



Unveiling the Link between Short Selling and ESG Performance in China's Heavily Polluting Industries: A Double Machine Learning Approach

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Abstract. Environmental, social, and governance (ESG) performance is crucial for business transformation in sustainable development, which is consistent with management science's emphasis on strategic decision-making. We examine the impact of short selling on ESG efficiency using data from Chinese heavy-pollution listed companies from 2010 to 2023. Using data from the Wind and RESSET databases, we combine the double machine learning (DML) and difference-in-differences (DID) approaches. DML can properly determine the causal influence of short selling on ESG efficiency since it is powered by modern computers, which can manage complicated linkages and control confusing variables. DID guarantees the accuracy of the results. According to our findings, short selling greatly improves ESG performance. For robustness, we use computer-aided techniques to resolve DML biases in accordance with management science's validation requirements. By substituting lasso, gradient boosting, and random forest for neural network regression and modifying the DML sample split ratio, we bolster the validity of our results. This research advances the field of management science by: Theoretically, it makes the connection between short selling and ESG more clear for strategic management; methodologically, it innovates by combining DML and DID; and practically, it helps regulators create sustainable legislation and helps heavy-pollution company managers optimize their ESG plans.

Keywords: Short selling, ESG performance, Double machine learning, Heavy-pollution industries

1 Introduction

In the process of promoting sustainable global progress and building China's ecological civilization, the effectiveness of environmental, social, and governance (ESG) has gradually become a key criterion for assessing corporate sustainability[1]. As an important basis of the national economy, the highly polluted industry has long faced the challenges of high resource consumption and severe environmental pollution, and its ESG performance is inevitably at the focus of all walks of life. With the proposal of "double carbon" target and the increasingly strict environmental protection policy, improving

ESG performance has become a necessary way for heavy polluting enterprises to realize sustainable development. Meanwhile, the ongoing enhancement of short-selling within China's capital market offers a distinctive lens through which to examine the manner in which the market surveillance mechanism influences firms' ESG performance[2]. In March 2010, China officially initiated the pilot program for margin trading and securities financing, which put an end to the unilateral trading mode of the stock market for 30 years. This institutional innovation allows qualified investors to conduct short selling on pilot companies, marking a new era of "bilateral market" in China's capital market.

2 Literature Review

2.1 Short Selling Mechanism

A crucial part of the financial market system, the short selling mechanism enables investors to profit by borrowing stocks and then selling them in the market to buy them back at a reduced price, particularly if the price of the underlying asset declines. By enhancing price discovery, boosting market liquidity, and simplifying corporate governance, short selling enhances market efficiency in established financial markets[3]. Although market liquidity is challenging, short selling enhances corporate governance and investment efficiency[4]. Institutional restraints cause China's short selling mechanism and developed financial markets to realize their functions differently[5]. Short selling limitations reduce market pricing efficiency, especially in businesses with significant information asymmetry, by delaying the stock price's response to negative company news.

2.2 Short Selling and ESG Performance

The short-selling regime systematically strengthens corporate ESG performance through two interdependent pathways, as evidenced by multidisciplinary research: Firstly, short-selling pressures incentivize firms to improve ESG disclosure quality, which not only fosters competitive advantages by demonstrating multidimensional sustainability performance (economic, environmental, social) but also directly enhances financial outcomes[6]. Empirical studies confirm that rigorous ESG disclosure correlates with superior financial performance, particularly for firms with established operational histories and high media visibility [7]. Furthermore, robust ESG practices mitigate financing constraints and broaden access to diversified funding instruments, including green financing solutions [8]. Secondly, acting as specialized external monitors, short sellers complement traditional governance mechanisms by identifying and publicizing ESG-related governance deficiencies. This "short-selling threat" compels management to institutionalize ESG principles within strategic planning and operational processes. In China's capital markets, this effect is magnified for heavy-pollution industries, where short-selling scrutiny elevates non-compliance costs through reputational penalties and regulatory risks[9], driving accelerated environmental accountability.

Taken together, the above analysis leads to the main hypothesis H1.

H1. The ESG performance of listed companies in China's heavy pollution industry is significantly and positively influenced by the short selling regime.

3 Research Methodology

3.1 Sample and Data

A-share listed companies in China from 2010 to 2023 are chosen as the initial sample for analysis. This study then selects listed firms in heavily polluting industries as the analysis sample, in line with existing research paths[10].The initial matched sample in this paper is screened as follows: 1. Exclude ST and *ST listed companies from the sample; 2. Remove samples with missing main variables; 3. Tailor continuous variables at the 1% and 99% levels.

After the above screening and data processing, the study obtains a valid sample of 1,486 firms, with a total of 11,800 firm-year observation data points. The Huazheng ESG data comes from the authoritative Wind Database. Data on enterprise financing and securities are obtained from the Research and Education Support System for Economic and Social Sciences Database (RESSET), and additional financial data of enterprises are collected from the China Stock Market & Accounting Research Database (CSMAR).

