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The impact of low-carbon pilot policies on enterprise environmental performance

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Annotation. This study seeks to examine the influence of low-carbon pilot policies on the corporate environmental performance of Chinese enterprises. The results reveal that in SOEs, the impact of low-carbon pilot policies is more significant, while in non-SOEs, the effect is relatively small. In heavily polluting enterprises, the influence of the pilot policies is more significant, while in non-heavy polluting enterprises, the impact is relatively small. The mentioned pilot policy provides a variety of mechanisms, including policy incentives, technical support, industry norms, social pressure, and market opportunities, thereby improving their environmental performance. In addition, it effectively alleviates financing constraints and provides financial support for enterprises to implement low-carbon technologies or innovations. Further analysis shows that green innovation and financing constraints have partial mediating effects in the process of improving corporate environmental performance through low-carbon pilot policies. This paper provides corresponding policy recommendations, including increasing policy support, strengthening the effect of policy implementation, and implementing differentiated low-carbon policies for different types of firms and different regions. Simultaneously, the paper also calls on enterprises to actively participate in the pilot policies to achieve sustainable development goals.

Keywords: low-carbon, pilot policy, environmental performance, Differences-in-Differences (DiD) method.

JEL classification: F18, Q42, Q55, Q58.

Introduction

Amid increasing global warming, low-carbon development has become a common concern of the global community (Chen, 2023). Meanwhile, governments push enterprises towards low-carbon and eco-friendly development. China has also actively responded to the call for global climate governance and promoted low-carbon development (Gupta, Wong, 2014). To achieve the ‘carbon peak and carbon neutrality’ target, the pilot policy, such as the low-carbon policy, represents a crucial Chinese initiative. China guides its ecological civilisation thought, adheres to the new development concept, and persists in taking an ecologically prioritised, green development path (Geall, Ely, 2018). The country has incorporated the dual carbon target into the comprehensive framework of ecological civilisation development and has committed to the timeline for achieving its ‘dual carbon’ goals.

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The mentioned policy aims to improve the efficiency of energy utilisation through policy guidance and incentives, reduce greenhouse gas emissions, and achieve sustainable development (Jiang, Yin, 2023). Since the implementation of the policy, the pilot areas have attained commendable outcomes in advancing the development of green industries, providing useful experience and lessons for low-carbon development (Hunter *et al*., 2019). However, enterprises also face many challenges in their low-carbon transformation (Chen, 2023). Firstly, enterprises must allocate substantial capital and technological resources to implement technological transformation aimed at complying with low-carbon development. Secondly, the lack of relevant policies also hinders the advancement of low-carbon enterprises (Liu and Qin, 2016). Finally, enterprises must bear the risks of increased costs due to transformation and market competition pressure (Dai *et al*., 2023).

Regarding environmental performance, the extant literature primarily addresses the following aspects. Firstly, the pilot policies exert a prominent stimulating effect on green technology innovation (Shao, 2021), which remains valid following the common trend test, the PSM-DID test, and the placebo test. The low-carbon pilot policy is instrumental in promoting green technology innovation, especially among enterprises situated in the eastern region and non-SOEs. Command-based and market-oriented policies act as intermediaries in the relationship between the pilot policies and innovation in green technologies (Yang *et al*., 2022). Hong *et al*. (2022) believe that the pilot policies' implementation adversely affects the performance of high-polluting firms. Secondly, the pilot policies indirectly affect the performance of highly polluting industries through technological innovation and the external environment. Thirdly, the pilot policy exerts a notable negative effect on the performance of non-SOEs as well as SMEs. However, it does not exert a significant effect on the performance of SOEs and large firms.

In terms of environmental performance, the current literature mainly discusses the following aspects, one of which is the effect of government behaviour on corporate performance. For instance, the implementation of government environmental audits significantly affects corporate environmental performance, demonstrating a fixed excitation effect (Che, 2022). Likewise, environmental management system certification and 'energy-saving and low-carbon' policies are also positively correlated with ecological performance (Lin, 2022). The extant literature also reviews the impact of the international environment on ecological performance, mainly analysing the import and export market demand, global value chain position, and capital introduction. Primarily, external demand and import competition can improve production and management efficiency, reducing the pollution emission intensity of multi-product export firms (Wang, Xie, 2022; Shao, 2021; Liu, Chen, 2020). Furthermore, the opening up also promotes the enterprise green technology, management efficiency, and reallocation of resources among firms, optimising the environmental performance (Su, Sheng, 2021; Shao *et al*., 2019). Similarly, firms' participation in the value chain division of labour (global) and technological innovation significantly improves environmental performance (Song *et al*., 2021). In addition, past studies analyse the association between green technology innovation and environmental performance, with two key views, including indirect and direct effects. The former view advocates that there is a notable positive correlation between the two and external conditions, such as fiscal and tax incentives. Simultaneously, CSR strengthens the positive association between green technology innovation and environmental performance (Luo, 2020). The former view holds that green technology innovation plays a significant mediating role, which may diminish the positive effect of technology-based independent directors on environmental performance (Xu *et al*., 2018).

