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Research on the Impact of Green Finance Reform and Innovation Pilot Zone Policy on Corporate ESG Performance: An Empirical Analysis based on the Multi-period Difference-in-Differences Model

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Abstract

This paper takes the Green Finance Reform and Innovation Pilot Zones (GFRIPZ), established in batches since 2017 in China, under quasi-natural experimental conditions. Drawing on panel data of Shanghai and Shenzhen A-share publicly traded firms spanning 2014 to 2022, we adopt a staggered difference-in-differences (DID) framework to evaluate the policy's effects on firm-level ESG performance and its underlying mechanisms.Drawing on panel data of Shanghai and Shenzhen A-share publicly traded firms spanning 2014 to 2022, we adopt a staggered difference-in-differences (DID) framework to evaluate the policy's effects on firm-level ESG performance and its underlying mechanisms. Our findings are threefold. First, the GFRIPZ policy significantly improves the ESG performance of firms in the test areas, and the results passed a series of stability tests. Secondly, the analysis of the mechanism shows that the policy enhances ESG performance by promoting digital transformation, stimulating corporate green innovation and optimizing the quality of environmental disclosure. Third, heterogeneity analysis shows that the policy exerts a more prominent effect among state-owned enterprises, non-heavily polluting industries, as well as firms based in the eastern and western regions, while the benefits for firms in central regions and private enterprises are relatively limited. This present study furnishes theoretical as well as empirical evidence for policymakers and enterprises to optimize green finance policy design and improve ESG performance.

Keywords

Green Finance; Corporate ESG Performance; Policy Effect.

1. Introduction

With global warming and environmental pollution becoming increasingly prominent, it has become a global consensus to realize the Dual Carbon strategic targets. Accelerating the shift toward an eco-friendly and decarbonized economy stands as a central strategy for China's high-standard economic growth. As an important institutional arrangement supporting this green transition, green financial regulations can channel financial resources into eco-friendly sectors and decarbonization initiatives through mechanisms such as credit allocation and financing incentives. The ultimate effectiveness of these policies directly affects the achievement of green transition goals. Since the release of the Guidelines for Establishing a Green Financial System in 2016, the development of China's green financial system has entered a period of comprehensive advancement. In 2017, the State Council took the lead in establishing eight pilot areas for green financial reform and innovation in five provinces: Guangdong, Zhejiang, Jiangxi, Guizhou and

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Xinjiang. Lanzhou New Area joined the pilot in 2019, and Chongqing City joined in 2022, forming a pilot pattern covering seven provinces and ten regions.Through targeted policy experimentation, China's Green Finance Reform and Innovation Pilot Zones have sought to tackle the longstanding challenges of difficult and costly financing for green projects while encouraging firms to step up their environmental and social commitments. Because ESG performance captures a firm's sustainability across environmental, social, and governance dimensions, it offers a useful lens through which to evaluate the microcosmic influences of eco-financial incentive policies Investigating how the pilot zone policy shapes corporate ESG outcomes can therefore yield deeper insights into whether green finance delivers on its promises, while also informing policymakers on how to refine program design and help firms raise their game.

The present research offers three contributions to the existing literature. First, moving beyond the single-dimension focus that characterizes much prior work, we examine comprehensive ESG performance as a holistic outcome measure, thereby broadening the scope of pilot zone evaluation. Secondly, we have deeply analyzed the inherent mechanism of policy operation - specifically, including digital transformation, green innovation and environmental information disclosure quality - revealing the channels for green finance to transform into better ESG results.Secondly, we have deeply analyzed the inherent mechanism of policy operation - specifically, including digital transformation, green innovation and environmental information disclosure quality - revealing the channels for green finance to transform into better ESG results. Third, we document substantial heterogeneity in policy effects across ownership types, pollution intensity, and regions, which speaks directly to the need for place-based policy design.

2. Literature Review

In recent years, abundant existing studies have investigated the heterogeneous effects brought by pilot regions for green financial reform initiatives.. Since the State Council launched the first batch of pilot zones in 2017, scholars have shown increasing interest in green finance policies, with most studies approaching the issue from either a macroeconomic or microeconomic perspective.

At the macro level, there is a broad consensus that green finance policies can facilitate high-quality economic development and support the green transition. Several concrete studies suggest that the establishment of these pilot zones helps optimize regional industrial structures and boost the quality of green development.For instance, take an efficiency-oriented approach and find that China's green finance development exhibits pronounced regional disparities, with local financial foundations and industrial structures serving as key determinants of green finance efficiency[1]. Lin take this further by showing that the experimental policy has obviously promoted the economic development[2]. More recently, some researchers have begun to link the pilot zones with broader topics such as regional economic transformation and the development of new quality productive forces. Xu et al. demonstrate that the policy fosters urban new quality productive forces by promoting industrial restructuring and green transition[3]. Tan et al. in a related vein, show that the pilot zones help reduce carbon emission intensity in treated areas, and that this effect is stronger in regions with more developed financial systems, with industrial upgrading serving as a key transmission channel[4].

