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Article

The Impact of Green Finance Policies on Green Total Factor Productivity in Strategic Emerging Industry Firms: A Study on the Catalytic Effect

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Abstract: Existing research on the effects of green finance policy suffers from two primary limitations. Firstly, it predominantly focuses on how these policies "force" heavily polluting enterprises to transition, while overlooking their "enabling" effect on Strategic Emerging Industries (SEIs), which are key agents of green development. Secondly, the mechanistic analysis is often confined to a static perspective, lacking an in-depth examination of the policy's dynamic transmission pathways. To address these research gaps, this paper utilizes the Green Finance Reform and Innovation Pilot Zones policy as a quasi-natural experiment. Based on data from A-share listed companies within SEIs from 2011 to 2023, we construct a multi-period Difference-in-Differences (DID) model for systematic investigation. Our findings reveal that: First, the policy significantly enhances corporate Green Total Factor Productivity (GTFP). Second, this effect is realized through a chain-mediating pathway of "alleviating financing constraints → driving green innovation." Third, the policy's impact exhibits structural heterogeneity; it leads to significant improvements in technology-intensive and non-highly polluting enterprises, but has a limited effect on highly polluting, labor-intensive, and asset-intensive enterprises. Fourth, environmental regulation exerts a positive moderating effect, creating a synergistic "guidance + forcing" dynamic. This study provides micro-level evidence for understanding the "enabling" mechanism of green finance and emphasizes that policy design must be precisely coordinated with firms' intrinsic characteristics and the external institutional environment.

Keywords: Green Finance Policies; Green Total Factor Productivity; Strategic Emerging Industries; Financing Constraints; Environmental Regulation

1. Introduction

Amid the global push for climate governance and sustainable development, the transition towards green and low-carbon industries is gaining significant momentum. Strategic Emerging Industries (SEIs), recognized for their inherent environmental attributes and strategic importance, act as a pivotal engine for driving high-quality economic development [1]. However, these industries often find themselves at a critical juncture of technological breakthroughs and market expansion, grappling with substantial challenges including heavy R&D investments, prolonged return periods, and difficulties in internalizing environmental benefits [2-4]. Compounding these issues, the inherent high risks and positive externalities of green innovation activities often lead to constrained access to financing within traditional financial systems. This results in a development paradox where "strong prospects are stifled by a lack of capital," which severely impedes technological advancement and large-scale commercialization [5]. As a critical policy instrument, green finance addresses these market failures through mechanisms such as green credit and green bonds, thereby alleviating financing constraints for enterprises [6]. Beyond merely improving capital availability, it incentivizes firms to allocate resources toward green technology innovation via differentiated pricing and enhanced oversight of fund utilization, ultimately catalyzing their green transformation and upgrading [7]. Consequently, a systematic investigation into the impact and underlying mechanisms of green finance policy on the Green Total Factor Productivity (GTFP) of SEI firms carries substantial theoretical significance and practical urgency for overcoming the barriers to their high-quality and sustainable development.

The literature relevant to this paper can be broadly categorized into two streams. The first stream focuses on the measurement of Green Total Factor Productivity (GTFP). Research on GTFP has established a relatively systematic analytical framework. Regarding measurement methodologies, the academic community primarily employs Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). For instance, Jing Guowen (2024) utilized the DEA-Malmquist index to measure China's provincial GTFP [8], while Xie Dongjiang et al. (2023) evaluated GTFP at the city level based on an SBM-DEA model [9].The second stream concerns studies on the effects of green finance policy, which are primarily conducted from both macro and micro perspectives. At the macro level, research by Chai Shuanglei et al. (2025) and Liu Zimin et al. (2023) both confirms that green finance policy can significantly enhance regional economic quality through pathways such as driving the transformation of the energy structure, stimulating regional innovation, and optimizing the industrial structure [10][11].At the micro level, Liu Hewang et al. (2025) found that the policy can improve corporate ESG performance [12]. Hao Dapeng et al. (2025), from a supply chain perspective, revealed a transmission mechanism through which the policy reduces pollution by stabilizing supply chains and promoting innovation [13]. Bauer et al. (2024) discovered that green finance policy exerts heterogeneous effects on corporate stock prices through channels such as increasing carbon premiums and altering investor preferences, with brown (high-carbon) firms experiencing significantly greater negative impacts [14]. Xu Xinkuo et al. (2025) found that it effectively enhances the green innovation level of highly polluting enterprises through two core pathways: reducing financing costs and incentivizing R&D investment [15].

Although the existing literature on green finance and corporate Green Total Factor Productivity (GTFP) has established a foundational understanding, it still exhibits notable limitations. Firstly, most studies concentrate on heavily polluting enterprises, emphasizing the "compelling" or "forcing" transition effect of the policies, while generally neglecting the role of Strategic Emerging Industries (SEIs) as key agents in the green transformation. Secondly, the mechanistic analysis is often confined to a static perspective, lacking an in-depth exploration of the dynamic transmission pathways throughout the policy's evolution. Within the context of the ongoing critical phase of economic transition, clarifying the impact mechanism of green finance policy on the GTFP of SEI firms carries significant theoretical and practical importance. This study therefore addresses the following critical questions: Can the green finance pilot policy significantly enhance the GTFP of SEI firms? What is the specific underlying "enabling" mechanism? Furthermore, does environmental regulation play a moderating role between the policy and corporate GTFP? To answer these questions, this paper utilizes panel data from 536 Strategic Emerging Industry enterprises from 2011 to 2023, constructing a Difference-in-Differences (DID) model to systematically examine the impact of the green finance policy on corporate GTFP. It further seeks to identify the chain-mediating mechanism of "financing constraints → green transformation" and the moderating effect of environmental regulation. Based on the empirical findings, the study proposes targeted recommendations for both policy optimization and corporate practice.