Predominantly, existing studies focus on government behaviour to investigate the influence of environmental policies on environmental performance in the context of pilot policies, as global environment and technological innovation are associated with environmental performance and ecological protection policies (Lin, 2022; Song *et al*., 2021; Luo, 2020; Liu, Chen, 2020). Therefore, this paper takes technological innovation and financing constraints as the intermediary mechanism to analyse in depth the relationship between the pilot policy and environmental performance. Hence, examining the impact of the pilot policies on enterprise environmental performance not only assists in thoroughly comprehending the effectiveness of policy implementation but also offers valuable guidance for enterprises (Peng *et al*., 2018). As a result, this paper contributes theoretically to the realization of the low-carbon emission reduction and economic efficiency of high-polluting industrial firms (Hong *et al*., 2022).

1. Theoretical Analysis and Hypothesis Development

1.1 Low Carbon Pilot Policies and Environmental Performance

1.1.1 Porter Hypothesis

This hypothesis posits that legal environmental regulations incentivise firms to engage in innovative activities, which not only reduce pollution but also improve competitiveness (Zhao *et al*., 2015). Within the framework of pilot policy, firms expand their R&D input as a result of policy pressure, and explore eco-friendlier production technologies, thereby improving environmental performance (Qu *et al*., 2024; Sharma, Henriques, 2005). Porter's hypothesis stresses the positive linkage between environmental regulation and innovation, believing that regulations are not merely a burden on firms but an opportunity to upgrade and transform.

1.1.2 Cost Benefit Analysis Theory

This theory is a critical instrument for assessing the effect of pilot policies on ecological performance (Coates, 2014). Firms balance their costs and benefits when adopting ecological protection measures (Sunstein, 2005). When the cost is less than the benefits, such as reducing pollution and improving firm image, the firm implements these measures (Ambec, Lanoie, 2008). Driven by low-carbon pilot policies, enterprises may find that the cost of adopting such measures is gradually decreasing while the benefits are gradually improving (Chen *et al*., 2021), thus becoming actively involved in improving environmental performance.

1.1.3 Sustainable Development Theory

This theory emphasises the balance between economic advancement and the protection of the environment (Hariram *et al*., 2023). The carbon pilot policy is formulated to achieve this goal. As micro-social entities, environmental performance directly affects sustainable development (Gu, Tian, 2023). Hence, firms should actively respond to low-carbon pilot policies, optimise resource utilisation, and reduce pollution emissions to enhance environmental performance.

1.1.4 Stakeholder Theory

The theory holds that the enterprise's progress is closely related to its stakeholders, including shareholders, employees, and consumers (Miles, 2017). Within the framework of relevant policies, firms aim to meet the requirements of their stakeholders (Huang, Kong, 2010). By improving environmental performance, companies can better fulfill their social obligations toward stakeholders. Based on the stated four theories, this study proposes the following hypothesis:

H1: Low-carbon pilot policies have a notable positive effect on corporate environmental performance.

1.2 Mediating Effects of Technological Innovation and Financing Constraints

During the relevant policy implementation, enterprises face the dual challenges of technological innovation and financing restrictions (Gu, Tian, 2023). Firstly, enterprises need to invest substantial capital and technological capacity to carry out technological transformation and meet low-carbon requirements (Li *et al*., 2023; Ma *et al*., 2022). The existence of financing constraints also restricts low-carbon development (Huwei *et al*., 2023). Hence, to explore the effect of pilot policies on environmental performance, the mediating effect of financing constraints must be assumed. The pilot policy for low-carbon development is crucial in promoting corporate technological innovation (Pan *et al*., 2022; Qi *et al*., 2021). The guidance and incentives of the policy can prompt enterprises to boost the innovation level of environmental conservation technology and the R&D of environmental conservation technology. Secondly, technological innovation is a crucial factor in achieving low-carbon development. Through technological innovation, enterprises can enhance energy utilisation efficiency, decrease carbon emissions, and reduce environmental pollution (Li *et al*., 2023). Finally, financing constraints are another important obstacle for enterprises to realise low-carbon development. The matter of financing difficulties often constrains the low-carbon shift (Hall *et al*., 2017).

Aimed to explore the effect of the mentioned policies on environmental performance, the important factor of financing constraints cannot be ignored (Yu *et al*., 2021; Walls *et al*., 2012; Lanoie *et al*., 2011). When carrying out the pilot policies, policy orientation stimulates the technological innovation motivation of firms, but whether this positive effect can be truly transformed into environmental performance also needs to consider the financing constraints. The in-depth analysis of the mediating effect of financing constraints can enable management to develop a more comprehensive understanding of the effect of relevant policies on corporate performance while providing useful references and guidance for the government to formulate and implement relevant policies. Therefore, the following hypothesis is proposed:

H2: The effect of low-carbon pilot policies on enterprise environmental performance is affected by the joint effect of technological innovation and financing constraints.

2. Research Design

2.1 Sample Selection and Data Sources

A-share listed companies in heavy-polluting industries from 2008 to 2023 are selected as the research object in this paper. To reduce the extreme values' impact, the continuous variables were trimmed at the 1% upper and lower quantiles, resulting in a total of 27,659 observations. Study data is sourced from the CSMAR and the Wind database.