3.2 Variable Definition

3.2.1 Explained Variable.

We select Huazheng ESG rating serves as a key explained variable, quantitatively assessing enterprises' ESG performance metrics while offering a systematic framework for in-depth analysis [11].

3.2.2 Explanatory Variables.

Following[12][13], we implement DID method with Treat (1 if firms are listed as securities financing short-selling targets, 0 otherwise) and Post (set as 1 for the years after being included in the short-selling list). The core explanatory variable TreatPost captures the policy effect, where Treat identifies eligibility and Post marks the intervention timeline.

3.2.3 Control Variables.

This paper selects control variables with reference to prior studies[14][15], including shareholding concentration(Top1), ratio of independent directors (IDR), the leverage ratio (Lev), the size of the board (Board), cash ratio (Cash), return on equity (ROE), firm size (Size), Listed years(LY) and the price-to-book ratio (BM).

3.2.4 Empirical Model.

DML model.

Drawing from existing studies[16] we develop a partially linear model with DML in the following manner:

$$ESG_{it+1} = \theta_0 \text{TreatPost}_{it} + g(X_{it}) + U_{it}, E(U_{it} | \text{TreatPost}_{it}, X_{it}) = 0 \quad (1)$$

$$\hat{\theta}_0 = \left(\frac{1}{n} \sum_{i \in I, t \in T} \text{TreatPost}_{it}^2 \right)^{-1} \frac{1}{n} \sum_{i \in I, t \in T} \hat{V}_{it} (ESG_{it+1} - \hat{g}(X_{it})) \quad (2)$$

$$\text{TreatPost}_{it} = m(X_{it}) + V_{it}, E(V_{it} | X_{it}) = 0 \quad (3)$$

$$\hat{\theta}_0 = \left(\frac{1}{n} \sum_{i \in I, t \in T} \hat{V}_{it} \text{TreatPost}_{it} \right)^{-1} \frac{1}{n} \sum_{i \in I, t \in T} \hat{V}_{it} (ESG_{it+1} - \hat{g}_{it}(X_{it})) \quad (4)$$

In previous equations, ESG is the dependent variable, with TreatPost acting as a key explanatory factor. X_{it} , denote the previously discussed control variables; U_{it} and V_{it} represent the error term with a conditional mean of zero, while g and $\hat{m}(X_{it})$ must be estimated using machine learning methods; Estimation of the available coefficient ($\hat{\theta}_0$) in equations (2) is based on equation (1). If equations (1) and (2) are estimated directly, the estimates of $\hat{\theta}$ are biased. To solve this problem, the constructed auxiliary regression is shown in equation (3). Furthermore, we use a machine learning model to estimate $m(X_{it})$, obtain the estimate $\hat{m}(X_{it})$, then calculate the estimate of the residual term $\hat{V}_{it} = \text{TreatPost}_{it} - \hat{m}(X_{it})$, and use it as an instrument variable for regression, which can obtain unbiased estimate coefficients in equation (4).

DID model.

Guided by the earlier theoretical framework and research propositions, we moved forward to examine the empirical implications, developing a baseline regression model to assess how short selling volume influences ESG performance metrics:

$$ESG_{i,t} = \beta_0 + \beta_1 \text{TreatPost}_{i,t} + \sum_{m=2}^{10} \beta_m \text{Controls}_{i,t} + \sum \text{Year} + \sum \text{Ind} + \varepsilon_{i,t} \quad (5)$$

In the provided equation, the year effect and industry effect are controlled, while all standard errors are clustered at the firm level to further strengthen the robustness of the analytical framework.

4 Results of Data Analysis

4.1 Descriptive Statistics

The sample size is 11,800. The mean ESG is 4.0932, with a standard deviation of 0.922, indicating that there are differences in ESG performance but the distribution is rela-

tively symmetrical. TreatPost mean 0.4209, standard deviation 0.494, range 0 - 1, median 0.00, indicating a dispersed distribution in the sample with significant variation in value states.

4.2 Regression Results

4.2.1 DML Model Results.

This paper employs a DML model to assess how short selling affects corporate ESG performance, using a 1:2 sample split ratio. The main and auxiliary regressions rely on neural network regression for prediction and problem-solving, with results presented in Table 2 column (1), showing a positive and significant regression coefficient for TreatPost on ESG at the 1% level, indicating that short selling enhances ESG performance. Table 2 column (2) shows that extends DML model by incorporating second-order terms of control variables, showing a consistently positive regression coefficient with minimal numerical shift, thereby confirming H1.

4.2.2 DID Model Results.

The results of the analysis in table 1 column (3)-(4) show that TreatPost achieved a statistically significant improvement in performance measuring environmental, ESG efficiency at the 1% level. The results of the analysis show that support for the H1 hypothesis.