2. Theoretical Analysis and Research Hypotheses

1) Green Finance Policy Promotes GTFP in Strategic Emerging Industries

The Green Finance Reform and Innovation Pilot Zones policy establishes a systematic green financial service system, providing crucial financial support and clear market signals for Strategic Emerging Industry (SEI) enterprises. On one hand, through instruments such as green credit and green bonds, the policy directly broadens corporate financing channels and reduces the capital cost for green projects [16]. On the other hand, its embedded "green" criteria and information disclosure requirements create a persistent mechanism of incentive and screening, guiding firms to prioritize the allocation of resources towards green technology R&D and cleaner production processes [17]. This dual effect, combining "guidance" and "incentive pressure," effectively encourages enterprises to integrate environmental performance into the total factor productivity framework, thereby achieving synergistic improvements in both green development and efficiency. Accordingly, this paper proposes the following hypothesis:

H1: The green finance policy can significantly promote the enhancement of Green Total Factor Productivity (GTFP) in Strategic Emerging Industry enterprises.

2) Alleviating Financing Constraints and Driving Green Innovation: The Transmission Mechanism of Green Finance Policy on GTFP

The positive impact of the policy on GTFP relies on critical micro-level transmission channels. Firstly, through targeted financial support and risk sharing, the green finance policy directly alleviates the financing constraints commonly faced by Strategic Emerging Industry (SEI) enterprises [18], creating a "resource provision" effect. Secondly, the unlocked financial resources enable firms to undertake high-investment, long-cycle green innovation activities. Concurrently, the policy's oversight and incentives regarding the "green usage" of funds further ensure that resources are substantively channeled into green technology innovation, thereby facilitating a green transition within the innovation structure [19]. This sequential process of "financing constraints alleviation → green innovation enhancement" constitutes the core mechanism through which the policy drives GTFP growth. Accordingly, this paper proposes the following hypothesis:

H2: Financing constraints and green innovation play a chain-mediating role in the process through which green finance policy enhances corporate GTFP.

3) Heterogeneity of Policy Effects

The policy effects are likely to vary depending on firms' intrinsic characteristics. Technology-intensive enterprises typically possess stronger R&D absorption capacity and innovation conversion efficiency, enabling them to more rapidly transform financial resources into outcomes in green technology innovation [20]. Concurrently, compared to heavily polluting firms that are "compelled" to transition, non-highly polluting Strategic Emerging Industry enterprises exhibit strategic objectives that are more aligned with the "support-oriented" nature of green finance [21], resulting in lower transition resistance. Consequently, the enabling effect of the policy is likely to be more direct and pronounced for these firms. Accordingly, this paper proposes the following hypothesis:

H3: The promoting effect of green finance policy on GTFP is more significant in technology-intensive enterprises and non-highly polluting enterprises.

4) Environmental Regulation Strengthens the Policy Effect

The external institutional environment constitutes a critical boundary condition influencing policy effectiveness. When the intensity of regional environmental regulation is high, it signifies that firms face stronger environmental compliance pressure and stricter enforcement constraints [22]. This creates a synergistic effect of "guidance + pressure" in conjunction with the incentive signals of the green finance policy. On one hand, it heightens the sense of urgency for firms to pursue green transformation; on the other hand, it increases the opportunity cost of non-green investments. Consequently, firms are prompted to more actively allocate green financial resources towards green innovation, thereby leading to more substantial enhancements in GTFP. Accordingly, this paper proposes the following hypothesis:

H4: Environmental regulation plays a positive moderating role in the relationship between green finance policy and corporate GTFP; that is, the stronger the environmental regulation, the more pronounced the policy's promoting effect.

3. Research Design

3.1. Model Specification

This paper uses cities involved in the 2017 green finance policy pilot program as the treatment group and strategic emerging industry enterprises in non-pilot cities as the control group to design a double difference model:

$$GTFP_{i,j,t} = \alpha_0 + \alpha_1^* DID_{i,j,t} + \beta^* Control_{i,j,t} + \gamma_i + \varepsilon_t + \epsilon_{i,t} \tag{1}$$

Where $GTFP_{i,j,t}$ is the explained variable; i denotes the i-th enterprise, j denotes the j-th city, t denotes time, Control denotes the control variable, ε_t and γ_i denote time and industry dummy variables.

To examine the regulatory mechanism of environmental regulations on the impact of technology finance on the high-quality development of enterprises, a regulatory effect model was established:

$$GTFP_{i,j,t} = \alpha_0 + \alpha_1^* DID_{i,j,t} + \alpha_2 EV_{i,j,t} + \alpha_3^* EV_{i,j,t} \times DID_{i,j,t} + \beta^* Control_{i,j,t} + \gamma_i + \varepsilon_t + \epsilon_{i,t} \tag{2}$$

Where $EV_{i,j,t}$ is the moderating variable, and $EV_{i,j,t} \times DID_{i,j,t}$ is the interaction term between the moderating variable and the policy dummy variable.

To examine the impact mechanism of financing constraints and innovation capabilities on the green total factor productivity of strategic emerging industries, an intermediary effect model was established:

$$GTFP_{i,j,t} = \alpha_0 + \alpha_1^* DID_{i,j,t} + \alpha_2^* M_{i,j,t} + \beta^* Control_{i,j,t} + \gamma_i + \varepsilon_t + \epsilon_{i,t} \quad (3)$$

Where $M_{i,j,t}$ is the mediating variable, and KZ and PA are used separately in the regression.

3.2. Variable Definition

1) Explained variable

The explained variable in this paper, green total factor productivity (GTFP), is estimated using the SBM-GML model to calculate the green total factor productivity of enterprises. The main indicators for calculating GTFP include two aspects: inputs and outputs. First, the input aspect. Capital input: The perpetual inventory method is used to estimate each firm's capital input. That is, $K_t = K_{t-1}(1-\delta_t) + I_t / P_t$. Here, K_t represents the capital stock at period t, δ_t is the depreciation rate (set at 5%), I_t is the net fixed assets of the firm at period t, and P_t is the investment price index of the province where the firm is located at period t. Labor input: Represented by the number of employees in the enterprise. Energy input: Represented by the electricity consumption of industrial enterprises in the city where the listed company is located. Second, output. Expected output: measured by the company's main business revenue as a proxy indicator for expected output. Unexpected output: measured by the three wastes generated by industrial enterprises, including industrial SO_2 emissions, industrial wastewater emissions, and industrial engineering emissions. First, calculate the adjustment coefficient W_j for each pollution indicator in each prefecture-level city, i.e., the weight.