Table 1. Explanation of Variables

Variable type	Variable name	Abbreviation	Variable description
Explanatory variable	EEP	Environmental performance of the firm	Data is obtained from Hexun.com
Core explanatory variables	inter	Low-carbon pilot policies	$inter_{it}$=$treatment_i \times post_t$
Control variable	Size	Companies size	Natural logarithm of total assets
	Lev	Gearing	Total liabilities at the end of the fiscal year are divided by total assets at the end of the fiscal year

Table 1 (*continuation*). Explanation of Variables

Variable type	Variable name	Abbreviation	Variable description
	ROA	Return on total assets	Net profit/average balance of total assets
	FIXED	Ratio of fixed assets	Net fixed assets to total assets
	Board	Board size	The number of board members is taken as a natural logarithm
Intermediary variable	GI	Green Innovation	Natural logarithm of total green patent filings
	SA	Financing constraints	SA index, the larger the absolute value, the more severe the degree of financing constraints.

Source: created by the authors.

2.2 Model Construction

This study uses the pilot policy as a quasi-natural experiment and employs the DID method to evaluate the effect of the mentioned policies on enterprise environmental performance. The DID method can be employed to assess whether there is a significant disparity in environmental performance in enterprises between the experimental group and the control group, both before and after the implementation of policies. Therefore, the model setup is as follows:

$$\mathrm{EEP}_{it} = \alpha_0 + \alpha_1 inter_{it} + \alpha_4 control_{it} + \varepsilon_{it} \qquad (1)$$

Where *i* denotes individual, *t* denotes the year. Enterprise environmental performance (EEP) is the explanatory variable (*Table 1*). Low carbon pilot policy (inter) as *treat*post* is the core explanatory variable, and control is the relevant control variable: firm size (Size), financial leverage (Lev), profitability (ROA), fixed assets ratio (FIXED), and board size (Board). $treat_i$ denotes experimental and control group dummy variables, taking the value of 1 for the experimental group, and 0 for the control group. $post_t$ denotes policy year dummy variables, which take the value of 1 for the year of policy occurrence and the year after, and 0 for the year before. μ_d denotes individual fixed effects, whereas γ_t denotes time effects, accounting for potential serial correlation and heteroscedasticity. Aiming to explore the transmission mechanism or possible mediating variables of the mentioned policy on environmental performance, this section adopts the mediating effect model, using green innovation (GI) and financing constraints (SA) as the mediating variables M to conduct an empirical analysis, and formulates the model as follows:

$$\mathrm{EEP}_{\mathrm{it}} = \alpha_0 + \alpha_1 \mathrm{inter}_{\mathrm{it}} + \alpha_3 control_{it} + \delta_i + \rho_t + \varepsilon_{it} \qquad (2)$$

$$\mathrm{M}_{it} = \alpha_0 + \alpha_1 \mathrm{inter}_{\mathrm{it}} + \alpha_3 control_{it} + \delta_i + \rho_t + \varepsilon_{it} \qquad (3)$$

The above expression establishes the presence of a transmission relationship among the core explanatory variables, mediating variables, and explanatory variables. Alternatively, it evaluates the extent to which the mediating variables function as influence pathways. Firstly, it assesses the influence of the pilot policies and various control variables on environmental performance, addressing the question of whether the primary explanatory variables impact the dependent variables. Secondly, the second formula for each mediating effect, mediating variables green innovation (GI), and financing constraints (SA) evaluates the degree to which the core independent variables affect the mediating variables, resulting in this study addressing whether these fundamental explanatory variables affect the mediating variables. Finally, by employing Jiang Boat's 2-step approach, this study elucidates the correlation between the mediating variables and the explanatory variables. This examination aims to address whether the mediating variables affect the explanatory variables.

3. Empirical Results and Analysis

3.1 Descriptive Statistics

The mean value of the environmental performance of enterprises (EEP) is 1.1572 (*Table 2*), which suggests that in the broader context, the EEP is at the medium level on average. The standard deviation of EEP is 3.8709, which points to a significant disparity in the environmental performance among the firms. The minimum value of 0.0000 refers to the fact that the EEP may be very low, while the maximum value of 19.0000 indicates that the environmental performance of some firms may be very high. The mean value of the inter is 0.6131, which indicates that overall, some of the firms are involved in the mentioned policy. In addition, the standard deviation is 0.4871. The findings suggest that there exists a degree of variation among the firms involved in the mentioned policy. The mean value of green innovation is 0.3934, which indicates that the overall level of green innovation of enterprises is at a low level on average. The standard deviation is 0.8452, suggesting that there are notable variations in the level of green innovation among enterprises. The mean value of SA is 3.7857, revealing that the level of financing constraints is at a medium level on average. The standard deviation is 0.2600, indicating a slight variation in the level of corporate financing constraints.

Table 2. Descriptive Statistics

Variable Name	Obs.	Mean	SD	Min	Median	Max
EEP	27659	1.1572	3.8709	0.0000	0.0000	19.0000
inter	27659	0.6131	0.4871	0.0000	1.0000	1.0000
GI	27659	0.3934	0.8452	0.0000	0.0000	7.0622
SA	27659	3.7857	0.2600	1.4554	3.7926	5.6000
Size	27659	22.1834	1.2822	19.8389	22.0031	26.1053
Lev	27659	0.4288	0.2070	0.0487	0.4217	0.8937
ROA	27659	0.0407	0.0627	-0.2345	0.0385	0.2162
FIXED	27659	0.2132	0.1613	0.0021	0.1801	0.6967
Board	27659	2.1294	0.1988	1.6094	2.1972	2.7081

Source: own calculations.

