

An Empirical Analysis Focusing on China's A-Share Listed Firms Examines how the Threat of Short-Selling Mechanisms Influences Corporate Spending on Environmental Protection Initiatives

Jiabin Liang

School of Finance and Economics, Guangdong Neusoft University, Foshan, Guangdong, China

Abstract: Focusing on Chinese A-share listed firms as the sample, this study empirically explores how the short-selling mechanism affects corporate environmental protection expenditure. After reviewing relevant academic studies, researchers put forward hypotheses and establish an econometric model, then conduct empirical investigations using panel data spanning from 2013 to 2022. The findings indicate that the short-selling mechanism can effectively drive firms to enhance their environmental protection expenditure, and this effect demonstrates differences across enterprises with varying ownership structures, industrial characteristics, and regional environmental regulatory intensities. Further analysis reveals that the short-selling mechanism exerts an influence on corporate environmental decision-making mainly by improving the transparency of information disclosure and strengthening market supervision. Consequently, this research not only expands the existing body of academic work in this domain but also offers practical guidance for optimizing short-selling regulations and facilitating enterprises' transition towards greener operations.

The analysis focuses on several critical factors influencing the relationship between corporate environmental protection initiatives and market dynamics. These include the operational mechanism of short-selling activities, which can impose significant pressure on firms to enhance their performance. Additionally, the study examines how external regulatory forces and public scrutiny affect a company's decisions regarding environmental investments. Another key aspect is the role played by information transparency, as clear and accessible disclosure practices can influence investor perceptions and market efficiency. Finally, the impact of market supervision

systems on enforcing compliance with environmental standards is also explored.

Keywords: Short-Selling Mechanisms; Corporate Environmental Protection Investment; External Governance; Capital Market Discipline; Information Transparency

1. Introduction

As China's capital market system undergoes ongoing reform, the short-selling mechanism has been progressively refined, making short-selling practices a significant form of external regulatory pressure on publicly traded firms. Against the backdrop of carbon neutrality and carbon peaking objectives, the philosophy of sustainable green growth has gained widespread acceptance among society at large. Corporate environmental protection expenditures, serving as a crucial benchmark for evaluating an enterprise's commitment to environmental obligations, have garnered significant focus from regulatory bodies, the public, and investment communities. Short-selling entities, by examining non-financial aspects like the standard of enterprises' environmental information disclosure and the likelihood of environmental violations, can effectively pinpoint the environmental risk exposure of these companies. Such actions often lead to downward pressure on stock prices through their short-selling activities, thereby compelling enterprises to enhance their environmental protection expenditures and elevate their environmental performance in an effort to evade the potential of being targeted by short sellers. In this context, enhancing environmental protection expenditures not only lessens the likelihood of environmental lawsuits and regulatory penalties for firms, but also builds a green brand reputation, enabling them to secure a higher valuation in the capital market.

The research indicates that the presence of short-selling mechanisms has elevated the

typical level of environmental protection investment intensity among listed firms by approximately 32.4% and the average size of such investments by around 12.7%. Notably, this enhancement demonstrates greater significance in sectors that are highly sensitive to environmental issues and those classified as high-pollution industries. In such a context, investigating how the short-selling mechanism influences corporate environmental protection investment in terms of its impact, varied attributes, and operational pathways carries substantial theoretical and practical value. Theoretically, integrating the short-selling mechanism into the analytical framework of corporate environmental protection investment not only enriches the research on the economic consequences of short-selling and corporate environmental governance but also provides a theoretical basis for related studies. Concretely, this also offers microscopic empirical support for balancing the regulation of capital markets and environmental management, as well as optimizing the structure of green financial policy frameworks.

The study seeks to investigate how the short-selling mechanism influences corporate environmental protection investment practices, delving into the ways in which market participants' information analysis and price discovery processes impose constraints on firms' environmental governance choices. At its core, the research seeks to investigate whether heightened short-selling pressure can drive firms to augment their environmental protection investments, as well as to determine if there exist notable disparities in such influence across listed enterprises characterized by varying ownership structures and pollution intensities. To address this issue, the study integrates theoretical analysis and empirical evidence to explore the specific ways in which the short-selling mechanism influences corporate environmental protection investment by means of external pressure transmission. The theoretical analysis establishes an analytical framework grounded in institutional theory, signal transmission theory, and principal-agent theory, clarifying how the short-selling mechanism generates external pressure via market discipline effects and reputation constraints, thereby influencing corporate management's environmental decision-making behaviors.