Following the computational methods of Zhao Xikang, Li Bin, and others [23-25], the value of W_j is: $W_j = \left(P_{ij} / \sum P_{ij}\right) / \left(O_i / \sum O_i\right) = \left(P_{ij} / O_i\right) / [\Sigma P_{ij}\big) / \left(\Sigma O_i\right)\big] = UP_{ij} / \overline{UP_{ij}}$, where P_{ij} is the emission quantity of pollutant j (j=1,2,3) in prefecture-level city i, $\sum P_{ij}$ is the total national emission of pollutant j, O_i is the total industrial output value of prefecture-level city i, and $\sum O_i$ is the total national industrial output value. Next, the weighted adjusted emission of pollutant j from prefecture-level city i is obtained as: $em_{i,j} = W_j \times Y_{ij}$, where Y_{ij} is the original emission of pollutant j from prefecture-level city i. Finally, the emissions of pollutant j from enterprise k in prefecture-level city i are obtained as: $em_{k,j} = em_{i,j} \times \left(Q_k / \Sigma Q\right)$, where Q_k is the industrial output of enterprise k, and ΣQ is the total industrial output of the prefecture-level city where enterprise k is located. The non-expected output data is sourced from the China Urban Statistical Yearbook.

2) Explanatory variables

This study focuses on cities involved in China's "green finance" policy launched in 2017, specifically Huzhou City, Quzhou City, Ganjiang New District, Guangzhou City, Gui'an New District, Hami City, Changji Prefecture, and Karamay City. Among them, Gui'an New District involves the surrounding cities of Guiyang City and Anshun City, while Ganjiang New District involves Jiujiang City and Nanchang City. To assess the impact of this policy, this paper constructs an interaction term variable for policy implementation. Specifically, a time-based dummy variable ($D_{i,j,t}$) is first created, taking a value of 1 if the year is 2017 or later, and 0 otherwise. Next, a city dummy variable ($Treat_{i,j,t}$) is created, taking a value of 1 if the city is a pilot city, and 0 otherwise. Then, the interaction term ($DID_{i,j,t}$) is constructed by multiplying these two dummy variables, i.e., $DID_{i,j,t} = D_{i,j,t} * Treat_{i,j,t}$. When $DID_{i,j,t}$ is 1, it indicates that the city where the firm is located has already implemented the "green finance" policy in that year; if the value is 0, it indicates that the policy has not yet been implemented.

Table 1. Variable Definitions.

Variable Type	Name	Symbol	Definition
Explained Variable	Green Total Factor Productivity	GTFP	Following Guo & Liu (2020), we measure GTFP using the SBM-GML model to account for undesirable outputs [26]
Explanatory Variable	Dummy Variable for Green Finance Policy Implementation	DID	$DID_{i,j,t} = 1$if firm i's city j implemented green finance policy in year t, and 0 otherwise
Control Variable	Enterprise Scale	size	Ln (year-end total assets)
	Leverage Ratio	Lev	Year-end total liabilities / Year-end total assets
	Return on Equity	Roe	Net profit / Shareholders' equity
	Tobin's Q	Tobinq	Market value of equity / Book value of total assets
	Firm Growth	Growth	(Current year revenue − Prior year revenue) / Prior year revenue
	Loss Dummy	Loss	1 if net profit < 0 in year t, and 0 otherwise
	Operating Cash Flow	Cashflow	Operating cash flow / Total assets
	Capital Appreciation Rate	Car	(Ending equity − Beginning equity) / Beginning equity
	Regional Financial Development Level	Fd	Year-end bank loan balance / Regional GDP
Other Variable	Firm Financing Constraints	KZ	KZ Index (from the CSMAR Database)
	Firm Innovation Capability	PA	Ln(1 + Number of patent applications)
	Environmental Regulation	EV	Proxy variables constructed following Zhang & Chen (2021)
	Pollution-intensive Industry Dummy	PID	1 if firm belongs to high-pollution industries per the Guidance on Environmental Protection Classification of Listed Companies, 0 otherwise

3) Control variables and other variables

The control variables and other variables in the study are shown in Table 1. The moderating variable, environmental regulation, was measured using the method described by Zhang Jianpeng and Chen Shiyi (2021) [27], as follows: First, the proportion of heavy industry output in the GDP of each prefecture-level city was calculated based on the China Industrial Enterprise Database. Second, quantify the average annual frequency of policy keywords such as "environmental protection," "pollution control," and "green development" in provincial government work reports; Finally, perform an interactive calculation between the economic weight of heavy industry in prefecture-level cities and the intensity of provincial environmental policy texts to generate a composite indicator reflecting the enforcement strength of local government environmental regulations. This design captures the actual policy enforcement intensity of prefecture-level city governments in environmental governance through dual dimensions of industrial sensitivity and policy attention.

3.3. Sample and Data Sources

Based on data availability, this study uses data from small and medium-sized enterprises listed on the Shanghai and Shenzhen main boards from 2011 to 2023 that belong to strategic emerging industries as the research sample. Regional-level data is sourced from the China Statistical Yearbook, local statistical yearbooks, and the EPS database. Micro-level enterprise data is sourced from the Wind database, CSMAR database, and annual reports disclosed by the enterprises. Traditional financial sector enterprises, ST enterprises, and ST* enterprises were excluded from the original sample. Missing data was imputed using interpolation methods. To mitigate the impact of outliers on the study, data outside the 1%-99% range was trimmed, resulting in a final dataset of 6,968 observations, including 536 strategic emerging industries enterprises.

4. Analysis of Empirical Results

4.1. Descriptive Statistics

Table 2. Descriptive Statistics of Variables.