3.2 Correlation Analysis

This study conducts a straightforward correlation analysis of the variables related to enterprise environmental performance (EEP), low-carbon pilot policy (inter), enterprise size (Size), and financial leverage (Lev). The results are presented in *Table 3*, which illustrates the correlation coefficients among the variables.

Table 3. Descriptive Statistics

	EEP	inter	Size	Lev	ROA	FIXED	Board
EEP	1						
inter	0.024***	1					
Size	0.172***	0.064***	1				
Lev	0.084***	0.002	0.502***	1			
ROA	0.048***	-0.017***	-0.002	-0.358***	1		
FIXED	0.068***	-0.152***	0.090***	0.078***	-0.090***	1	
Board	0.114***	-0.050***	0.260***	0.148***	0.017***	0.148***	1

Notes: *** p< 0.01, ** p<0.05, * p<0.1.

Source: own calculations.

Notably, the correlation coefficient between enterprise environmental performance and low-carbon pilot policy is measured at 0.024, and the absolute value of this correlation coefficient. In addition, these variables exhibit a relatively high degree of correlation. Outright, the correlation coefficients among the variables do not approach -1 or 1, suggesting that these variables are independent. The presence of serious multi-collinearity issues is negligible, and the likelihood of adverse effects on subsequent regression analyses remains minimal. The findings suggest that the data utilised in this study are generally reliable, which, to some extent, mitigates the issue of covariance in regression equations. Consequently, these data can be employed for subsequent regression analyses.

3.3 Regression Analysis

The double difference model is chosen for empirical analysis using panel data, based on the selection of indicators and model testing in the previous subsection. In the regression process, the low-carbon pilot policy serves as the primary variable, with additional control variables incorporated for regression analysis. This approach enhances the stability of the results. In the regression results presented in *Table 4*, the first column is only the pilot policy (inter) as an explanatory variable for regression.

Table 4. Benchmark Regression Results

	(1) EEP	(2) EEP
inter	0.3614***	0.3283***
	(7.536)	(7.012)
Size		0.7463***
		(34.081)
Lev		-0.5143***
		(-3.676)
ROA		0.9340**
		(2.439)
FIXED		0.0734
		(0.433)
Board		0.2113*
		(1.844)
_cons	2.9589***	-13.5617***
	(30.070)	(-29.009)
Ind	Yes	Yes
Year	Yes	Yes
N	27659	27659
R^2	0.1248	0.1710

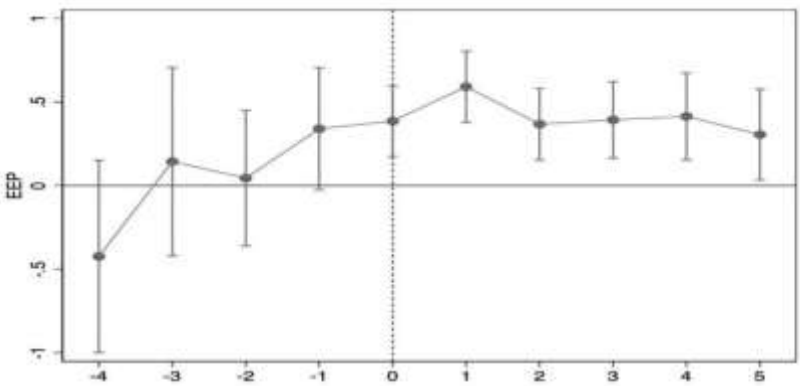
Source: own calculations.

The regression results indicate that the inter passed the significance test at the 1% level, with the coefficient of 0.3614. This indicates that the implementation of the mentioned policy will promote the enhancement of the enterprise's environmental performance. In the second column, after adding the control variables, the regression coefficient of low carbon pilot policy (inter) is 0.3283. The results indicate a significant positive correlation at the 1% level. This suggests that, after incorporating the aforementioned variables, the coefficient values of the explanatory variables of primary concern in this study exhibit only minor fluctuations. Nevertheless, the positive relationship between these variables and the environmental performance of enterprises remains consistent. The policy exerts a substantial positive influence on the environmental performance of enterprises. This is because policies are usually accompanied by a series of incentives and financial support, which provide enterprises with economic incentives to carry out environmental technology innovation and implement environmental protection measures. Through government subsidies and tax incentives, firms can reduce the cost of the implementation of low-carbon technologies, which gives them more incentive to make environmental investments. In addition, low-carbon pilot policies often encourage enterprises to adopt advanced low-carbon technologies, which often originate from R&D cooperation between research institutions and enterprises. Through policy guidance, enterprises can more easily access and apply these technologies, thereby improving environmental performance. The control variables show that firm size, profitability, and board size exert a significant positive influence on corporate environmental performance. Financial leverage has a significant negative effect on corporate environmental performance.

3.4 Robustness Tests

3.4.1 Parallel Trend Test

There exists a distinction between the dynamic effects and the parallel trends tests. In the analysis of parallel trends, it is crucial to evaluate the significance of the cross-multiplier term prior to period 0. In addition, if it is not significant, the statement indicates that there is no statistically significant difference between the treatment group and the control group during the ex-ante period, and the double difference method can be used. While the dynamic effects test not only examines the ex-ante but also focuses on the difference between groups ex-post, if the cross-multiplier term after period 0 (including period 0) is significant, it indicates that there is a certain continuity effect of policy implementation. It should be noted if the conclusions indicate that the coefficients of the interaction terms involving dummy variables do not show significance prior to the policy implementation for the experimental group's dummy variables. Then the parallel trend test is passed. As illustrated in *Figure 1*, the coefficients on the interaction terms do not exhibit a significant difference from zero prior to the policy implementation (the 95% confidence intervals encompass a value of zero). This finding suggests that there is no statistically significant distinction between the control and experimental groups before the designated policy time point, thereby satisfying the criteria for parallel trends.