At the micro level, existing research tends to focus on how green financial policies affect the behavior of enterprises in the fields of financing, investment and green innovation. Wang Hezhang's research found that the pilot areas have relaxed the financing constraints of environmental protection enterprises, expanded their financing scale, and improved the efficiency of capital utilization, although these effects have a certain lag.[5]. At the same time, the research of Zhuge and Cai shows that the pilot regions exert a significant facilitating effect on

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green innovation in industrial enterprises, especially in environmentally friendly enterprises, non-state-owned enterprises and large enterprises.[6]. They attribute this to the scaling-up of green credit facilities and the relaxation of financing constraints.

To explore the mechanism of green financial policies affecting the ESG performance of enterprises, the literature points out that there are multiple channels. For digital-related dimensions, Li and others uncover that digitalization improves ESG outcomes by reducing agency costs and improving operational efficiency[7]. Porter's hypothesis provides a useful perspective here: elaborate environmental regulations and policy incentives can promote green technology innovation. Many studies support this view, showing that green financial policies - especially green credit - exert a substantial influence on promoting enterprises' green R&D investment and thus improving their environmental performance. Zhou and others came to a similar conclusion. The study further found that the innovation promotion role of green finance is particularly significant in the pollution industry[8]. In addition to financing and innovation, green financial policies can also influence corporate behavior by improving the transparency of environmental information. With the increasing maturity of the green financial system, environmental information disclosure has become an important condition for enterprises to seek external financing and market recognition, and also provides valuable information for market supervision and investor decision-making. Wang and others pointed out that regulatory measures such as green manufacturing demonstration projects can improve the quality of environmental information disclosure, thereby encouraging more research and development and green innovation, and ultimately improving the environmental, social and governance (ESG) performance of enterprises[9]. This shows that improving transparency may be one of the important ways for green financial policies to work.

In short, although the existing literature has extensively explored the economic consequences of green financial policies, there is still a lot of room for research. There are still relatively few literatures specializing in the micro-level impact of green financial policies; most studies focus on narrower dimensions such as financing constraints or carbon emission reduction, and pay less attention to a more comprehensive ESG perspective. In addition, although most existing studies emphasize the positive results of green financial policies, the impact exhibits substantial heterogeneity across regions and enterprise classes, which indicates the need for more in-depth research on potential mechanisms - especially under the influence of emerging factors such as digital transformation and environmental information disclosure, the comprehensive The combined research is unexpectedly few.

3. Policy Background and Theoretical Hypotheses

3.1. Policy Background

The pilot zone for green financial reform and innovation is an important policy measure for China to build a green financial system. In 2017, the State Council made a strategic decision to launch pilot reform in five provinces: Zhejiang, Jiangxi, Guangdong, Guizhou and Xinjiang, aiming to promote economic green transformation through regional experiments. Lanzhou New Area joined the pilot ranks in 2019, and Chongqing City joined in 2022, eventually forming a pilot system covering seven provinces and ten regions.

The pilot policy spans extensive fields and employs diverse tools to stimulate green development. These tools include government-subsidized green credit, tax incentives, special funds for green innovation, and comprehensive support for the issuance of green bonds and green funds. In addition to these financial incentives, the regulatory framework also requires financial institutions to strengthen environmental risk management and encourage enterprises to improve information disclosure and social responsibility practices. Pilot projects are implemented in stages in different regions and different periods, coupled with the differences

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in the development characteristics of each region, which provides a valuable foundation for our quasi-natural experiments.

3.2. Theoretical Discussion and Hypotheses Formulation

3.2.1. GFRIPZ Policy and Firm-Level ESG Performance

At its core, the green finance innovation pilot zone policy aims to allocate financial resources more rationally and direct capital flows into green, low-carbon and sustainable development projects, so as to promote the green transformation and high-quality development of enterprises. Institutional theory shows that enterprise behavior is not only influenced by market forces, but also by the external institutional environment. Wang et al. documented that the pilot regions push firms to make adjustments along environmental, social and governance (ESG) dimensions via perfected green credit incentives and stricter environmental disclosure rules[10].

From the perspective of incentive theory, the policy tools provided to pilot areas - such as green credit subsidies, risk compensation and tax incentives - can effectively reduce the cost of green transformation, ease financing constraints, and motivate enterprises to actively pursue energy conservation and emission reduction, fulfill social responsibilities and optimize corporate governance.Lin and Xiao similarly observe that green finance policies contribute to better resource allocation and stronger corporate green development capabilities[11].

Empirical evidence also supports a link between green finance policies and corporate ESG performance. Shi and Yu , for example, find that the establishment of GFRIPZs improves firms' comprehensive ESG scores, such influence manifests more remarkably in non-high-pollution enterprises and corporations located in China’s eastern and western provinces. [12]. Liu et al. further note that, compared to local green finance pilots, national-level pilot programs exert a stronger influence on resource integration and institutional constraints, leading to more substantial improvements in firms' green management practices[13]. Based on the above-mentioned evidence, the following hypothesis is proposed:

H1: Comprehensive ESG performance of firms is improved by the enforcement of the GFRIPZ policy.