Name	Mean	Var	SD	Skewness	Kurtosis
Size	22.1888	1.4845	1.2184	0.6371	3.4840
Roe	0.0556	0.0154	0.1241	-2.1209	13.0063
Lev	0.3823	0.0345	0.1859	0.1641	2.2936
Tobinq	2.2556	1.9766	1.4059	2.3407	10.6647
Growth	0.1686	0.1446	0.3802	3.1085	21.5475
Loss	0.1383	0.1383	0.1383	2.0949	5.3888
Cashflow	0.0423	0.0038	0.0620	0.1229	4.2295
Fd	4.2314	3.0738	1.7532	0.3160	2.4743
Car	1.1699	0.2107	0.4590	4.4063	36.8183

The descriptive statistics for the variables are presented in Table 2. The results show that the mean value of regional financial development (FD) for the sample enterprises is 4.23 (standard deviation 1.75), and its dispersion indicates possible regional heterogeneity in green financial policies. The distribution of enterprise size (mean 22.19, standard deviation 1.22) is concentrated and mildly skewed, indicating that the scale effects of strategic emerging industries are converging. The extreme right skew of Tobin's Q (mean 2.26, skewness 2.34) and capital appreciation rate (mean 1.17, skewness 4.41) indicates significant valuation differences among firms, with some firms potentially receiving market-driven excess valuations. The proportion of loss-making enterprises (Loss mean 0.138) and cash flow volatility (Cashflow mean 0.042, standard deviation 0.062) suggest significant financial vulnerability stratification within the sample. Loss-making enterprises may face a "double threshold constraint" in green transformation— —both lacking short-term cash flow support (average is only one-third of profitable companies) and being excluded from green financial support due to credit risks, which may lead to divergent capabilities in accessing policy benefits [28]. Meanwhile, the synergistic distribution of high growth (Growth mean 0.1686) and debt-to-equity ratio (Lev mean 0.3823) indicates that strategic emerging companies in the sample generally exhibit a "high growth-moderate leverage" characteristic.

4.2. Benchmark Regression

Table 3. Baseline Regression Results.

Name	(1) GTFP	(2) GTFP	(3) GTFP
Did	0.0815*** (0.0019)	0.0094** (0.0044)	0.0104** (0.0047)
Size		-0.0083*** (0.0015)	-0.0085*** (0.0015)
Roe		0.0038 (0.0050)	0.0322*** (0.0057)
Lev		0.0044 (0.0069)	0.0040 (0.0067)
Tobinq		-0.0025*** (0.0006)	-0.0024*** (0.0007)
Growth			-0.0051*** (0.0013)
Loss			0.0152*** (0.0025)
Cashflow			-0.0356*** (0.0098)
Fd			-0.0012 (0.0014)
Car			0.0099*** (0.0021)
Constant	1.0136*** (0.0010)	1.0776*** (0.0342)	1.0712*** (0.0351)
Year Fe	No	Yes	Yes
Code Fe	No	Yes	Yes
Observations	6968	6968	6968
R2	0.0222	0.829	0.832

Note: *** , ** , * indicate that the regression coefficients are significant at the 1%, 5%, and 10% levels, respectively; values in parentheses are robust standard errors clustered by industry. The same applies hereafter.

To examine the impact of the Green Finance Reform and Innovation Pilot policy on the Green Total Factor Productivity (GTFP) of Strategic Emerging Industry (SEI) enterprises, this paper constructs a Difference-in-Differences (DID) model for baseline regression. Control variables were added progressively, with the results presented in Table 3.Column (1) reports the regression results without any control variables. The coefficient of the core explanatory variable (Did) is 0.0815, which is positive and statistically significant at the 1% level. This indicates that the green finance policy effectively promotes the GTFP of SEI enterprises. Columns (2) to (3) present the results after progressively adding control variables. The core explanatory variable (Did) remains positively significant at the 5% level across these specifications. Notably, the coefficient magnitude increases with the addition of control variables. This pattern suggests not only an effective correction for omitted variable bias by the model but also implies that the green finance policy may exert a structurally promoting effect on GTFP through multidimensional transmission channels, such as financing support, risk mitigation, and technological synergy. Therefore, further mechanism tests or grouped regressions are warranted to verify the significance of specific pathways.

Regarding the control variables, the coefficient for firm size (Size) is significantly negative (-0.0085). This might reflect efficiency losses in the green transition for larger firms due to management complexity or path dependency, aligning with the theory of "scale diseconomies" [29]. Tobin's Q shows a significantly negative coefficient (-0.0024), suggesting that firms with higher market valuations might prioritize short-term financial returns over long-term investments in green technology, consistent with the market myopia hypothesis [30].It is noteworthy that the Return on Equity (Roe) becomes significantly positive (0.0322) after controlling for cash flow. This indicates that firms with stronger profitability may support green innovation using internal funds. Conversely, the loss-making status (Loss) shows a significant positive association with GTFP (0.0152), potentially because financial pressure forces firms to improve cost efficiency through green efficiency gains. Furthermore, the regional financial development level (Fd) is statistically insignificant, possibly because the policy effect overshadows the moderating role of regional financial resources. The positive coefficient for the capital appreciation rate (Car) (0.0099) reflects the supportive role of capital accumulation in adopting green technologies. In summary, the model's goodness-of-fit improves (R^2 increases from 0.022 to 0.832) as endogenous factors are progressively controlled for. However, the net policy effect requires further validation combined with heterogeneity analysis.

4.3. Sensitivity Testing

4.3.1. Parallel Trend Test

The difference-in-differences method is a commonly used approach for evaluating policy effects, whose validity is based on the assumption that the experimental group and control group follow the same trend prior to policy implementation. To verify whether the changes in the experimental group before and after policy implementation are indeed caused by the policy rather than other time-related factors, this study conducted a parallel trends test. Specifically, this study constructed time dummy variables covering the three years prior to policy implementation, the year of policy implementation, and the three years following policy implementation. These were multiplied by the treatment group dummy variable (treat) to form interaction terms pre_3, pre_2, pre_1, current, post_1, post_2, and post_3. Among these, pre_1 was set as the reference group. These interaction terms were then used as explanatory variables in regression analysis to test whether trends before and after policy implementation were parallel.