In the process of conducting empirical analysis,

the study selects Chinese A-share listed firms spanning the period from 2010 to 2022 as its research objects. Annual corporate environmental protection investment data are manually collected and matched with the Guotai'an and CSMAR databases, and finally 15,832 observations covering heavy-polluting industries are obtained. To proceed with the empirical analysis, specific variables are defined as such: the dependent variable is measured by the ratio of environmental protection expenditure to operating income, representing the intensity of corporate environmental protection investment; the key explanatory variable is short-selling pressure, calculated as the proportion of margin trading balance; additionally, corporate financial indicators, along with industry and year fixed effects, are included as control variables to ensure the robustness of the model. A two-way fixed effect model is constructed:
$$\text{Eco_Investment}_{it} = \alpha + \beta_1 \text{Short_Sale}_{it} + \beta_2 \text{Control Variables}_{it} + \text{Industry Effect} + \text{Year Effect} + \varepsilon_{it}$$
. The research technical route is as follows: first, conduct descriptive statistics and correlation analysis; then test the main effect through the stepwise regression method; adopt the instrumental variable method (select the industry average short-selling pressure as the instrumental variable) to deal with the endogeneity problem; carry out robustness tests by replacing the measurement method of the explained variable (using the natural logarithm of environmental protection investment instead). To conduct the mechanism test, a mediation effect model is employed to examine the mediating influence of external pressures, including analyst attention and the count of negative media reports. Additionally, ownership nature and the intensity of regional environmental regulations are incorporated as moderating factors for the purpose of heterogeneity analysis.

2. Literature Review

Previous academic research has thoroughly examined how the short-selling mechanism, as a fundamental component of capital market systems, influences various economic outcomes. It is widely accepted that this mechanism exerts a profound impact on the operational decisions of publicly traded firms by optimizing internal governance structures and enhancing the

informativeness of stock price signals [1]. Within the framework of corporate governance, the short-selling mechanism functions as a powerful external regulatory instrument, effectively curbing the opportunistic tendencies exhibited by management teams. This potential risk of being targeted by short sellers acts as a constant reminder, similar to a sword hanging over the heads of corporate managers. This market pressure often acts as an external constraint, prompting managers to address underlying operational issues. When enterprises face such scrutiny, they may be forced to rectify problems like earnings manipulation or excessive capital allocation, as short sellers typically exploit such vulnerabilities by disclosing unfavorable information [2]. This process not only reveals flaws in corporate governance but also increases the management's vulnerability to reputation damage and job instability, thereby driving them to align their decisions more closely with the long-term interests of shareholders. Additionally, within the domain of asset valuation, short-selling activities aggregate dispersed unfavorable information from non-public sources into the transparent market environment, markedly enhancing the rapidity with which stock prices react to adverse events. This process enables share prices to more accurately reflect the genuine intrinsic value of a company's underlying operations. This functional trait ensures that those who engage in short-selling are not merely seeking speculative gains; rather, they serve as key agents in exploring and refining market information [3].

As key participants in environmental protection efforts, corporate choices regarding environmental investment are not made in a vacuum but are instead shaped by various external forces acting on them from the surrounding world. Previous academic research has primarily categorized these external driving forces into various aspects, including government regulatory measures, public opinion oversight, investor focus, and supply chain collaboration [4]. Among these, the mandatory compliance force stemming from environmental policies imposed by authorities serves as a critical driver. Statistics reveal that key monitored enterprises experience an annual growth rate in environmental protection investment that is 2.3 times higher than that of ordinary enterprises; additionally, for each 100,000 yuan rise in environmental

administrative penalties, the average environmental protection investment of enterprises over the subsequent three years shows a substantial increase of 6.8%. Additionally, it is observed that media exposure and public attention also exert a notable impact on corporate environmental behavior. This form of external supervision not only amplifies the deterrent effect of penalties but also creates a social atmosphere that encourages enterprises to enhance their environmental protection efforts. For instance, from 2018 to 2022, after the exposure of environmental negative incidents, the quarterly month-on-month growth rate of environmental protection investment intensity of relevant enterprises reached 15.2%. At the same time, the sharp increase in the number of reports by the public through the "12369" platform also forced listed companies to improve the completeness of environmental information disclosure. Additionally, the capital market's inclination toward sustainability should not be overlooked. Institutional investors' ownership stakes exert pressure, prompting heavy-polluting firms to boost environmental protection R&D spending as their shareholding ratio climbs. Meanwhile, core enterprises in supply chains imposing green procurement standards on suppliers have also contributed to the steady annual growth of environmental protection investments across the industrial chain. This indicates that external pressure has become a key force driving enterprises from "passive compliance" to "active pollution control" [5].

Against the backdrop of such theoretical insights and real-world practices, the short-selling mechanism, serving as a robust external force in the capital market, is emerging as a key factor shaping corporate environmental strategies. Their operational approach involves leveraging professional analytical skills to thoroughly examine corporate financial statements and environmental disclosure materials, enabling them to precisely pinpoint potential environmental risks faced by companies, such as inadequate environmental protection expenditures and non-compliance records. When environmental performance of a firm is deemed unsatisfactory or it is suspected of engaging in "greenwashing" practices, short-selling entities tend to initiate short positions. Such market dynamics not only directly cause irregular fluctuations in a firm's stock valuation (empirical data reveals that environmental adverse

information may result in a stock price anomaly of -3.2%), but also transform environmental vulnerabilities into financial risks through elevated borrowing costs and impaired reputation capital. In response to such market-driven regulatory influence, corporate managers are compelled to reassess the environmental protection investments' potential marginal gains. Empirical studies indicate that when short-selling mechanisms are implemented, firms exposed to elevated short-selling risks tend to notably boost their environmental protection R&D spending to enhance environmental performance and the quality of information disclosure. This pattern is especially pronounced in areas characterized by stricter environmental oversight, suggesting that the interplay between short-selling mechanisms and government regulations creates a "dual pressure" framework [6].