3.2.2. Pathways through Which the GFRIPZ Policy Affects ESG Performance

(1) Digital Transformation

Against the backdrop of the booming digital economy, digital transformation has become an increasingly important means for firms to upgrade their resource allocation and environmental governance capabilities. While promoting green finance, the pilot zones also facilitate firms' digitalization efforts through the application of fintech tools, which in turn may enhance ESG outcomes. On the one hand, policies and measures such as green credit subsidies and green bond support reduce the initial cost of enterprises adopting digital technology, enabling them to deploy intelligent monitoring systems, carbon management platforms as well as whole-chain emission tracing mechanisms. The integration of financial technology has also improved the accessibility of green credit, making it easier for enterprises to obtain low-cost digital upgrade funds. [14].

Digital technology can also enhance information transparency and internal governance efficiency, thus alleviating information asymmetry between enterprises and their stakeholders. Li and others found that digital transformation improves ESG performance by reducing agency costs and improving management efficiency, which is more significant in industries facing high environmental risks[15]. Based on this reasoning, we propose:

H2: The GFRIPZ policy improves corporate ESG performance by promoting digital transformation.

(2) Green Innovation

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For enterprises, green innovation is not only a response to environmental regulations, but also a strategic way to build a long-term competitive advantage. Porter's hypothesis believes that reasonably designed environmental regulations and policy support can stimulate technological innovation, and the resulting "innovation compensation" can help enterprises cope with the pressure of green transformation. The Green Financial Innovation Park (GFRIPZ) has eased the financing constraints encountered in corporate green R&D through green credit support, financing incentives and government R&D subsidies, thus encouraging enterprises to participate more actively in green technology innovation. Wei believes that although environmental regulations will bring additional financing and cash flow pressure to enterprises, green technology innovation can help cushion these pressures[16]. However, Wang and Li also pointed out that although government R&D subsidies can effectively stimulate green innovation, excessive subsidies may crowd out the R&D investment of enterprises themselves[17].

In addition to improving environmental performance, green innovation can also affect social responsibility and corporate governance results by optimizing resource utilization and improving corporate reputation. Wang and Zhang pointed out that the energy saving and resource efficiency improvement brought about by green innovation will help reduce negative environmental externalities and enhance the social responsibility image of enterprises[18]. Tan and others also observed that the carbon-mitigation effect of green finance policies is at least partly achieved through enterprise green innovation.[19]. We thus propose:

H3: The GFRIPZ policy improves corporate ESG performance by stimulating green innovation.

(3) Environmental Information Disclosure

Corporate environmental reporting acts as a vital medium through which firms convey their environmental performance and sustainable development commitments to external stakeholders. In light of asymmetric information, superior environmental transparency mitigates informational disparities between listed firms and investors, facilitating optimal capital resource distribution. The GFRIPZ regulation tightens environmental risk oversight rules applicable to banking and financial entities, and simultaneously lifts the threshold for corporate environmental disclosure documents. According to this policy, enterprises need to disclose more comprehensive information on environmental governance, energy conservation and emission reduction measures and social responsibility activities, so as to strengthen external supervision of investors and the public.

Kong and others found that the pilot policy has enhanced enterprise transparency and external supervision by improving green financial standards and environmental information disclosure requirements[20].Higher quality environmental information disclosure can not only improve the environmental factors in the ESG score, but also improve corporate governance through a stronger external accountability mechanism. Wang and Guo further pointed out that sound environmental information disclosure helps to curb the "green" behavior of enterprises and strengthen social responsibility constraints[21]. In summary, these arguments show that the improvement of the quality of environmental information disclosure may become an important transmission mechanism for green finance policies to affect ESG results. Therefore, we propose:

H4: The GFRIPZ pilot policy elevates enterprise ESG performance through the improvement of environmental information transparency.

Figure 1 outlines the mechanistic channels linking the policy to corporate ESG outcomes.