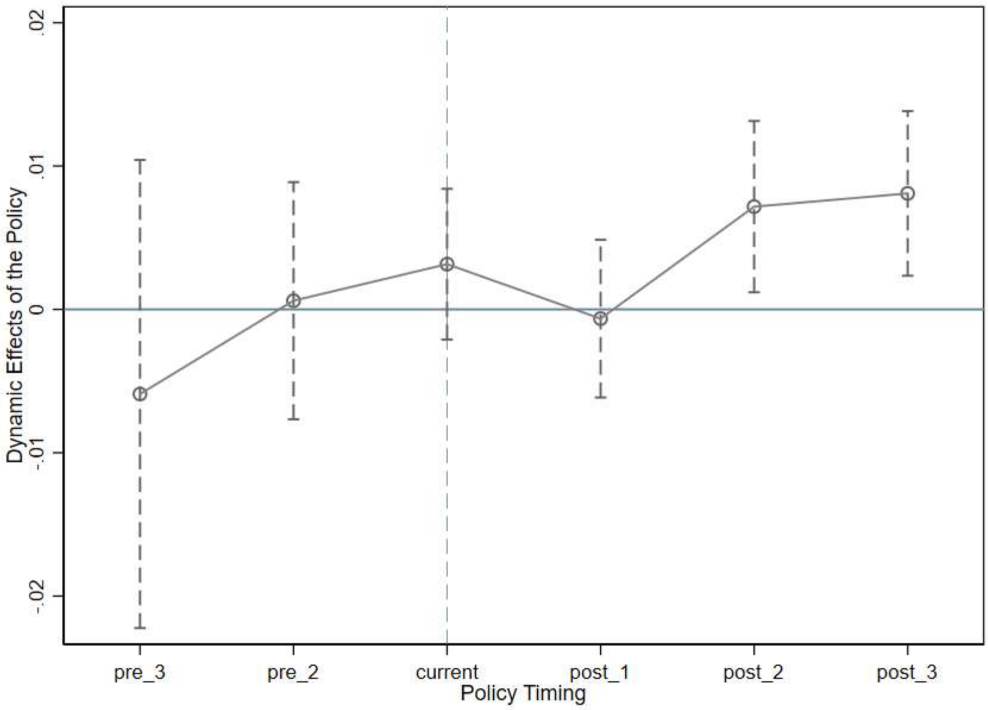

Figure 1. Parallel Trends Diagram.

Figure 1 shows the results of the parallel trend analysis, indicating that there was no statistically significant difference in green total factor productivity between the experimental group and the control group prior to the implementation of the green finance pilot policy. However, after the policy was implemented, it can be observed that the green total factor productivity levels of enterprises in the experimental group showed a significant improvement three years after the policy was implemented, but no significant improvement was observed in the first year after the policy was implemented, possibly due to the time lag associated with green finance policies [31]. The test results support the parallel trend hypothesis of this study, indicating that the trends of the two groups were consistent before and after the policy implementation, thereby providing a reliable prerequisite for subsequent difference-in-differences analysis.

4.3.2. Placebo Test

This study conducted a placebo test by introducing two strategies—virtual policy implementation time and virtual policy impact targets—to verify the robustness of the results.

First, virtual enterprises affected by the policy were set. Based on the actual number of enterprises affected by green finance policies each year, an equal number of enterprises were randomly selected as the virtual experimental group. On this basis, the virtual interaction term random_treat × Post was constructed, and 500 repeated regression analyses were performed. This process aimed to validate the robustness of the model through random sampling and repeated experiments. As shown in the simulation results in Figure 2, the regression coefficients of the virtual variables are distributed around 0, which is significantly different from the estimated coefficient of

0.0140. From the data distribution, the results of the sampling regression are basically normally distributed. This phenomenon indicates that green financial policies have no significant impact on the green total factor productivity of randomly selected experimental group firms. The benchmark regression results are caused by the actual policy effects rather than random factors.

Overall, the placebo test results support the conclusions of this study, indicating that the results are not due to biases in the model specification. These tests further validate the robustness and reliability of the study findings.

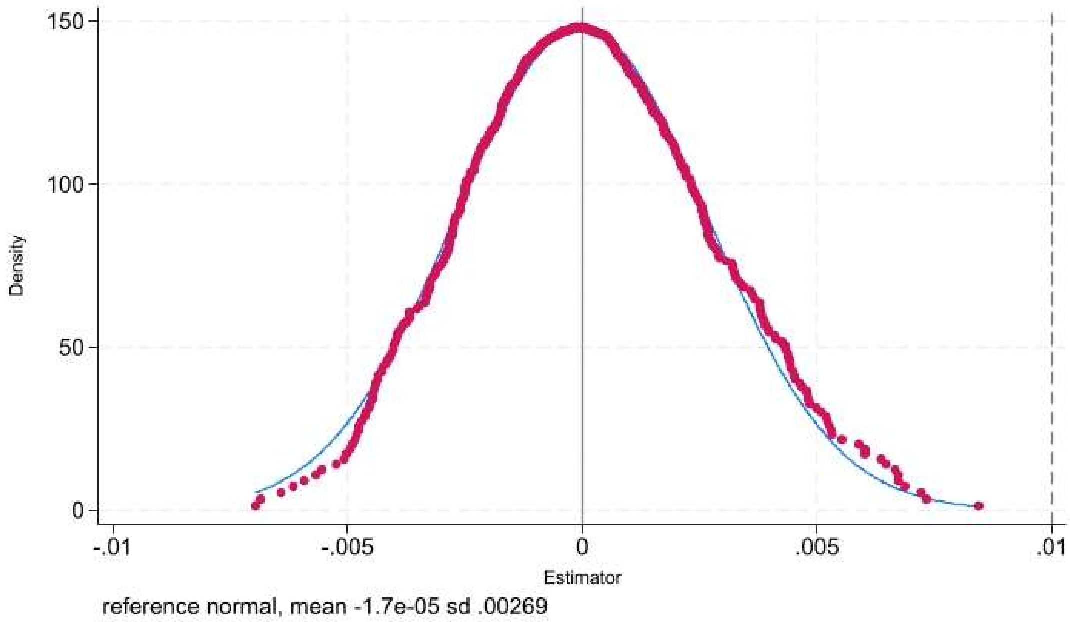

Figure 2. Simulation Results of Randomly Assigning Experimental Groups.

Table 4. Placebo Test Using Fictitious Policy Timing.

	Explained Variable: GTFP	
	(1)	(2)
DID2015	0.0068 (0.0076)	
DID2016		0.0042 (0.0068)
Observations	6968	6968
Year Fe	Yes	Yes
Code Fe	Yes	Yes
Control	Yes	Yes

Second, set the virtual policy time. Based on Chen Qiang et al. (2023) time placebo test method, 2015 and 2016 were defined as simulated policy implementation years, and time dummy variables were created accordingly [32]. These time dummy variables were then multiplied by the pilot region identification variable treat to form variables representing the effects of simulated policy implementation. Using these variables, this paper conducted time placebo test analyses to examine the impact of simulated policy implementation on firms. The results are shown in Table 4, where the interaction term coefficients are all insignificant, indicating that the benchmark conclusions of this paper are robust.