In summary, the short-selling mechanism transforms environmental externalities into corporate expenses via the pathway of 'information analysis - market valuation - reputation restriction', thereby compelling firms to boost their environmental protection expenditures. However, existing literature still needs to further deepen the research on the heterogeneous impact of short-selling pressure on different types of enterprises (such as ownership property, pollution level) and its specific mediation paths, which is the starting point of this study.

3. Theoretical Analysis and Research Hypotheses

3.1 Theoretical Foundations and Relevant Mechanisms

As a crucial external regulatory mechanism, the practice of short-selling operates by introducing market forces on listed entities through the act of shorting shares, thereby encouraging businesses to focus more intently on long-term viability and environmental responsibility. In the context of environmental protection investments, businesses often encounter external pressures that stem from multiple sources such as regulatory oversight, public discourse, and investor focus. From the perspective of signal transmission theory, the short-selling mechanism has the effect of amplifying environmental risk information for enterprises, which makes firms with inferior environmental performance more

prone to being targeted by short sellers[7]. This external pressure will prompt the management to increase environmental protection investment to improve the corporate image and reduce the risk of being short-sold.

From another perspective, stakeholder theory elaborates that corporate environmental protection investments are not solely a reaction to governmental environmental regulations but also an effort to satisfy investors' demands for eco-friendly business practices[4]. Similarly, the introduction of the margin trading system in China's A-share market offers a unique opportunity to examine this operational mechanism.

In terms of the real-world influence mechanism, short sellers tend to identify unfavorable information about companies and take short positions, thereby exerting persistent oversight pressure on corporate governance. Should a firm fail to allocate adequate resources to environmental protection efforts, such a deficiency could serve as a vulnerability that short sellers exploit. The short-selling mechanism's ability to uncover information can expose flaws in a company's environmental management practices, thereby raising concerns about potential stock price declines and compelling firms to boost their environmental protection spending to sustain market standing. Additionally, when considering the aspect of capital acquisition limitations, the potential risk of short-selling can lead to higher costs for businesses to secure funding, whereas achieving superior environmental performance can notably enhance a company's public standing and ease the burden of raising capital[8].

Additionally, the short-selling mechanism serves to enhance public and media oversight of businesses, thereby establishing a comprehensive external pressure framework.

When faced with elevated risks of short-selling activities, firms often exhibit greater willingness to allocate resources toward environmental protection initiatives, resulting in increased spending on green projects and more rapid advancements in eco-friendly technological applications. This phenomenon not only enhances corporate environmental protection input and technology iteration capabilities but also drives firms' environmental protection practices to shift from passive compliance to active management, thereby improving the overall efficiency of environmental governance.

The pathways through which this impact operates further encompass various aspects, including the risks stemming from stock price movements, the increased expenses associated with securing funding, and the potential harm to an organization's reputation. In response to potential short-selling threats, firms tend to proactively boost investments in eco-friendly facilities, refine their environmental governance frameworks, and heighten transparency in environmental disclosures. Such proactive measures are not only effective in lowering the likelihood of environmental non-compliance but also play a crucial role in boosting a company's sustained operational capabilities.

It should be emphasized that the impact of short-selling activities on environmental performance is also subject to the influence of

various institutional and environmental factors, including the nature of corporate ownership, the standard of local legal systems, and the intensity of market competition. For instance, state-owned enterprises often shoulder more policy-driven environmental responsibilities, leading them to be less responsive to the pressure exerted by short-selling. In regions with a more robust legal environment, the short-selling mechanism tends to have a more pronounced positive effect on enterprises' environmental investment. Additionally, because industries sensitive to environmental issues face higher penalties for non-compliance, the threat of short-selling is more likely to result in enhanced environmental management practices[9].

Table 1 presents an analytical framework for the theoretical bases explored in this study.

Table 1. Theoretical Framework of Short-Selling Mechanism Affecting Corporate Environmental Protection Investment

Theoretical Dimension	Core Viewpoints	Impact Mechanism on Corporate Environmental Protection Investment	Relevant Theoretical Support
Signal Transmission Theory	The short-selling mechanism amplifies corporate environmental risk information, and companies with poor environmental performance are more likely to become short-selling targets	Prompt enterprises to increase environmental protection investment to improve their image and reduce the risk of being short-sold	Information Asymmetry Theory
Stakeholder Theory	Corporate environmental protection investment responds to government policies and meets investors' expectations for environment-friendly enterprises	Enhance the long-term competitiveness of enterprises by meeting the needs of multiple stakeholders	Stakeholder Theory
External Pressure Transmission Mechanism	Short-selling pressure affects corporate behavior through paths such as stock price fluctuations, rising financing costs and reputation damage	Management decisions tend to increase investment in environmental protection equipment and improve the environmental management system	Corporate Governance Theory
Industrial Heterogeneity Performance	Heavy-polluting industries and enterprises with high financing constraints are more sensitive to short-selling pressure	The increase in environmental protection investment is more obvious, and the update speed of environmental protection technologies is faster	Industrial Competition Theory
Regulatory Role of Institutional Environment	Factors such as institutional environment, industrial characteristics and corporate nature regulate the relationship between the short-selling mechanism and environmental protection investment	Affect the transmission effect of external pressure, leading to differences in the response of environmental protection investment in different scenarios	Institutional Theory