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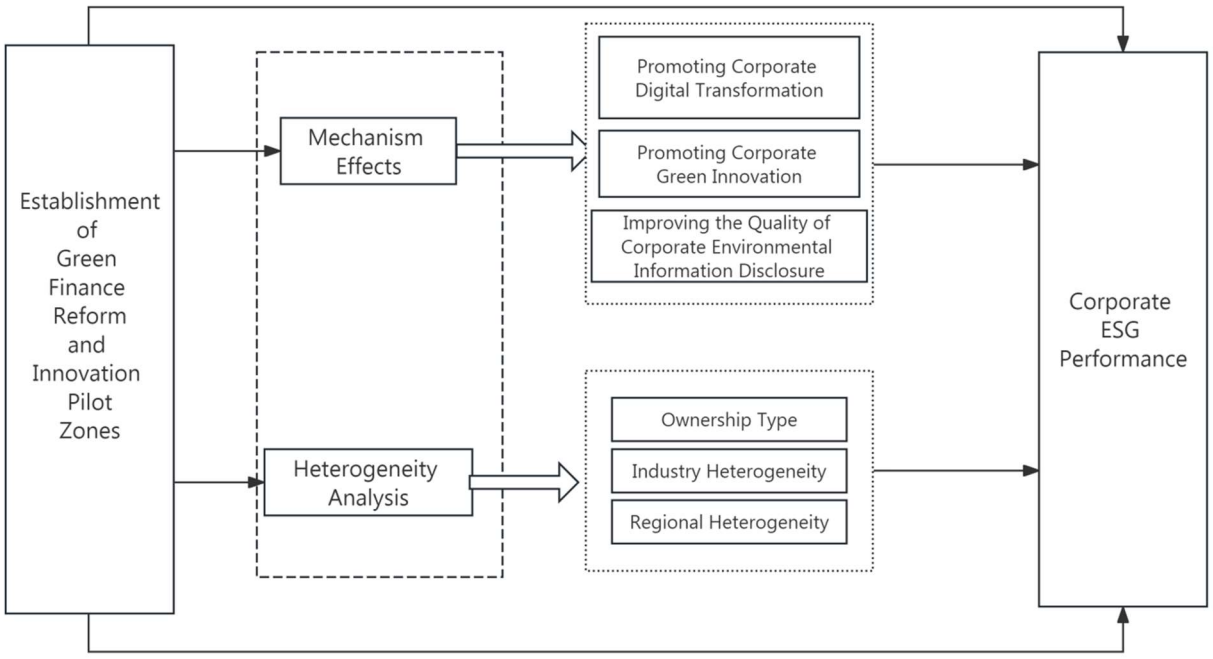


Figure 1. Mechanism Pathways

4. Research Design

4.1. Sample Selection and Data Sources

We take longitudinal data covering A-share publicly traded firms listed on the Shanghai and Shenzhen Stock Exchanges over 2014–2022 as the preliminary sample for empirical analysis. We exclude firms under special treatment (ST and ST*) and remove sample entries with incomplete records on primary indicators. The data comes from the China Urban Statistical Yearbook, the China Stock Market and Accounting Research Database (CSMAR), the Wind Database and the China Research Data Service Platform (CNRDS).

4.2. Model Specification

To evaluate the impact of the Green Finance Reform and Innovation Pilot Zones on corporate ESG performance, we estimate a staggered difference-in-differences (DID) model specified as follows:

$$ESG_{it} = \alpha + \beta_1 did_{it} + \beta_2 controls_{it} + \mu_i + \lambda_t + \varepsilon_{it}. \quad (1)$$

Where ESG_{it} denotes the ESG performance of firm i in year t;$did_{it}$is the policy dummy variable, which takes the value of one if the city in which firm i is situated is designated as a GFRIPZ by year t, and zero otherwise.;$controls_{it}$ represents a vector of control variables;μ_i and λ_t denote firm fixed effects and year fixed effects, respectively; and ε_{it} is the error term.

4.3. Variable Definitions

Dependent variables. The dependent variable in this study is the aggregated ESG rating score, which comprehensively captures firms' environmental, social, and governance performance across three dimensional dimensions. According to the practice in the literature, we use Huazheng ESG rating as an indicator to measure the ESG performance of enterprises. The higher the rating, the better the ESG performance.

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The core explains the variables. The main regression variable is the policy dummy for the green-finance reform and innovation pilot zone, denoted as did. According to a previous study (Yan et al., 2022), if the city where the enterprise is registered has been approved as a pilot area for green financial reform and innovation in t year, the virtual variable is equal to 1, otherwise it is equal to 0[22].

Control variables. To account for the potential bias caused by omitted variables, we add provincial macroeconomic indicators into regressions, we draw upon the research of Xue et al. (2023) and Lei et al. (2023), and incorporate a series of control variables that may affect the ESG results of enterprises at the city and company levels[23][24]. At the city level, we control for economic development (lngdp) and industrial structure upgrading (indus). At the firm level, the controls comprise firm size (Size), board size (Boardsize), CEO-chair duality (Dual), loss status (Loss), Tobin's Q (TobinQ), and firm age (Age). The complete definition of each variable is summarized in Table 1.