4.3.3. Replace Core Explained Variables

Referring to the SBM-GML method (Cheng Liwei and Xiao Caixia, 2023 [25]; Cui Xinghua and Lin Mingyu, 2019 [33]), the green total factor productivity of enterprises was calculated as a replacement indicator for the core explanatory variable. The regression results are shown in Table 5. The regression coefficient of the dummy variable for the implementation of green finance policies on the green total factor productivity of enterprises is 0.0073, which is significant at the 5% level, indicating that the benchmark regression results in this paper are robust.

Table 5. Regression Results with Alternative Dependent Variables.

	Alternative Dependent Variables
DID	0.0073**
	(0.0033)
Constant	0.9341***
	(0.0404)
Observations	5354
Year Fe	Yes
Code Fe	Yes
Control	Yes

4.4. Mechanism Analysis

4.4.1. Chain Mediating Effect

Table 6 presents the results of the mediation effect analysis of financing constraint relief. First, in column (1), the regression coefficient of the dummy variable for the implementation of green finance policies on the explained variable is 0.0104, which is significantly positive at the 5% level. This indicates that in cities where green finance policies are implemented, the green total factor productivity (GTFP) of enterprises is significantly improved. Second, in column (2), the regression coefficient of the dummy variable for the implementation of green financial policies on the alleviation of financing constraints (KZ) is -0.3210, which is significant at the 10% significance level. This indicates that the policy has a significant positive impact on alleviating financing constraints for enterprises in strategic emerging industries. Additionally, Column (3) shows that the coefficient of financing constraint capacity (KZ) on innovation capacity (PA) is -0.0289, which is significant at the 10% significance level. This indicates that in regions where green finance policies are implemented, the reduction in financing constraints significantly enhances corporate innovation capacity. Furthermore, in Column (4), the regression coefficient for the impact of alleviating financing constraints on green total factor productivity is -0.0049, which is significant at the 1% significance level; the regression coefficient for innovation capacity (PA) on green total factor productivity is 0.0032, which is significant at the 1% significance level. This indicates that the implementation of green financial policies promotes innovation in strategic emerging industries by alleviating financing constraints, thereby enhancing corporate green total factor productivity, thereby validating Hypothesis 2.

Empirical results show that the total effect of green financial policies (DID) on GTFP is 0.0104 ($p<0.05$), indicating that the implementation of policies significantly enhances corporate green productivity. After controlling for financing constraints (KZ) and innovation capacity (PA), the direct effect of the policy is 0.0096 ($p < 0.05$), accounting for 92.3% of the total effect, highlighting the immediate impact of green financial policies; The indirect effect is transmitted through the theoretical pathway of "alleviation of financing constraints → innovation-driven → green transformation," with a value of 0.0008 ($p < 0.01$), accounting for 7.7%. Although weak, it is significant and consistent with the resource-based view and innovation economics framework.

Table 6. Mediation Effect Test.

	Explained Variable			
	(1)	(2)	(3)	(4)
	GTFP	KZ	PA	GTFP
DID	0.0104**	-0.3210*	-0.2491	0.0096**
	(0.0047)	(0.1587)	(0.2077)	(0.0043)
KZ			-0.0289*	-0.0049***
			(0.0146)	(0.0012)
PA				0.0032***
				(0.0010)
Constant	1.0712***	-1.3784	-5.8350***	1.0828***
	(0.0351)	(1.2291)	(1.7029)	(0.0341)
Year Fe	Yes	Yes	Yes	Yes
Code Fe	Yes	Yes	Yes	Yes
Control	Yes	Yes	Yes	Yes
Observations	6968	6968	6968	6968

4.4.2. The Moderating Mechanism of Environmental Regulation

The variable for environmental regulation (EV) is defined as the proportion of environmental protection term frequency relative to the total term frequency in prefecture-level city government work reports. Specifically, EV1 is calculated as the frequency of environmental protection terms divided by the precise total term frequency, while EV2 is the frequency of environmental protection terms divided by the full-text total term frequency. To ensure the robustness of the model, EV2 is used as an alternative measure of environmental regulation.

EV is selected as the moderating variable in this study on the promoting effect of green finance policy on the green total factor productivity (GTFP) of strategic emerging industry (SEI) enterprises. To ensure accuracy, the environmental regulation variable (EV) is mean-centered. The test results are presented in Table 8. The coefficient of the interaction term between the green finance policy dummy variable and the mean-centered environmental regulation is 2.2701, which is positive and statistically significant at the 5% level. This indicates that environmental regulation significantly strengthens the promoting effect of the green finance policy on GTFP. This finding aligns with the "innovation compensation effect" mechanism of the Porter Hypothesis, suggesting that stringent environmental regulation forces enterprises to increase investment in green technology R&D and optimize resource allocation efficiency, thereby amplifying the effect of the green finance policy. It verifies the positive moderating role of environmental regulation (EV) in the impact of green finance policy (DID) on the green total factor productivity (GTFP) of strategic emerging industry enterprises.

Table 7. Moderation Effect Analysis Results.

	Explained Variable: GTFP
DID	0.0122**
	(0.0049)
Z_EV1	-0.3757
	(0.3135)
C.Z_EV1#C.DID	2.2701**
	(0.9830)
Constant	1.0763***
	(0.0342)
Control	Yes
Year Fe	Yes
Code Fe	Yes
Observations	6945
R2	0.8131

Table 8. Regression Results After Replacing Moderating Variable.

	Explained Variable: GTFP
DID	0.0119**
	(0.0049)
Z_EV2	-0.4543
	-0.4543
C.Z_EV2#C.DID	2.9919**
	(1.3307)
Constant	1.0762***
	(0.0342)
Control	Yes
Year Fe	Yes
Code Fe	Yes
Observations	6945
R^2	0.8320

Specifically, the direct effect of the green finance policy (DID) is 0.0122 ($p < 0.05$), indicating that its independent implementation can promote GTFP improvement. However, the moderating effect further reveals that this effect is significantly enhanced under conditions of higher environmental regulation intensity. This underscores the necessity for policy synergy: green finance provides financial support for enterprises, while environmental regulation creates innovation incentives by increasing pollution costs. The complementarity between these two policies amplifies the marginal benefits of technological upgrading.