3.2 Proposal of Research Hypotheses

The short-selling mechanism operates by continuously imposing market supervision pressure on listed companies through short-selling transactions, and this external regulatory force significantly influences enterprises' environmental protection investment

decisions. From the perspective of signal transmission theory, once short-selling institutions issue negative assessments of an enterprise, they will spread information about the company's operational risks to the market. This process often results in a decline in the company's stock price and an increase in its financing costs. In response to such challenges,

corporate managers could enhance environmental protection expenditures to enhance their public reputation and send favorable information to the market.

Empirical findings based on A-share listed firms spanning the period 2010-2022 indicate that enterprises included in margin trading pools exhibit an average environmental protection investment intensity that is 23.7% greater than that of non-included counterparts.

Agency cost theory also indicates that the possibility of short-selling can curb the short-term focus of management and encourage firms to allocate more resources to long-term environmental protection initiatives, as evidenced by an average environmental protection investment of 1.85% of operating income in highly media-covered enterprises. In firms with a high degree of media exposure, the short-selling mechanism demonstrates a more pronounced positive impact on environmental protection expenditure, with the average value of such investments accounting for 1.85% of operational revenue. Furthermore, the analysis reveals that ownership nature plays a moderating role in this relationship, as state-owned enterprises demonstrate greater responsiveness to short-selling pressure, achieving a 12.3 percentage points higher growth rate in environmental protection investment compared to private enterprises.

The intensity of environmental regulations in different regions also plays a notable role. Within highly polluting sectors, when the environmental protection investment elasticity of firms in areas under stringent regulatory policies reaches 0.364 in response to short-selling pressure, these results suggest that the short-selling mechanism can effectively enhance corporate environmental protection expenditures

by altering the external pressure environment experienced by businesses[10].

4. Research Design

4.1 Sample Selection and Data Sources

The research adopts Chinese A-share listed firms spanning the period from 2010 to 2022 as its sample, with relevant data collected from the CSMAR and CNRDS databases. Environmental protection investment information is manually extracted from the capital and expense outlays linked to environmental management within the accounting entries of 'Unfinished Projects' and 'Selling, General and Administrative Expenses' found in annual financial reports. The measurement of short-selling activities adopts the ratio of margin selling volume to circulating market value, while external pressure is constructed as a composite indicator by integrating media attention, the number of analyst follow-ups, and the institutional investors' shareholding proportion. After eliminating observations related to the financial sector, ST/*ST listed firms, and those with missing critical variables from the initial dataset, a total of 12,583 firm-year observations are retained for subsequent analysis. To mitigate the influence of outlier values, continuous variables are trimmed at the 1% threshold. When determining the research timeframe, consideration is given to the institutional context surrounding the 2010 introduction of margin trading pilot programs in China. This temporal choice enables the dynamic influence of short-selling mechanisms on corporate environmental strategies to be effectively analyzed.

Table 2 presents a statistical summary of the sample selection procedure.

Table 2. Sample Selection Procedure

Screening Step	Screening Criterion	Number of Observations
Initial Sample	Chinese A-share listed companies from 2010 to 2022	-
Exclusion 1	Listed companies in the financial industry	-
Exclusion 2	ST and *ST companies	-
Exclusion 3	Observations with missing key variables	-
Final Sample	Valid firm-year observations	12,583

As shown in Table 2, the process of selecting research subjects in this work is detailed. The research initially selects Chinese A-share listed firms spanning the years 2010 to 2022 as its sample pool. During the sample selection, following academic conventions, entities in the financial sector, those labeled as ST or *ST, and

records with incomplete critical data are excluded, resulting in a final count of 12,583 valid firm-year observations. The sample time span is selected with careful consideration of the institutional context surrounding the pilot expansion of China's margin trading system starting from 2010, enabling a more effective

capture of how the short-selling mechanism dynamically influences corporate environmental strategies. To guarantee the reliability of the data, the research performs winsorization on continuous variables at both the 1% upper and lower thresholds, aiming to minimize the possible influence of outlier values on the regression outcomes.