Table 1. Variable Definitions

Variable Type	Variable Name	Symbol	Definition
Dependent Variable	Corporate ESG Rating Score	ESG	Comprehensive ESG rating score; higher values indicate better ESG performance.
Core Explanatory Variable	Pilot Zone Indicator	did	Equals 1 if the firm's city is a Green Finance Reform and Innovation Pilot Zone, 0 otherwise.
Mediating Variables	Digital Transformation	Digital	Indicator built by tallying digital transition keywords in listed firms' textual filings; larger figures represent advanced corporate digital upgrading.
	Green Innovation	lnGreenPatent	Natural logarithm of (1 + total number of green invention and utility model patent applications filed in the year).
	Environmental Disclosure Quality	EID	Environmental information disclosure quality index; higher values indicate better disclosure quality.
Control Variables	Economic Development	lngdp	Natural logarithm of GDP of the prefecture-level city where the firm is located.
	Industrial Structure Upgrading	indus	Prefectural-level industrial structure coefficient measured as service sector value added divided by secondary industry increments.
	Board Size	Boardsize	Natural logarithm of the number of directors on the board.
	CEO-Chair Duality	Dual	Dummy variable equal to 1 if the chairman and CEO are the same person, 0 otherwise.
	Firm Size	Size	Natural logarithm of total book assets.
	Loss Status	Loss	Dummy variable equal to 1 if annual net profit is negative, 0 otherwise.
	Tobin's Q	TobinQ	Market value of equity divided by total assets.
	Firm Age	FirmAge	Natural logarithm of the number of years since the firm's founding.

5. Empirical Results and Analysis

5.1. Descriptive Statistics

Summary statistics for the main variables are reported in Table 2. Our final sample comprises 26,337 firm-year observations. The dependent variable, ESG score, has a mean of 27.49 and a standard deviation of 11.06, with values ranging from a minimum of 1.58 to a maximum of

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79.32. Such a large degree of dispersion shows that marked gaps in corporate ESG outcomes can be observed among distinct listed firms. The mean value of our core independent variable (did) is 0.045, indicating that about 4.5% of the observations in the sample are affected by the GFRIPZ policy. This proportion is consistent with the characteristics of phased and staggered implementation of pilot projects.

Table 2. Descriptive Statistics of Main Variables

Variable	Observations	Mean	Std. Dev.	Min	Max
ESG	26,337	27.49	11.06	1.58	79.32
did	26,337	0.045	0.208	0	1
lngdp	26,337	11.88	0.73	9.19	13.19
indus	26,337	1.805	1.129	0.262	5.650
Boardsize	26,337	2.108	0.200	1.099	2.890
Dual	26,337	0.302	0.459	0	1
Size	26,337	22.28	1.342	14.94	28.64
Loss	26,337	0.121	0.327	0	1
TobinQ	26,337	2.008	1.156	0.859	6.855
Age	26,337	2.981	0.312	1.386	4.290

5.2. Baseline Regression Results

Table 3. Baseline Regression Results

	(1)	(2)
	ESG	ESG
did	1.1538***	1.2494***
	(0.3900)	(0.3997)
lngdp		0.4339
		(0.6067)
indus		-0.2356
		(0.2750)
Boardsize		0.0541
		(0.5082)
Dual		-0.3696*
		(0.2083)
Size		0.9794***
		(0.1644)
Loss		0.0021
		(0.1648)
TobinQ		0.0093
		(0.0143)
Age		3.8563***
		(1.1749)
_cons	27.4308***	-10.6048
	(0.0185)	(8.9788)
Firm FE	Yes	Yes
Year FE	Yes	Yes
Clustering Level	City	City
N	26,337	26,337
adj. R^2	0.6562	0.6577

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

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To examine how the GFRIPZ pilot policy shapes corporate ESG performance, we estimated the staggered double difference model. Table 3 shows the results of the benchmark regression. Column (1) reports the estimated results without any control variables, while column (2) contains the company and year fixed effects,with standard errors clustered by city and the full set of control variables incorporated. Under the two model settings, the coefficients of the core independent variable (did) are positive and statistically significant. Specifically, in the complete model setting, the coefficient of did is 1.2494, which is significant at the significance level of 1%. The regression outcomes confirm that the launch of the GFRIPZ pilot substantially enhances the comprehensive ESG performance of local enterprises, which strongly corroborates Hypothesis H1.

5.3. Robustness Checks

5.3.1. Parallel Trends Test

Staggered DID models rely crucially on the parallel trends assumption, which demands consistent pre-policy trends between treatment and control samples. We carried out an event study to test this hypothesis and constructed the following model:

$$ESG_{i,t} = \alpha + \sum_{k=-5}^{-1} \beta_k D_{i,t+k} + \gamma_0 Current_{i,t} + \sum_{k=1}^{5} \delta_k D_{i,t+k} + \theta X_{it} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$

Where $\sum_{k=-5}^{-1} \beta_k D_{i,t+k}$ denotes a set of binary event-study dummies tracking the years preceding policy implementation, and the coefficients β pick up the divergence of ESG performance between the treatment and control groups during each pre-intervention period. The term $\gamma_0 Current_{i,t}$ is a dummy for the year of policy implementation, with γ_0 measuring the contemporaneous impact of the policy shock. Finally, $\sum_{k=1}^{5} \delta_k D_{i,t+k}$ represents post-treatment year dummies; their coefficients trace out the year-by-year effects of the policy, capturing the dynamic impact upon corporate ESG performance.

