. The results presented in Column (3) show that the regression coefficient of the policy variable is -0.026 and statistically significant. Since the Financing Constraints (FC) Index is a negative indicator (a smaller FC value represents weaker financing pressure), this result verifies the optimization of the corporate financing environment. Overall, the carbon trading policy indirectly promotes the comprehensive improvement of enterprises' ESG ratings by increasing external research attention, enhancing corporate profitability and alleviating financing constraints.

Table 3. Mediation effect regression results

	(1)	(2)	(3)
Variables	Attention	lnEBIT	FC
DID	3.890***	0.098***	-0.026**
	(1.39)	(0.03)	(0.01)
Control Variables	Y	Y	Y
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
N	4933	4664	4933
adj. R^2	0.684	0.944	0.869

5.2. Heterogeneity analysis

On the basis of the results acquired from baseline regression testing, this research conducts grouped regression analysis from three independent dimensions, including industrial factor concentration, environmental reaction capability and corporate governance framework, with the purpose of investigating the differentiated traits of the policy's practical implementation effects. First and foremost, factor concentration exerts a significant influence on the effectiveness of resource allocation. Enterprises that are not capital-intensive are inclined to attain more outstanding ESG performance due to their flexible operation patterns and reduced costs in the process of green transformation, where the DID coefficient reaches 0.018 and demonstrates statistical significance at the 1% level; by contrast, capital-intensive enterprises present no obvious response, as they are restricted by large-scale asset investment and inflexible operation modes. In the second instance, the environmental susceptibility of diverse industries generates divergent expectations from stakeholders. Non-heavy-polluting enterprises undertake a lighter initial environmental burden, and can more easily achieve the growth of ESG scores by elevating the quality of information disclosure, with the regression coefficient amounting to 0.014 and being significant at the 1% level; heavy-polluting enterprises are constrained by high costs of environmental governance and path dependence, which makes the improvement of ESG performance extremely difficult, and the corresponding policy effect has no statistical significance. Last but not least, the dual-post setting in corporate governance produces heterogeneous policy effects through the internal decision-making mechanism. The separation of the chairman and general manager positions ensures the steady implementation of ESG strategies via a complete system of power checks and balances, with the regression coefficient being 0.014 and highly statistically significant; conversely, enterprises where the chairman and general manager roles are integrated fail to pass the significance test, owing to the

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insufficient stability of implementation caused by the lack of effective supervision mechanisms. In conclusion, the implementation effect of the carbon trading policy is not evenly distributed among enterprises with diverse attribute characteristics, and this finding provides valuable reference significance for the formulation of differentiated environmental regulation policies and regulatory tools.

Table 4. Subgroup regression results

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Cap=1	Cap=0	Pollute=1	Pollute=0	CP=0	CP=1
DID	0.012	0.018***	0.019	0.014***	0.014***	0.023
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.02)
Control Variables	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	794	4125	683	4243	4108	749
adj. R^2	0.623	0.561	0.637	0.557	0.581	0.578

6. Conclusions and policy implications

Against the backdrop of the constant in-depth advancement of global climate governance and sustainable development initiatives, systematically sorting out and organizing the mutual interaction mechanism between carbon trading policies and corporate ESG performance not only represents an in-depth expansion of research on the effects of environmental regulatory measures, but also provides effective theoretical support and reference for the optimization and improvement of enterprise development strategies. In this research, theoretical analysis and deduction are first carried out, which reveals that carbon trading policies can enhance ESG ratings by means of increasing the attention paid to analyst reports, promoting and driving corporate profitability, and alleviating corporate financing difficulties; furthermore, this kind of promotive impact is more obvious and remarkable in enterprises with low environmental pollution, low capital intensity, as well as those enterprises that implement the separation of the positions of chairman and general manager. Subsequently, this paper regards the 2013 carbon trading pilot project as a quasi-natural experimental setting, and employs the difference-in-differences (DID) research method to systematically examine and explore its impact and influence as well as the internal action mechanisms. The empirical results indicate that carbon trading policies can significantly enhance and optimize the comprehensive ESG ratings of enterprises by internalizing the external environmental costs borne by enterprises, and this core research conclusion still holds true after undergoing a series of strict robustness tests. The analysis of the transmission mechanism paths shows that the policy exerts an indirect promoting effect on corporate ESG performance through three major channels: external supervision and constraint, profit support and drive, and alleviation of corporate financing constraints. In addition, the impact of the carbon trading policy exhibits obvious heterogeneous characteristics, with more significant and prominent effects in non-capital-intensive enterprises, non-heavy-pollution enterprises, and those with the separation of chairman and general manager roles. This finding confirms and verifies the moderating effect of industry characteristics and attributes as well as corporate governance models and structures.

In light of the aforementioned empirical findings and theoretical analysis, this study proposes the following targeted policy insights and recommendations: Firstly, deepen the application of market-oriented environmental regulation tools. As an effective economic incentive means, carbon trading

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can significantly boost the upgrading of corporate ESG. We should construct a combined system of market-oriented policies and administrative means, flexibly adopt economic incentives and expand public participation channels to give full play to regulatory efficiency. Secondly, optimize the resource supply and government support mechanism. Alleviate the resource constraints of enterprises by increasing the scale of government subsidies, and give substantive subsidies to emission reduction measures. This can not only provide financial support, but also weaken the managers' worries about the risks of ESG investment, ensuring the sustained progress of green transformation. Thirdly, strengthen the supervision and incentive role of market players. Actively cultivate green capital, and guide capital to focus on the green value creation of enterprises with the help of green attention and institutional investor communication mechanisms, so as to improve the effectiveness of external governance. Finally, improve the policy design adapted to heterogeneous characteristics. For capital-intensive and heavy-polluting industries, reduce their ESG improvement costs through green technology subsidies and transformation funds; provide governance optimization guidance for enterprises with the combination of chairman and general manager positions, simplify transaction processes and lower thresholds, create a fair carbon trading environment for all types of enterprises, and comprehensively promote the improvement of ESG performance.

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