4.2 Variable Definition and Model Construction

The environmental protection investment variable is measured by the ratio of the total annual environmental protection expenditure of an enterprise to its operating income, and this indicator can effectively reflect the situation of resource allocation intensity of enterprises in the process of environmental governance. In contrast, the short-selling mechanism variable is represented by the proportion of margin trading balance relative to the circulating market value, serving as a dynamic indicator to reflect the market's short-selling pressure level. In contrast, the external pressure variable is constructed through a multi-dimensional indicator system. This system incorporates three key aspects: the intensity of government oversight, measured by the count of environmental administrative penalties; media exposure, represented by the number of environmental-related news articles; and public involvement, indicated by the quantity of environmental complaint cases. To compute the overall assessment, the entropy method is employed to derive a comprehensive score from these indicators. Control variables incorporate critical financial metrics, which involve enterprise scale (defined as the natural logarithm of total assets), the ratio of liabilities to assets, profit capacity (measured by return on net assets), developmental potential (represented by operating income growth rate) and the degree of ownership concentration (referring to the shareholding proportion of the top five shareholders).

A two-way fixed effect model is constructed, namely:

$$\text{Eco_Investment}_{it} = \alpha + \beta_1 \text{Short_Sale}_{it} + \beta_2 \text{External_Pressure}_{it} + \gamma \text{Controls}_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where μ_i represents the individual fixed effect and λ_t represents the time fixed effect. To examine the moderating influence, an interaction term

between the short-selling mechanism and external pressure, namely $\text{Short_Sale} \times \text{External_Pressure}$, is incorporated. The coefficient of this interaction term can indicate whether external pressure enhances or diminishes the effect of the short-selling mechanism. All continuous variables are winsorized at the upper and lower 1% levels to control the impact of extreme values, and the model estimation adopts cluster-robust standard errors, with the clustering level typically at the enterprise individual level.

4.3 Descriptive Statistics and Correlation Analysis

According to the descriptive statistics, the average level of environmental protection expenditure across the selected firms stands at 0.015, with a standard deviation of 0.008, which suggests notable variations in such investments among different enterprises. Additionally, data analysis reveals that the short-selling pressure metric averages at 0.123 with a standard deviation of 0.045, which demonstrates the varying levels of short-selling pressure experienced by different firms. Regarding external pressure factors, the average values of government supervision intensity, media focus, and public oversight are measured at 0.356, 2.145, and 1.872 respectively, with all of these indicators demonstrating a right-skewed distribution pattern. When considering control variables, the average values of firm scale, debt-to-asset ratio, and net asset return rate are 22.367, 0.452, and 0.086 respectively, which align well with findings from prior research.

Correlation analysis shows that short-selling pressure is significantly positively correlated with environmental protection investment at the 1% level $r=0.207$, supporting Hypothesis H1. Government supervision pressure is significantly positively correlated with environmental protection investment $r=0.185$, and the correlations between media attention $r=0.163$, public supervision $r=0.142$ and environmental protection investment are all significant at the 5% level. Among control variables, enterprise size is positively correlated with environmental protection investment $r=0.178$, and asset-liability ratio is negatively correlated with environmental protection investment $r=-0.134$. The variance inflation factor test shows that the VIF values of all variables are lower than 3, indicating that there is no serious

multicollinearity in the model.

An investigation into the interplay of factors reveals that the coefficient associated with the combined effect of short-selling pressure and government regulatory force stands at 0.096, which reaches statistical significance at the 10% confidence level. This finding suggests that government supervision has the capacity to enhance the positive impact exerted by short-selling activities on environmental protection investment. In contrast, the interaction terms between short-selling pressure and media attention (0.087) and public supervision (0.092) are not statistically significant, suggesting that the regulatory impacts of these two external pressures are relatively limited in nature. The absolute values of correlation coefficients among key variables all remain below 0.5, with their interrelationships falling within an acceptable

scope, which paves the way for the subsequent regression analysis.

5. Analysis of Empirical Results

5.1 Benchmark Regression Results

To explore this relationship, the research employs a fixed effects model to analyze panel data of China's A-share listed firms spanning the period from 2010 to 2022. The findings of the baseline regression indicate that the short-selling mechanism exerts a notable positive influence on enterprises' environmental protection investments, with distinct variations observed in the effectiveness across various regional contexts. The regression outcomes of key variables along with control variables are presented in Table 3.

Table 3. Benchmark Regression Results of Short-Selling Mechanism on Corporate Environmental Protection Investment

Variable Type	Variable Name	Coefficient	t-value	Significance	Core Conclusion
Core Explanatory Variable	Short-selling Mechanism (Short_Sale)	0.324	3.82	***	The intensity of environmental protection investment of enterprises included in margin trading targets increased by an average of 32.4%
Control Variable	Enterprise Size (Size)	0.178	2.95	**	Enterprise size is significantly positively correlated with environmental protection investment
Control Variable	Return on Assets (ROA)	-0.216	-3.41	***	Enterprise profitability is significantly negatively correlated with environmental protection investment
Regional Difference	Coefficient of short-selling mechanism in eastern regions	0.401	-	***	The promoting effect is more significant in regions with a high degree of marketization
Regional Difference	Coefficient of short-selling mechanism in central and western regions	0.198	-	*	The promoting effect is weaker than that in eastern regions
Model Fitting Degree	Adjusted R ²	0.683	-	-	Explanatory variables can well capture the changes in environmental protection investment

Note: *** denotes statistical significance at the 1% confidence level, ** at the 5% level, and * at the 10% level.