Source: created by the authors.

Figure 1. **Parallel Trend Test**

3.4.2 Replacement Regression Methods

When performing regression analysis, it is frequently essential to reduce the influence of extreme values on the results by appropriately shrinking the data. Tailoring involves truncating the extreme values in the data set, usually by a certain percentage (e.g., 5%). This method can reduce the estimation bias of extreme values on regression coefficients and improve the robustness of the model. Therefore, in this paper, the regression data are tested by shrinking the tail by 5% (*Table 5*).

Table 5. Robustness Test Results

	(1) EEP	(2) EEP
inter	0.3614***	0.3468***
	(7.536)	(7.410)
Size		0.8252***
		(34.225)
Lev		-0.4862***
		(-3.290)
ROA		2.2033***
		(4.170)
FIXED		0.1560
		(0.860)
Board		0.2425*
		(1.777)
_cons	2.9589***	-15.4611***
	(30.070)	(-29.477)
Ind	Yes	Yes
Year	Yes	Yes
N	27659	27659
R^2	0.1248	0.1721

Source: created by the authors.

The results of the significance test for the core explanatory variables indicate that they remain significant, while their positive correlations maintain their original direction. This suggests that the modeling and estimation methods in the previous paper are appropriate and effective in capturing the true relationships among the variables.

3.4.3 Rejecting Time Impacts

When analysing the entire spectrum of data sets collected, the conclusions drawn can vary significantly across different data segments calculated using diverse methodologies. Therefore, with the aim of evaluating the robustness of the empirical findings presented in the previous section and to ensure the rigor of our research outcomes, this paper conducts a robustness test by excluding epidemic data (*Table 6*).

Table 6. Robustness Test Results

	(1) EEP	(2) EEP
inter	0.4055***	0.3621***
	(7.469)	(6.861)
Size		0.8622***
		(34.506)
Lev		-0.6527***
		(-4.114)
ROA		1.1994***
		(2.679)
FIXED		0.0899
		(0.470)

Table 6 (*continuation*). Robustness Test Results

	(1) EEP	(2) EEP
Board		0.2280*
		(1.754)
_cons	2.9436***	-16.0923***
	(28.005)	(-30.281)
Ind	Yes	Yes
Year	Yes	Yes
N	24267	24267
R^2	0.1159	0.1696

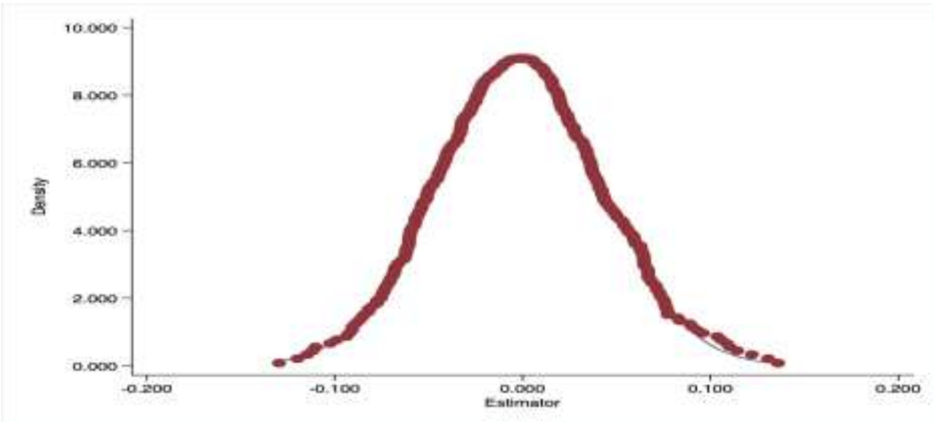
Notes: values presented in parentheses are standard errors. '***', '**', and '*' indicate that the indicator is significant at the 1%, 5%, and 10% levels, respectively.

Source: own calculations.

The robustness test confirms the empirical robustness of the previous section. There is no significant change in the core explanatory variables' significance and their positive and negative correlations, which indicates the high stability of regression results.

3.4.4 Placebo Test

In the model, the placebo test serves to eliminate the influence of non-policy factors on the study's results. This approach aims to prevent subjective alterations in research subjects that may arise from prior signals regarding the forthcoming policy implementation, which could potentially lead to inaccuracies in assessing the 'policy effect'. To assess the robustness of the empirical results derived from the double-difference model established in the previous section, this study repeats the process 500 times. This will yield 500 regression outcomes. Ultimately, this study illustrates the distribution of the estimated coefficients for the pseudo-policy dummy variables, along with their corresponding p-values (*Figure 2*).



Source: created by the authors.