The calculation method for environmental regulations (EV) was replaced, and the regression was performed again. The results are shown in Table 9. The coefficient of the interaction term between the dummy variable for green finance policy and environmental regulations is 2.9919, which is significantly positive at the 5% level, further confirming that environmental regulations significantly strengthen the promotional effect of green finance policy on GTFP.

4.5. Heterogeneity Analysis

4.5.1. Corporate Pollution Attributes

Heavily polluting enterprises typically face higher environmental compliance costs, making their production models more sensitive to policy changes. According to the Porter Hypothesis, while stringent environmental regulations may compel such firms to pursue green transformation through technological innovation, in the short term, resource crowding-out effects could inhibit the improvement of their green total factor productivity (GTFP). Furthermore, due to technological path dependency formed by historical investments, heavily polluting enterprises incur higher marginal costs for green transition, leading to delayed or weakened policy effects. In contrast, non-heavily polluting enterprises, which generally exhibit higher initial environmental standards, can more readily achieve GTFP enhancement as green finance policies directly support their technological upgrades by alleviating financing constraints. Dividing heterogeneous groups based on pollution characteristics not only aligns with the interactive logic of environmental policy and green finance but also provides micro-level evidence for "targeted pollution control" and "differentiated policy implementation." This methodological choice resonates with the Porter Hypothesis while fulfilling the need to control for key heterogeneity in empirical research.

Consequently, this paper examines the heterogeneous effects of green finance policy on the GTFP of strategic emerging industry (SEI) enterprises based on their pollution attributes. Specifically, the impact of green finance policy on the GTFP of heavily polluting SEI enterprises is found to be statistically insignificant. In the short term, the resource crowding-out effect significantly suppresses their GTFP improvement. This mechanism is corroborated by the negative cash flow coefficient (Cashflow = -0.0575*) and the insignificant policy effect (DID = 0.0007) for the heavily polluting enterprise group in Table 9.In contrast, non-heavily polluting enterprises, benefiting from their higher initial environmental standards, are directly empowered by green finance policies to pursue technological upgrades through eased financing constraints. As shown in Table 9, the policy effect coefficient for the non-polluting enterprise group is 0.0105 ($p < 0.05$), indicating that funds are more likely to flow into "incremental innovation" areas such as clean energy application and energy efficiency optimization, thereby rapidly enhancing GTFP.

4.5.2. Industry Structure Attributes

From the perspective of industrial structure heterogeneity, this study systematically examines the differentiated mechanisms of green financial policies on the green total factor productivity (GTFP) of enterprises in strategic emerging industries by categorizing them into labor-intensive, technology-intensive, and asset-intensive groups.

Table 9. Heterogeneity Analysis Results.

Name	Corporate Pollution Attributes		Industry Structure Characteristics		
	(1)	(2)	(3)	(4)	(5)
	Non-polluting	High-polluting	Labor-intensive	Asset-intensive	Technology-intensive
did	0.0105**	0.0007	-0.0100	-0.0135	0.0135***
	(0.0040)	(0.0150)	(0.0126)	(0.0094)	(0.0026)
Size	-0.0072***	-0.0086	-0.0058	-0.0103	-0.0083***
	(0.0015)	(0.0065)	(0.0044)	(0.0082)	(0.0013)
Roe	0.0260***	0.0544**	0.0293	0.0367	0.0289***
	(0.0044)	(0.0202)	(0.0230)	(0.0246)	(0.0045)
Cashflow	-0.0349**	0.0096	-0.0575*	0.0072	-0.0377**
	(0.0134)	(0.0291)	(0.0331)	(0.0287)	(0.0154)
Growth	-0.0058***	-0.0030	-0.0020	0.0002	-0.0060**
	(0.0018)	(0.0038)	(0.0030)	(0.0047)	(0.0023)
Tobinq	-0.0021***	-0.0059*	-0.0035**	-0.0097***	-0.0026***
	(0.0006)	(0.0031)	(0.0015)	(0.0028)	(0.0006)
Loss	0.0085***	0.0276**	0.0096	0.0249***	0.0083***
	(0.0024)	(0.0105)	(0.0084)	(0.0089)	(0.0023)
Car	0.0105***	0.0067	0.0015	0.0049	0.0105***
	(0.0026)	(0.0057)	(0.0060)	(0.0066)	(0.0025)
Lev	-0.0041	-0.0241	-0.0071	-0.0085	0.0086
	(0.0078)	(0.0177)	(0.0114)	(0.0208)	(0.0081)
Fd	-0.0013	0.0014	-0.0018	0.0063	-0.0012
	(0.0014)	(0.0030)	(0.0016)	(0.0065)	(0.0017)
Constant	1.0375***	1.0941***	1.0322***	1.1220***	1.0612***
	(0.0323)	(0.1372)	(0.0993)	(0.1787)	(0.0286)
Year FE	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
N	5772	1196	1186	996	5015
R2	0.8460	0.7590	0.8500	0.7660	0.8410

Theoretically, there are fundamental differences in the factor endowment characteristics and policy response pathways across industries: (1) Labor-intensive industries heavily rely on low-skilled labor and have low technological substitution elasticity [34], facing significant skill mismatch risks during green transitions. Policy-induced capital deepening may temporarily suppress productivity growth in the short term; (2) Technology-intensive industries are centered on R&D investment and knowledge capital, leveraging technological absorption capabilities to form innovation network effects, enabling efficient conversion of green financial resources into clean technology breakthroughs, thereby driving GTFP growth; (3) Asset-intensive industries are constrained by path dependencies in heavy asset investments, with sunk costs and capital replacement pressures leading to investment inertia in green transitions. Empirical results indicate that green finance policies have a significant promotional effect on GTFP for technology-intensive firms (DID = 0.0135, $p < 0.01$), while the policy effects for labor-intensive (DID = -0.0100) and asset-intensive firms (DID = -0.0135) fail to pass the significance test. This finding aligns with the "factor endowment-policy fit" logic within the new structural economic framework, revealing that the effectiveness of green finance policies is highly dependent on industrial technological attributes and factor structures. The study provides a basis for differentiated policy design: technology-intensive firms should strengthen R&D tax credits and risk-sharing mechanisms, while labor-intensive and asset-intensive firms should address transition constraints through skill subsidies and asset replacement incentives, ultimately achieving coordinated industrial advancement in green transition.