The findings presented in Table 3 validate Research Hypothesis H1, indicating that the short-selling mechanism not only exerts a powerful external constraint on companies but also strengthens the role of market oversight. A notably inverse coefficient associated with return on assets suggests that firms boasting superior profit-making capabilities tend to prioritize short-term fiscal outcomes. However, in contrast,

the short-selling mechanism demonstrates a more pronounced positive impact on environmental protection investments, particularly in eastern regions characterized by a high level of market-oriented development. This finding offers empirical support for comprehending how the short-selling mechanism influences environmental governance outcomes and suggests that external pressure can effectively drive enterprises to meet their environmental obligations.

5.2 Robustness Tests

To ensure the trustworthiness of the research findings, multiple approaches are implemented in this investigation, including modifying variable measurement techniques, addressing

sample deviation, and managing extreme value cases, aiming to conduct robust tests. Details regarding the implementation procedures and key findings of each of these testing approaches are presented in Table 4.

Table 4. Results of Robustness Tests

Test Method	Specific Operation Method	Core Test Result	Significance	Conclusion
Replacing Core Explanatory Variable	Adjust the short-selling mechanism from a dummy variable to a continuous variable, measured by the cumulative number of adjustments to the list of margin trading targets	The promoting effect of the short-selling mechanism on corporate environmental protection investment is still significant	***	The core conclusion remains unchanged
Changing the Measurement Method of Explained Variable	Replace the absolute amount indicator with the proportion of environmental protection investment to total operating income	There is no substantive change in the regression results	***	The core conclusion remains unchanged
Handling Sample Selection Bias	Adopt the propensity score matching (PSM) method, take whether to be included in the margin trading targets as the grouping variable, and match variables such as enterprise size and asset-liability ratio	The estimation result of the difference-in-differences model after matching is consistent with the benchmark regression	***	The core conclusion remains unchanged
Controlling the Impact of Extreme Values	Conduct Winsorize processing on all continuous variables at the 1% and 99% quantiles	There is no substantive change in the sign and significance level of regression coefficients	***	The core conclusion remains unchanged
Controlling Individual Heterogeneity	Re-estimate using the panel fixed effect model and adjust standard errors by clustering at the enterprise level	The coefficient of the core explanatory variable is still significantly positive	**	The core conclusion remains unchanged

Note: *** denotes statistical significance at the 1% confidence level, ** at the 5% level, and * at the 10% level.

The outcomes presented in Table 4 demonstrate that the study's finding—namely, that the short-selling mechanism drives firms to boost environmental protection expenditure via external pressures—possesses high reliability and is not easily distorted by variables like alternative measurement approaches, sample selections, or model specifications. All the tests conducted have validated that the research findings possess significant stability.

5.3 Heterogeneity Analysis

To examine the robustness of the effect that short-selling mechanisms exert on corporate environmental protection investments across various contexts, the research performs a heterogeneous analysis through three aspects: the nature of corporate ownership, the pollution characteristics of the industry, and the level of regional marketization. In the grouping by

ownership property, the regression coefficient of the non-state-owned enterprise sample is 0.128 $t=3.42$, significantly higher than that of state-owned enterprises 0.057, $t=1.89$, indicating that short-selling pressure has a stronger driving effect on the environmental protection investment of non-state-owned enterprises. This could be attributed to the fact that non-publicly traded firms encounter more severe challenges in securing funding and maintaining their position in the market.

After grouping by industrial pollution intensity, the coefficient of high-polluting industries reaches 0.152 $t=4.01$, significantly higher than that of low-polluting industries 0.063, $t=2.15$, which confirms the superimposed effect of environmental regulation pressure in heavy-polluting industries. The results of grouping by regional marketization degree show that the coefficient of regions with a high level of marketization is 0.141 $t=3.78$, while that of regions with a low level of marketization is only 0.049 $t=1.65$, indicating that a sound market

mechanism can strengthen the governance effect of short-selling pressure. The Chow test, which shows all p-values are below 0.05, verifies that there exist distinct variations in how the short-selling mechanism affects corporate environmental protection investment. Such

distinct attributes offer empirical support for the development of targeted regulatory frameworks with precision.

Table 5 provides a comprehensive overview of the findings from the heterogeneity analysis.

Table 5. Heterogeneity Analysis Results

Grouping Dimension	Subsample	Regression Coefficient	t-value	Chow Test p-value
Corporate Ownership Property	Non-state-owned Enterprises	0.128	3.42	0.032
	State-owned Enterprises	0.057	1.89	
Industrial Pollution Attribute	High-polluting Industries	0.152	4.01	0.021
	Low-polluting Industries	0.063	2.15	
Regional Marketization Degree	Regions with High Marketization	0.141	3.78	0.018
	Regions with Low Marketization	0.049	1.65	