Table 1. Results of DML model and DID model

Variables	(1) ESG	(2) ESG	(3) ESG	(4) ESG
TreatPost	0.212*** (10.44)	0.232*** (11.50)	0.377*** (9.82)	0.241*** (6.74)
Controls' linear	YES	YES		
Controls' Quadratic	NO	YES		
Year	YES	YES	YES	YES
Ind	YES	YES	YES	YES
Controls			NO	YES
Cons			3.934*** (169.84)	1.719*** (5.57)
R ²			0.053	0.165
N	11800	11800	11800	11800

t statistics in parentheses; * *p* < 0.1, ** *p* < 0.05, *** *p* < 0.01

4.3 Robustness Test

4.3.1 Modify DML Algorithms and the Sample Split Ratio.

To prevent the bias of the DML algorithm, the neural network regression is substituted with lasso regression, gradient boosting, and random forest algorithm for re-estimation. In addition, this paper changes the DML model's sample split ratio from 1:2 to 1:5. The results in Table 2 column (1) -(4) support H1.

Table 2. Robustness test outcomes

	(1)	(2)	(3)	(4)
	ESG	ESG	ESG	ESG
TreatPost	0.235*** (12.04)	0.209*** (10.65)	0.201*** (9.91)	0.197*** (10.42)
Controls' linear	YES	YES	YES	YES
Controls' Quadratic	YES	YES	YES	YES
Year	YES	YES	YES	YES
Ind	YES	YES	YES	YES
Model	lassocv	gradboost	rf	nnet
Sample split ratio	3	3	3	6
N	11800	11800	11800	11800

4.3.2 Parallel Trend Test.

Figure 1 illustrates the outcomes of the parallel trend test. This result suggests that prior to policy implementation, the treatment and control groups do not exhibit statistically significant differences in the outcome variables examined, and the two groups show consistent trends. With the policy adjustment, it's clear that gradually lifting the short selling restriction has started to positively influence the ESG performance of listed companies, showing a steady improvement over time.

4.3.3 Placebo Test.

To account for the possible impact of unobservables, a placebo test is carried out following established practices in the literature. In this process, the short-selling transaction periods for each firm are randomly chosen, the model (1) is re-estimated, and the regression is repeated 500 times at random to ensure robustness. As illustrated in Figure 2, the policy effect is considerably diminished in both significance and magnitude following the double randomization procedure, thereby substantiating the robustness of the study's conclusions.

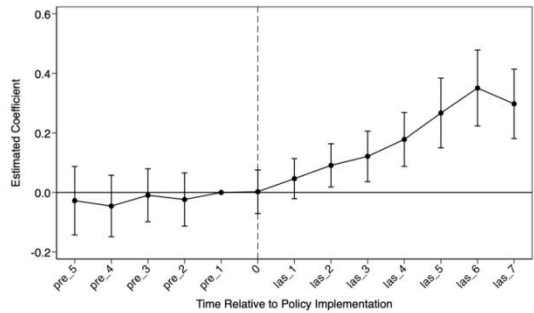


Fig. 1. Parallel trend test results

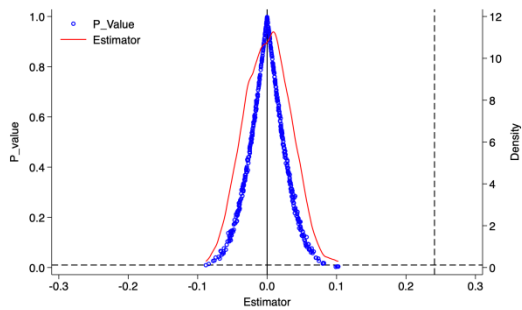


Fig. 2. Placebo test results

5 Conclusions

5.1 Research Findings

(1) Methodological Innovation: Integrating Double Machine Learning (DML) with the Difference-in-Differences (DID) method, using modern computational capabilities to handle complex data, accurately identifying the causal effect of short selling on corporate ESG efficiency, and offering a new perspective on complex decision-making and performance in corporate management research.

(2) Core finding: Short-selling can significantly improve corporate ESG performance, highlighting its role in promoting sustainable corporate governance, according to 2010–2023 data from listed companies in heavily polluting industries in China. ESG management in strategic decision-making helps decrease environmental, social opinion, and governance crises, allowing organizations take the lead in risk management and achieve long-term stability.

(3) Conclusion is reliable: Robustness checks like replacing neural network regression with lasso regression, gradient boosting, and random forest algorithms and adjusting the DML model's sample split ratio have confirmed that short selling improves corporate ESG performance.

5.2 Recommendations and Research Limitations

First, regulatory authorities could further optimize the short-selling transaction system, moderately relax short-selling constraints, and improve related supporting rules; Second, for heavily polluting industries, the government could formulate differentiated policies, coordinating the short-selling mechanism with environmental regulatory policies to guide companies in proactively improving their ESG performance; Third, encourage companies to strengthen ESG information disclosure, increase information transparency, and actively respond to market supervision. This analysis is limited to the industries that produce the greatest pollution in China. It is possible that in the future, it will be expanded to include other industries and geographical locations, and research can be conducted over a longer period of time to investigate the additional advantages of short selling for risk management and corporate management.

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