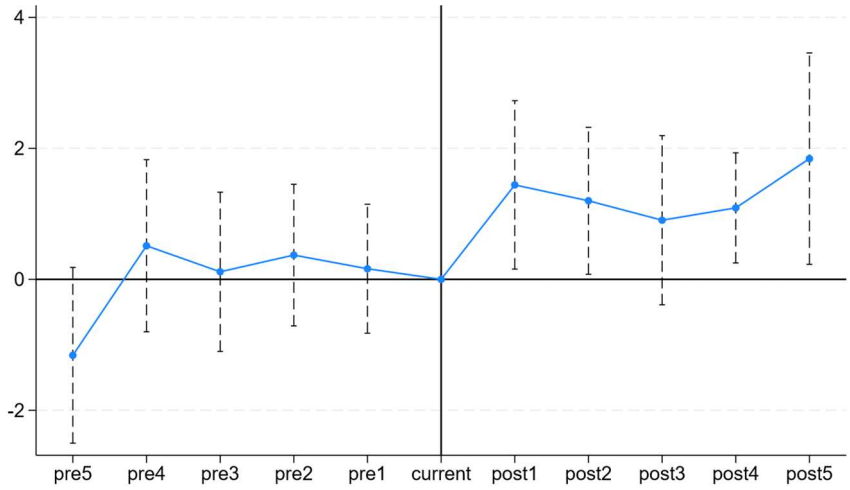


Figure 2. Parallel Trends Test

Figure 2 reveals two key patterns. In the period before the implementation of the policy, the estimated coefficient showed that the enterprise ESG scores of pilot cities and non-pilot cities showed a similar development trajectory before policy intervention. The above evidence lends credible support to the parallel trends premise. However, in the period after the implementation of the policy, the coefficient turned positive and reached a significant level immediately after the policy took effect, the coefficient curve rises sharply, indicating that the

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pilot initiative exerted an immediate favorable effect on corporate ESG ratings. In addition, this persistence in the following years means that the positive impact of the policy can be sustained for a long time.

5.3.2. Placebo Test

With the aim of further verify that the observed ESG score improvement is indeed driven by the policies of the pilot area, not caused by random shocks or missing variables, we perform placebo examinations via random permutation of policy implementation periods. Specifically, we randomly select a fictitious policy year from the sample period, assign the year to each company, construct a placebo treatment indicator, and re-estimate the benchmark regression model. We repeated this process many times, and Figure 3 shows the distribution of the obtained placebo coefficient.

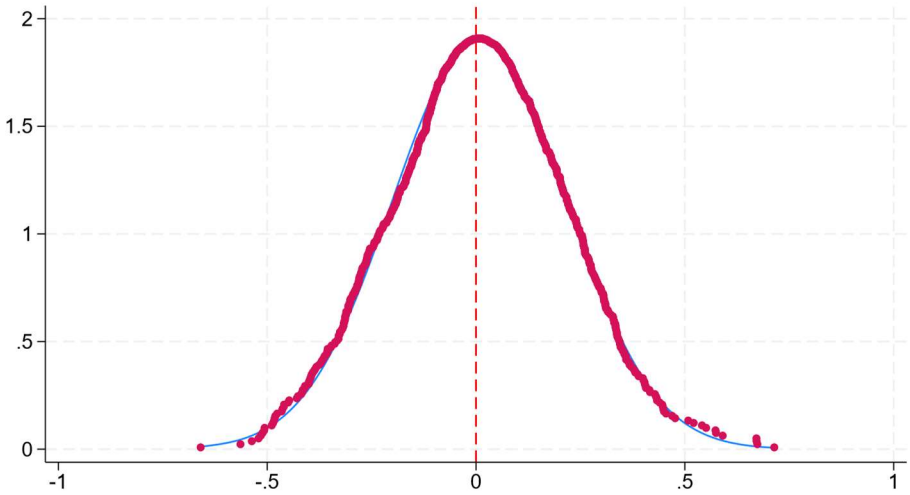


Figure 3. Placebo Test

As shown in Figure 3, in the absence of actual policy intervention, the randomly allocated placebo treatment did not have a significant positive impact on the ESG score. This confirms that the improvement of ESG performance of pilot enterprises is not caused by accidental factors, which further strengthens the robustness of our baseline research results.

5.3.3. Propensity Score Matching

To rule out the concern that inherent disparities in corporate attributes across treated and control samples could generate biased regression estimates, we use propensity score matching (PSM) to alleviate the endogenous problems caused by sample self-selection. First, we use the logit model to estimate the tendency score (that is, the probability that the enterprise is located in the pilot area), and then apply the nearest neighbor matching method to pair the experimental group enterprises with similar control group enterprises.

Before matching, the two sample groups exhibited remarkably distinct levels of covariates. After matching, the standardized deviation of all variables decreased significantly, and the t-test of the mean difference was no longer significant, indicating that the distribution of covariables between the two groups was well balanced. Figure 4 shows the standardized deviation before and after the match. It can be seen that the deviation after matching is significantly reduced and close to zero, confirming the satisfaction of the equilibrium test. Figure 5 further depicts the propensity score distribution for treated and control samples following matching.. The distribution of the two groups is highly overlapping, indicating that the matching sample has sufficient common support and good comparability.