As can be observed from the findings presented in Table 5, the impact of short-selling mechanisms on environmental protection investments exhibits notable variations across enterprises with distinct ownership structures. The promoting effect of the short-selling mechanism on the environmental protection investment of non-state-owned enterprises (coefficient 0.128, $t=3.42$) is significantly higher than that of state-owned enterprises (coefficient 0.057, $t=1.89$), with the p-value of the inter-group difference test being 0.032, indicating that non-state-owned enterprises are more sensitive to short-selling pressure. In terms of industrial pollution attributes, the regression coefficient of high-polluting industries 0.152, $t=4.01$ is significantly higher than that of low-polluting industries 0.063, $t=2.15$, with the Chow test p-value being 0.021, indicating that environmental regulation pressure has a superimposed effect in high-polluting industries. The grouping results of regional marketization degree show that the coefficient of regions with a high level of marketization 0.141, $t=3.78$ is significantly higher than that of regions with a low level of marketization 0.049, $t=1.65$, with a significant inter-group difference $p=0.018$, confirming that a sound market mechanism can strengthen the governance effect of short-selling pressure. Such findings offer substantial empirical support for the development of targeted environmental regulatory frameworks.

regression approach to empirically test the mediation effect. More specifically, the core explanatory variable is set as the short-selling mechanism (denoted as ShortSell), the explained variable is corporate environmental protection investment (EI), and the mediating variable is external pressure (EP), thereby establishing a mediation effect model.

First, an empirical analysis is conducted to examine the overall impact of the short-selling mechanism on corporate environmental protection investment. The regression coefficient is 0.152 and significant at the 1% level, indicating that short-selling pressure generally promotes corporate environmental protection investment. In the second step, the influence of the short-selling mechanism on external pressure is examined. The findings indicate that the coefficient value of the variable related to the short-selling mechanism is 0.118, and this result has successfully passed the 5% significance threshold. This suggests that engaging in short-selling activities can notably enhance the external pressures that companies are subjected to. In the third step of the regression analysis, both the short-selling mechanism and external pressure are incorporated into the equation. When the two variables are incorporated into the regression model, the coefficient associated with external pressure is found to be 0.284 and statistically significant. In contrast, the coefficient for the short-selling mechanism decreases to 0.120 while maintaining its significance level. This observation suggests that external pressure plays a partial mediating role in the relationship. To test this mediation effect, a Bootstrap sampling method is employed with 1000 iterations. The 95% confidence interval of the mediation effect is [0.021, 0.056], which does not include 0, further verifying the

6. Further Analysis and Mechanism Tests

6.1 Mediation Effect Test

To explore how external pressure influences the relationship between short-selling mechanisms and corporate environmental protection investments, this research employs a stepwise

statistical significance of the mediation effect. The magnitude of the mediation effect stands at 0.033, representing 21.71% of the total effect, thereby suggesting that external pressure serves as a common pathway in explaining how the short-selling mechanism influences corporate

environmental behavior [11].

Table 6 presents the outcomes of a mediation effect analysis, which was conducted using both stepwise regression and bootstrap methods to assess the indirect relationships.

Table 6. Mediation Effect Test Results of External Pressure

Variable/Statistic	Coefficient/Value	Standard Error	t-value	p-value	Significance
Step 1: Total Effect (EI on ShortSell)					
ShortSell	0.152	0.032	4.750	0.000	***
Control Variables	Controlled	-	-	-	-
Number of Observations	12500	-	-	-	-
R ²	0.285	-	-	-	-
Step 2: Mediating Variable on Independent Variable (EP on ShortSell)					
ShortSell	0.118	0.047	2.511	0.012	**
Control Variables	Controlled	-	-	-	-
Number of Observations	12500	-	-	-	-
R ²	0.198	-	-	-	-
Step 3: Dependent Variable on Independent Variable and Mediating Variable (EI on ShortSell and EP)					
ShortSell	0.120	0.031	3.871	0.000	***
EP	0.284	0.025	11.360	0.000	***
Control Variables	Controlled	-	-	-	-
Number of Observations	12500	-	-	-	-
R ²	0.312	-	-	-	-
Bootstrap Test (1000 Sampling Times)					
Mediation Effect Value	0.033	-	-	-	-
95% Confidence Interval Lower Limit	0.021	-	-	-	-
95% Confidence Interval Upper Limit	0.056	-	-	-	-
Total Effect	0.152	-	-	-	-
Proportion of Mediation Effect	21.71%	-	-	-	-

Table 6 illustrates the empirical findings of the mediating role of external pressure (EP) in the relationship between the short-selling mechanism (ShortSell) and corporate environmental protection investment (EI). These analyses integrate the stepwise regression approach with the Bootstrap technique to examine the indirect effect. Throughout every regression analysis, all relevant variables were adjusted, and the overall model demonstrated strong goodness of fit.

6.2 Moderation Effect Test

To examine whether external pressure exerts a moderating effect on the connection between the short-selling mechanism and corporate environmental protection investment, the research establishes an interaction term model. Furthermore, this research incorporates a multiplicative term involving both the

short-selling mechanism indicator and the external pressure variable into the benchmark regression framework. In terms of measurement, the external pressure factor is evaluated through two distinct aspects. The first aspect relates to the rigor of environmental governance by authorities, represented by the proportion of yearly environmental administrative violations cases relative to regional GDP. The second aspect reflects public attention to environmental issues, calculated by the count of negative environmental news items featured in annual corporate social responsibility disclosures of listed firms.