Figure 2. **Placebo Test**

Figure 2 depicts the distribution of estimated coefficients for 500 pseudo-policy dummy variables, along with their corresponding p-values. The x-axis represents the magnitude of the estimated coefficients, while the Y-axis indicates both the density value and the size of the p-value. The curve depicted represents the kernel density estimation of these coefficients. The density distribution of the estimated coefficients is illustrated, with red dots representing their p-values and a horizontal dotted line indicating the significance level of 0.1. The estimated coefficients of the test results are mostly concentrated near the 0 point, and the p-values of the estimated values are mostly greater than 0.1, which is insignificant at the 10% level. This suggests that our estimation is intentional. Thus, the probability of being affected by other policies or uncontrollable factors is low, and the model passes the placebo test.

3.5 Heterogeneity Test

3.5.1 Property Rights

In SOEs, the coefficient of the inter is 0.5839, with a 1% significance level (*Table 7*). This pilot policy has a significant positive effect on relevant performance in SOEs. Possible reasons include the fact that SOEs are more inclined to implement government policies and that the policy provides them additional incentives and resources to implement environmental protection measures and technological innovations more easily. In non-SOEs, the coefficient of the inter is 0.0918 and is significant at the 10% significance level. This indicates that in non-SOEs, the policies also have a positive impact on environmental performance, but to a relatively lesser extent. The possible reason for this is that non-SOEs may need more resources to implement low-carbon technologies as they may face greater financing constraints.

Table 7. Heterogeneity Analysis

	(1) Government Owned	(2) Non-municipal
inter	0.5839***	0.0918*
	(6.096)	(1.920)
Size	1.0166***	0.4308***
	(24.670)	(17.079)
Lev	-2.2935***	0.1827
	(-7.852)	(1.263)
ROA	0.2030	1.8636***
	(0.215)	(5.163)
FIXED	-0.5146*	0.2875
	(-1.656)	(1.479)
Board	0.1747	0.0597
	(0.753)	(0.497)
_cons	-17.8942***	-7.5183***
	(-19.473)	(-13.916)
Ind	Yes	Yes
Year	Yes	Yes
N	10169	17112
R^2	0.2366	0.1096

Source: own calculations.

3.5.2 Pollution Levels

The coefficient of inter is 0.6185 in heavy polluting firms, with a 1% significance level, which indicates that in these firms, the policy has a substantial positive impact on environmental performance (*Table 8*). Possible reasons for this include the fact that heavy polluting firms face greater environmental pressures and policy constraints, and the mentioned policy provides them with incentives to implement environmental protection measures and technological innovations to reduce pollution emissions and promote performance.

Table 8. Analysis of Heterogeneity across Districts

	(1) heavy pollution	(2) non-heavy pollution
inter	0.6185***	0.2239***
	(5.739)	(4.358)
Size	0.7068***	0.7592***
	(13.509)	(31.779)
Lev	-1.0830***	-0.4029***
	(-3.169)	(-2.667)
ROA	0.5919	1.1390***
	(0.585)	(2.815)
FIXED	0.2382	0.1108
	(0.633)	(0.574)
Board	0.6156**	0.0995
	(2.204)	(0.806)
_cons	-12.8207***	-13.8360***
	(-11.460)	(-27.161)
Ind	Yes	Yes
Year	Yes	Yes
N	6302	21357
R2	0.1733	0.1714

Source: own calculations.

In non-heavy polluting firms, the coefficient of the inter is 0.2239 and is significant at a 1% significance level. This suggests that among non-heavy polluting firms, the policy also has a positive impact on the relevant performance, but the impact coefficient is relatively small. Possible reasons for this include the fact that non-heavily polluting firms may have implemented more environmental protection measures and the mentioned pilot policy has less impact on their environmental performance.

3.6 Intermediation Effects

3.6.1 Green Innovation (GI)

Table 9 presents the regression results concerning green innovation as a transmission mechanism. Following the established procedures for testing mediation effects, the findings in the model (1) align with the benchmark regression and will not be reiterated here. In model (2), the estimated coefficients of the policy on green innovation demonstrate positive values (at a 1% significance level), as pilot policies are often accompanied by the establishment of industry standards and norms, which require firms to attain specific levels of green innovation. To comply with these standards, companies must enhance their production processes and operational models to foster green innovation. In addition, low-carbon pilot policies may offer additional incentives such as financial support, tax breaks, and subsidies. These incentives alleviate the financial burden associated with pursuing green innovation for enterprises, thereby increasing their motivation to engage in such initiatives.

Table 9. Mediating Effects of Green Innovation

	(1) EEP	(2) GI
inter	0.3283***	0.0578***
	(7.012)	(5.737)
Size	0.7463***	0.1843***
	(34.081)	(39.136)
Lev	-0.5143***	0.0701**
	(-3.676)	(2.329)
ROA	0.9340**	0.5535***
	(2.439)	(6.720)
FIXED	0.0734	-0.1144***
	(0.433)	(-3.139)
Board	0.2113*	0.0767***
	(1.844)	(3.112)
_cons	-13.5617***	-3.9728***
	(-29.009)	(-39.524)
Ind	Yes	Yes
Year	Yes	Yes
N	27659	27659
R^2	0.1710	0.1961

Source: own calculations.

3.6.2 Financing Constraints (SA)

Table 10 presents the regression results concerning financing constraints as a transmission mechanism.