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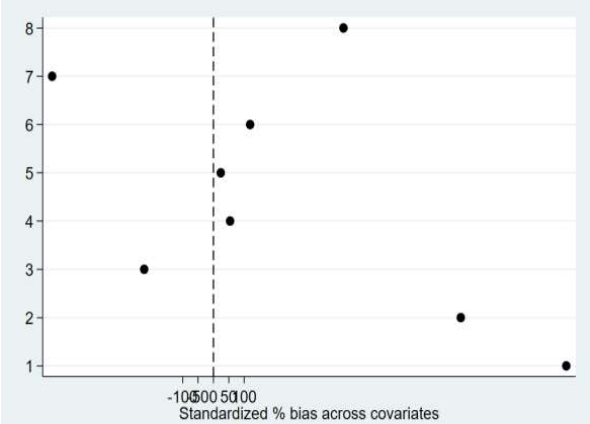


Figure 4. Standardized Bias of Covariates

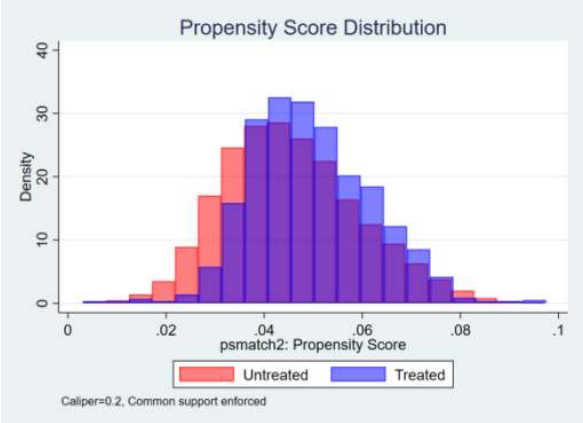


Figure 5. Propensity Score Distribution

Re-estimate the reference model for the matching sample, and get the results of column (1) in Table 4. Among them, the coefficient of did is 1.2505, and it is still significant at the significance level of 1%, indicating that even if the selection bias is corrected through the tendency score matching (PSM) method, the pilot area policy still significantly improves the corporate composite ESG development level. In summary, the results of PSM-DID further confirm that the pilot zone policy of green financial reform and innovation has a significant positive impact on the ESG score of enterprises, and verifies the robustness of the benchmark estimate.

5.3.4. Additional Robustness Checks

Table 4. Robustness Checks

	PSM-DID	Alternative Clustering	Winsorized at 1%
Dependent Variable	ESG	ESG	ESG
did	1.2050**	1.2494**	1.2623***
	(0.4038)	(0.5560)	(0.3941)
lngdp	0.3143	0.4339	0.2665
	(0.5917)	(0.4033)	(0.5861)
indus	-0.1990	-0.2356	-0.2165
	(0.2829)	(0.2751)	(0.2749)
Boardsize	0.0675	0.0541	0.1941
	(0.4938)	(0.5046)	(0.5049)
Dual	-0.3597*	-0.3696*	-0.3712*
	(0.2089)	(0.2081)	(0.2117)
Size	1.1034***	0.9794***	1.1338***
	(0.1678)	(0.2158)	(0.1733)
Loss	0.0356	0.0021	0.0529
	(0.1664)	(0.1623)	(0.1657)
TobinQ	0.2597***	0.0093	0.3259***
	(0.0459)	(0.0148)	(0.0540)
Age	3.0552**	3.8563*	2.6769**
	(1.1783)	(2.0396)	(1.2717)
_cons	-10.8713	-10.6048	-9.5565
	(8.6979)	(8.9588)	(8.9750)
Firm & year FE	Yes	Yes	Yes
Clustering level	City	Industry	City
N	16812	26337	26337
adj. R2	0.7712	0.6577	0.6603

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

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In order to further ensure the reliability of our research results, we carry out additional robustness tests in the following ways: (i) change the clustering level of the standard error; (ii) Winsorization of variables to reduce the impact of abnormal values.

First of all, we re-estimate the model and change the standard error clustering unit from the city level to the industry level. As displayed in Column (2) of Table 4, the estimated DID coefficient stands at 1.2494 with statistical significance at the 5% threshold, consistent with the benchmark estimation outcomes. This shows that our research results are not sensitive to the selection of cluster levels.

Secondly, we apply 1% Winsorization to all continuous variables to reduce the impact of extreme values. As shown in column (3) of Table 4, the coefficient of did is 1.2623, and it is still significant at the significance level of 1%. This shows that our main conclusion - the pilot policy has significantly improved ESG performance - is not driven by abnormal values, but is still stable after considering extreme observations.

In general, the results of all robustness tests unanimously support the conclusion that The pilot-zone policies significantly improve firm-level ESG performance of enterprises within the target area, confirming that our benchmark findings are highly robust.