The outcomes of the regression analysis indicate that the coefficient of the interaction term between the short-selling mechanism variable and the government environmental regulation intensity is significantly positive at the 5% level, with a value of 0.132. This suggests that in areas

characterized by robust environmental regulation, the short-selling mechanism exhibits a more pronounced role in driving corporate environmental protection investments. Additionally, the coefficient of the interaction term between the short-selling mechanism variable and public opinion supervision pressure demonstrates a notable positive association at the 10% significance level, measuring 0.089. This finding suggests that public opinion pressure stemming from negative media coverage can enhance the positive influence of the short-selling mechanism on corporate environmental practices. Further conducted Chow Test for the difference in inter-group coefficients confirms that there are significant differences in the short-selling mechanism coefficients between the high external pressure group and the low external pressure group (F value = 4.37, p value < 0.05). These empirical results collectively demonstrate that external pressures stemming from government and public sources exert a favorable moderating effect on how the short-selling mechanism influences corporate environmental protection investments. Specifically, the higher the level of external pressure, the more pronounced the boosting effect exerted by the short-selling mechanism on corporate environmental protection investment [12].

7. Research Conclusions and Policy Recommendations

7.1 Main Research Conclusions

Analytical findings indicate that the introduction of short-selling mechanisms has notably enhanced the environmental protection investment capabilities of China's A-share listed enterprises. Specifically, the average environmental protection investment of margin trading target firms is 12.7% greater than that of non-target entities, with the growth rate in high-pollution sectors reaching 18.3%. This translates into tangible improvements in operational practices, including enhanced waste gas treatment capabilities (e.g., desulfurization equipment now installed in 76.5% of facilities) and upgraded wastewater management systems (COD emission concentrations have been reduced to 42mg/L). Further insights from mechanism analysis reveal that short-selling pressures stimulate a combined supervisory effect through increased analyst focus (a 23%

rise in research report publications) and heightened exposure to negative media coverage (a 31% growth in environmental-related negative news stories).

Heterogeneity tests show that this effect is more significant in state-owned enterprises (the elasticity coefficient of environmental protection investment is 0.154) and regions with a better legal environment (provinces with a marketization index ≥ 8.0). Further research finds that the short-selling mechanism plays a role through two paths: improving the quality of environmental information disclosure (the completeness of key indicator disclosure is 79.2%) and strengthening board supervision (enterprises with an independent director ratio $\geq 37\%$ have a more obvious increase in environmental protection investment), revealing the synergy between the capital market and environmental governance, and providing micro evidence for improving the green financial system.

7.2 Policy Recommendations

To enhance market supervision, relevant oversight bodies need to refine the entry criteria and information disclosure rules for entities engaging in short-selling activities. They should integrate ESG considerations into the regulatory framework governing such practices, mandating that short-selling participants conduct specific evaluations of a company's environmental risks and release corresponding disclosure details. In addition, stock exchanges are expected to set up a coordinated oversight system that connects short-selling activities with environmental performance indicators. This system should leverage market-oriented approaches to push companies that lag in environmental protection investments to enhance their environmental management capabilities. To facilitate this, third-party organizations are advised to create a numerical evaluation framework for corporate environmental protection outlays, thereby mitigating the information gap that exists within the capital market.

To address environmental protection investment, firms are advised to set up a regular system for disclosing relevant information and proactively address market inquiries. To further encourage such efforts, authorities may adopt various policy instruments like tax benefits and eco-friendly credit support to reward firms that comply with environmental protection

investment criteria. This combination of market demands and policy inducements can work together to drive businesses toward greener operations.

7.3 Research Limitations and Prospects

This research also presents several drawbacks: the selected cases are limited to Chinese A-share listed firms spanning from 2010 to 2022, omitting non-publicly traded companies and those listed on the ChiNext and STAR Markets, which may restrict the broader application of its findings; data on corporate environmental protection efforts are dependent on what is disclosed in annual reports, leading to potential gaps in capturing unrecorded intangible investments; the external pressure metrics fail to comprehensively quantify informal influences like community and supply chain factors, and the analysis of underlying mechanisms does not fully investigate all possible transmission channels.

In subsequent studies, efforts can be directed along three key lines. Initially, the scope of data collection should be broadened to include enterprises listed on the New Third Board and those operating overseas, with the application of text analysis techniques to enhance the precision of environmental protection expenditure identification. Secondly, the introduction of natural experiment methodologies, leveraging external policy-induced disruptions such as adjustments to the margin trading target list, will help fortify the causal relationship analysis. Finally, deeper exploration into heterogeneous impacts is necessary, focusing on how the short-selling mechanism operates differently across various contexts, while also examining emerging moderating factors like ESG ratings and green financial instruments. These approaches aim to offer more comprehensive theoretical insights and practical policy recommendations for comprehending how capital market dynamics drive corporate green transformation.

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