Table 10. Mediating Effects of Financial Constraints

	(1) EEP	(2) SA
inter	0.3283***	-0.0068***
	(7.012)	(-3.985)
Size	0.7463***	0.0107***
	(34.081)	(10.853)
Lev	-0.5143***	0.0399***
	(-3.676)	(10.007)
ROA	0.9340**	0.0241***
	(2.439)	(3.017)
FIXED	0.0734	-0.0340***
	(0.433)	(-6.585)
Board	0.2113*	0.0028
	(1.844)	(0.780)
_cons	-13.5617***	3.3097***
	(-29.009)	(155.157)
Ind	Yes	Yes
Year	Yes	Yes
N	27659	27659
R^2	0.1710	0.9594

Source: own calculations.

Following the steps outlined for testing mediation effects, the findings in column (1) align with those of the baseline regression and will not be reiterated here. In model (2), the estimated coefficients of the pilot policy on financing constraints show negative values and pass the test of the significance level of

1%, which may be due to the fact that the policy may provide firms with more financing support, such as green credit and bond issuance. The opening up of these financing channels provides enterprises with more sources of funds and helps to alleviate their financing constraints. In addition, the pilot policies may have increased market recognition of enterprises implementing low-carbon technologies or innovations, thus attracting more investors and capital. This increased market recognition helps to reduce the cost of financing for enterprises, thereby alleviating financing constraints.

4. Discussion

In light of the rigorous statistical analyses presented above, this section discusses different aspects of the study results. Primarily, the low-carbon pilot policies demonstrate a significant positive impact on the environmental performance of Chinese firms, with the proposed effect substantially varying across different types of enterprises. The positive influence of pilot policies on enterprise environmental performance can be attributed to the fact that such policies are commonly accompanied by different financial support and incentive packages, offering corporations economic incentives to adopt environmental protection measures and undertake ecological technology innovation. Enterprises minimise the cost of employing low-carbon technologies through tax incentives and government subsidies, which provide them more incentives to make eco-friendly investments. Moreover, low-carbon policies most often motivate firms to employ advanced low-carbon technologies, which typically originate from R&D activities between research institutes and corporations. To be specific, enterprises can conveniently access and embrace such technologies through appropriate policy guidelines, consequently optimising environmental performance.

Business nature. In heavily polluting enterprises, the low-carbon pilot policy considerably affects corporate environmental performance since such enterprises experience higher policy constraints and environmental pressures. Meanwhile, these policies incentivise heavily polluting enterprises to integrate ecological preservation measures and technological innovation, in order to lower carbon emissions, thereby improving resource efficiency and realising a notable improvement in environmental performance. Although the pilot policy also exerts a substantial positive influence on the environmental performance of non-heavy polluting enterprises, this effect is relatively small as non-heavily polluting enterprises may have employed more ecological protection initiatives, rendering pilot policies less effective.

Ownership type. In non-SOEs, pilot policies significantly affect the environmental performance, as these firms may require more resources to adopt low-carbon technologies due to the greater risk of financing constraints. Given the continuous stress on policy improvements, non-SOEs also take part in the pilot policies to foster their ecological performance. In SOEs, the pilot policy shows a profound effect on environmental policy since these firms are more likely to adopt state policies. Furthermore, pilot policies offer firms additional incentives to practice technological innovations and environmental initiatives. The ecological performance of SOEs is of vital significance to sustainable development.

Financing constraints. The low-carbon pilot policy offers financial security for the low-carbon technologies' implementation by profoundly alleviating the financing constraints of enterprises. The green credit, bond issuance, and other financing channels enable relevant authorities to reduce financial pressure and offer low-cost financial support to the business sector, supporting low-carbon development among enterprises. The opening up of such financing channels extends more funds to enterprises, alleviating their financing constraints. Similarly, pilot policies also increase the market recognition of firms embracing low-carbon technologies, resulting in the attraction of more investments.

As a result, the increased market recognition reduces the cost of financing for businesses, thereby, eradicating financing constraints.

Green innovation. The pilot policy has a substantial positive impact on green innovation, for the establishment of industry norms often accompanies low-carbon pilot policies, which require firms to realise certain extents of green innovation. Specifically, enterprises must optimise their operational models and production processes to bolster green innovation, in order to comply with aforementioned standards. Pilot policies may also provide supplementary incentives such as subsidies, tax breaks, and financial support. The proposed incentives eradicate the financial burden related to seeking enterprise green innovation, thereby encouraging them to take part in such initiatives. By extending mechanisms such as market opportunities and social pressure, the pilot policy supports green innovation. With the growing market of green consumers and the increasing public awareness of ecological protection, enterprises are encountering increasing ecological pressure and market prospects. The low-carbon policy also extends a favourable outside environment for corporations, which assists them in capitalising on market opportunities, improving environmental performance, and promoting green innovation.

Other variables. Different control variables, including firm size, profitability, and board size, also have a noticeable positive effect on environmental performance. This implies that the larger firms with adequate resources are able to utilise a large amount of resources to improve their environmental performance. Similarly, a large board size supplements the corporate governance which eventually results in effectively regulating the enterprise's ecological performance. Conversely, a significant negative influence of financial leverage on environmental performance reflects that high financial leverage forces firms to use their finances for discharging debts, which could be otherwise used for optimising ecological performance.