5. Further Discussion

The empirical findings of this study demonstrate that green finance policy significantly promotes the Green Total Factor Productivity (GTFP) of Strategic Emerging Industry (SEI) enterprises. This effect is primarily realized through alleviating financing constraints and incentivizing green innovation, while being positively moderated by environmental regulation. This conclusion resonates with the existing literature to some extent but also exhibits distinct heterogeneity and mechanistic depth.

Firstly, this study validates the positive impact of green finance policy on corporate GTFP, which aligns with the macro-level findings of Jing Guowen (2024) and Xie Dongjiang et al. (2023) [8-9]. However, it further reveals the transmission pathways from a micro-enterprise perspective, addressing the gap in existing research that often focuses on heavily polluting enterprises while neglecting SEIs. Compared to the research by Xu Xinkuo et al. (2025), this paper not only confirms the dual pathways of reducing financing costs and increasing R&D investment [15] but also, through a chain-mediation model, uncovers the sequential transmission mechanism of "financing constraints → green transformation → GTFP," emphasizing the policy's dynamic impact on internal resource allocation within firms.

Secondly, this study finds significant heterogeneity in the policy effects. The GTFP improvement is more pronounced for technology-intensive and non-highly polluting enterprises, whereas the policy response is weaker for highly polluting, labor-intensive, and asset-intensive enterprises. This conflicts with conclusions from Zhang Chao et al. (2025) and Wang Jingru et al. (2025), who found green finance more significantly enhances the performance of heavily polluting enterprises [35-37]. The root of this significant heterogeneity in policy effects lies in the complex structural characteristics within the Strategic Emerging Industries. Technology-intensive and non-highly polluting enterprises, due to their innovation orientation being highly aligned with the goals of green finance policy, can more efficiently transform financial resources into green technology innovation, leading to significant GTFP improvement. In contrast, the highly polluting, labor-intensive, and asset-intensive firms within these industries, facing substantial compliance costs, technological path dependence, and pressure to adjust factor structures, see policy resources diverted towards end-of-pipe treatment and other such areas, resulting in a weaker promotional effect on GTFP. This finding reveals the dual operational logic of "development empowerment" and "survival safeguarding" inherent in green finance policy when promoting industrial green transformation, providing a useful complement to the mainstream research conclusion focused on "forcing transformation" in traditional heavily polluting enterprises.

Finally, the positive moderating effect of environmental regulation further supports the "innovation compensation effect" hypothesis, consistent with the findings of Li Qingyuan and Xiao

Zehua (2020) regarding heterogeneous environmental regulation tools incentivizing green innovation [38]. Interaction term analysis indicates that the synergy between green finance policy and stringent environmental regulation can significantly amplify the policy effect, suggesting that policy design should emphasize the coupling of financial incentives and institutional constraints.

6. Main Research Findings

6.1. Main Research Conclusions

Based on a sample of China's A-share strategic emerging industry enterprises from 2011 to 2023, this study constructs a multi-period difference-in-differences model to systematically examine the impact of the Green Finance Reform and Innovation Pilot Zones policy on corporate green total factor productivity (GTFP) and its underlying mechanisms. The empirical analysis yields the following core conclusions:

First, the green finance policy has significantly enhanced the GTFP of strategic emerging industry enterprises, a finding that remains robust after a series of rigorous tests.

Second, the policy effects exhibit structural heterogeneity: GTFP improvement is pronounced in technology-intensive and non-highly polluting enterprises, whereas the effect is weaker in highly polluting, labor-intensive, and asset-intensive enterprises. This indicates that within strategic emerging industries, the green finance policy primarily exerts a "development empowerment" effect on firms with an innovation foundation, while its impact remains limited for those burdened with heavy transition costs, revealing the profound correlation between policy effectiveness and firms' intrinsic capabilities and resource structures.

Third, mechanism analysis demonstrates that the policy enhances corporate GTFP through a chain-mediating pathway of "alleviating financing constraints → driving green innovation."

Fourth, environmental regulation plays a positive moderating role in the relationship between the policy and GTFP, with the synergistic mechanism of "guidance + pressure" formed by the two effectively strengthening corporate motivation for green transition.

6.2. Policy Implications

Based on the aforementioned conclusions, this study proposes the following more actionable policy recommendations:

1) Implement a Precise and Differentiated Policy Support System

Policymaking must move beyond simplistic industry classifications and establish a multi-dimensional categorization standard based on firms' technological intensity, pollution load, and factor structure. For technology-intensive enterprises, specialized incentives such as additional tax deductions for green technology R&D expenses and intellectual property pledge financing should be established. For the highly polluting and asset-heavy sub-categories within the industry, a "Green Transition Special Fund" should be set up to provide low-interest loans supporting their environmental equipment upgrades and cleaner production process transformation, thereby alleviating their initial cost pressures for transition.

2) Construct a Multi-layered Policy Coordination Mechanism

It is recommended to establish a cross-departmental information sharing and joint decision-making platform integrating "green finance - environmental regulation - industrial policy." Firms' environmental credit ratings and records of environmental penalties could be directly linked to financial institutions' green credit approval processes and interest rate pricing, creating a binding constraint. Simultaneously, in investment attraction and industrial planning, local governments should align the scope of green finance support with locally prioritized green technology industrial chains, achieving targeted delivery of policy benefits.

3) Refine the Whole-Process Fund Guidance and Effectiveness Evaluation Mechanism

Financial institutions need to go beyond traditional credit assessment models by developing specialized evaluation tools for green technology projects, focusing particularly on the emission reduction potential and commercial prospects of the technology. After fund disbursement, an environmental benefit monitoring and post-evaluation system covering the entire project lifecycle should be established. The evaluation results should be dynamically linked to firms' subsequent financing eligibility and costs, ensuring funds are genuinely used for core activities driving green innovation, preventing "greenwashing" for arbitrage, and safeguarding the substantive achievement of policy objectives.

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