Conclusions

It is concluded that low-carbon pilot policies exert a considerable positive effect on the environmental performance of Chinese firms. In SOEs, the effect of low-carbon pilot policies is more pronounced, whereas in non-SOEs, the proposed effect is relatively small. In heavily polluting firms, the influence of pilot policies is more pronounced, while this impact is relatively minor in non-heavily polluting firms. The low-carbon pilot policy extends various mechanisms, including policy incentives, industry norms, technical support, social pressure, and market opportunities, optimising their environmental performance. As a result, the pilot policy effectively alleviates the financing constraints and offers financial support for enterprises to implement low-carbon innovations or technologies. At the same time, green innovation and financing constraints exert partial mediating effects in the process of improving enterprise environmental performance through low-carbon pilot policies.

Based on the study findings, this study proposes the following policy implications. Firstly, there is a need to adjust and optimise policy incentives for different enterprises, including heavy polluters and non-heavy polluters, to ensure that such policies substantially exert their positive effect. For instance, heavy-polluting enterprises can be offered greater tax incentives and financial support to accelerate low-carbon technological innovation. Secondly, government authorities must publicise the stated pilot policies, and assist enterprises in comprehending the content, incentives, and application process of these low-carbon policies through seminars and training, in order to encourage enterprises to participate in low-carbon pilot policies. Thirdly, concerned authorities should also formulate stringent industry norms and standards to regulate enterprises to meet certain ecological performance levels. Simultaneously, both SOEs and non-SOEs must be equally motivated to participate in the formulation of industry norms and standards, thereby enhancing their recognition of low-carbon technologies. Fourthly, state departments must strengthen cooperation with universities and R&D institutions to extend innovation guidance and low-carbon technical support to enterprises, helping them apply advanced low-carbon technologies and improve their ecological performance. Fifthly, essential funding sources should be offered to enterprises, such as bond issuance and green credit. Likewise, the supervision of corporate financing behaviours must also be strengthened in order to allow funds flow to low-carbon technologies, thus, improving the financing efficiency. Lastly, government departments should also raise public awareness of green/low-carbon technologies and environmental protection.

Although this paper provides valuable insights, certain limitations are present. Primarily, the reliance on secondary data may limit the analysis depth, especially for SMEs and non-SOEs. Moreover, possible endogeneity concerns, such as reverse causality or omitted variable bias, could also affect the robustness of study findings. In addition, this paper concentrates on short-run impacts, avoiding the long-run sustainability of policy effects. Besides, the study analysis is confined to Chinese corporations, which may restrict the generalizability of study implications to other contexts. Finally, this study has treated pilot policies as homogenous, ignoring possible variations in their design and implementation.

To address these limitations, future studies should conduct longitudinal analyses to evaluate long-run policy effects, perform sector-specific analyses to explore industry-relevant enablers and barriers, and undertake cross-country comparisons to increase the findings' generalizability. Similarly, qualitative methods such as case studies can offer in-depth insights into policy mechanisms whereas studies on policy design and implementation can be helpful to explore factors affecting effectiveness. Further investigation of financial mechanisms, such as carbon trading and green bonds, should also be performed in future studies. Due attention must also be paid to SMEs and non-SOEs, experiencing distinct challenges. Further studies may also explore integrated approaches combining ecological policies with CSR and corporate governance frameworks. By addressing these limitations and exploring proposed research guidelines, future studies can provide a more in-depth comprehension of how pilot policies drive enterprise environmental performance.

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BANDOMOSIOS MAŽO ANGLIES DIOKSIDO KIEKIO POLITIKOS ĮTAKA ĮMONIŲ APLINKOSAUGINIAM VEIKSMINGUMUI

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Santrauka. Šiuo tyrimu siekiama įvertinti bandomosios mažo anglies dioksido kiekio politikos poveikį Kinijos įmonių aplinkosauginiam veiksmingumui. Rezultatai atskleidė, kad ši politika reikšmingiau veikia valstybines įmones (SOE) nei nevalstybines, kuriose jos įtaka yra palyginti nedidelė. Be to, nustatyta, kad didelės taršos įmonėse bandomosios politikos poveikis yra ryškesnis, o mažos taršos įmonėse – silpnesnis. Minėtoji politika veikia per įvairius mechanizmus, tokius kaip politinės paskatos, techninė pagalba, pramonės standartai, socialinis spaudimas ir rinkos galimybės, taip prisidėdama prie įmonių aplinkosauginio veiksmingumo didinimo. Be to, ji padeda mažinti finansavimo apribojimus ir suteikia finansinę paramą įmonėms, siekiančioms diegti mažai anglies dioksido išskiriančias technologijas bei inovacijas. Išsamesnė analizė atskleidė, kad žaliosios inovacijos ir finansiniai suvaržymai veikia kaip daliniai tarpiniai veiksniai, gerinant įmonių aplinkosauginį veiksmingumą taikant bandomąją mažo anglies dioksido kiekio politiką. Šiame straipsnyje pateikiamos atitinkamos politikos rekomendacijos, susijusios su didesne politikos parama, politikos įgyvendinimo įtakos stiprinimu ir diferencijuotų mažo anglies dioksido kiekio politikos priemonių įgyvendinimu skirtingų tipų įmonėms skirtinguose regionuose. Taip pat įmonės raginamos aktyviai dalyvauti įgyvendinant bandomąją politiką, kad būtų pasiekti darnaus vystymosi tikslai.

Reikšminiai žodžiai: mažas anglies dioksido kiekis; bandomoji politika; aplinkosauginis veiksmingumas; skirtumų skirtumuose (DiD) metodas.