5.4. Mechanism Analysis

The benchmark results show that the green financial reform and innovation pilot zone policies can improve the ESG performance of enterprises. In order to explore the specific action channel of this effect, we adopted the intermediary effect test framework proposed by Wen and Ye (2014). The mediation effect model is as follows:

$$M_{it} = \alpha_0 + \alpha_1 \cdot did_{it} + \alpha_2 \cdot Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

$$ESG_{it} = \beta_0 + \beta_1 \cdot did_{it} + \beta_2 \cdot M_{it} + \beta_3 \cdot Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

Where M_{it} represents the mediating variables,This analysis includes digital transformation (Digital), environmental information disclosure quality (EID) and green innovation (InGreenPatent). All other variables maintain definitions consistent with the baseline model (1). Table 5 presents the estimation results from the mediation analysis.

Column (1) reports the overall impact of policy variables (did) in benchmark regression on enterprise ESG performance. Columns (2), (4) and (6) show the findings of regression of three intermediary variables to policy variables respectively. In all three model settings, the estimated DID coefficient carries a positive sign and achieves significance at no less than the 5% threshold. Such evidence reveals that the pilot initiative exerts dual beneficial effects: it lifts firms' ESG ratings directly, while simultaneously advancing digital transformation, enhancing the quality of environmental disclosure, and incentivizing green technological innovation. These findings provide preliminary evidence for these three intermediary channels.

Then, we incorporate each intermediary variable into the benchmark model to formally test the intermediary effect. Column (3) shows that after joining the digital transformation, the coefficient of did decreased from 1.249 to 1.225, but it is still significant at the significance level of 1%. The standalone coefficient for Digital equals 0.007 and is statistically significant at the 1% level, indicating that digital transformation partially mediates the relationship between policy and ESG performance - which supports the hypothesis H2.

Column (5) reports the results of green innovation. After being included in lnGreenPatent, the coefficient of did dropped to 1.191, while the coefficient on green innovation was 0.467, which was significant at the level of 1%. This confirms that there is a partial intermediary effect in green innovation, which is consistent with the hypothesis H3.

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Finally, column (7) shows that the introduction of environmental information disclosure has led to a significant decrease in the did coefficient to 0.960 (remarkably at the significance level of 5%). The coefficient of EID is 2.234, which is significant at the significance level of 1%, indicating that environmental information disclosure plays an important intermediary role: the policy improves ESG performance by improving the quality of enterprise environmental information disclosure. This supports the hypothesis H4.

Table 5. Mediation Analysis

Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ESG	Digital	ESG	lnGreen Patent	ESG	EID	ESG
did	1.249***	3.567**	1.225***	0.126***	1.191***	0.130***	0.960**
	(0.400)	(1.678)	(0.400)	(0.038)	(0.392)	(0.035)	(0.378)
lngdp	0.434	0.992	0.427	-0.076	0.470	-0.019	0.476
	(0.607)	(1.526)	(0.613)	(0.049)	(0.599)	(0.061)	(0.556)
Indus	-0.236	1.813**	-0.248	0.026	-0.248	0.004	-0.243
	(0.275)	(0.748)	(0.277)	(0.030)	(0.282)	(0.022)	(0.256)
Boardsize	0.054	3.618*	0.029	0.036	0.037	-0.041	0.146
	(0.508)	(1.870)	(0.508)	(0.056)	(0.507)	(0.051)	(0.508)
Dual	-0.370*	0.608	-0.374*	0.010	-0.374*	0.002	-0.373*
	(0.208)	(0.597)	(0.209)	(0.019)	(0.205)	(0.014)	(0.202)
Size	0.979***	5.323***	0.942***	0.364***	0.810***	0.158***	0.627***
	(0.164)	(0.907)	(0.169)	(0.029)	(0.158)	(0.017)	(0.156)
Loss	0.002	2.187***	-0.013	-0.002	0.003	-0.007	0.019
	(0.165)	(0.608)	(0.168)	(0.020)	(0.165)	(0.020)	(0.156)
TobinQ	0.009	0.043***	0.009	0.005***	0.007	0.001	0.006
	(0.014)	(0.015)	(0.014)	(0.001)	(0.014)	(0.001)	(0.012)
Age	3.856***	5.468	3.818***	-0.007	3.860***	0.416***	2.928***
	(1.175)	(7.069)	(1.182)	(0.182)	(1.187)	(0.153)	(1.093)
Digital			0.007*** (0.003)				
lnGreen Patent					0.467*** (0.086)		
EID							2.234*** (0.108)
_cons	-10.605	-142.019***	-9.615	-6.340***	-7.642	-2.380**	-5.288
	(8.979)	(32.377)	(9.171)	(0.925)	(8.947)	(1.037)	(8.237)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	26337	26337	26337	26337	26337	26337	26337
AdjustedR^2	0.658	0.791	0.658	0.704	0.658	0.700	0.668

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

6. Further Analysis

The baseline results show that the Green Finance Reform and Innovation Pilot Zone policy, on average, improves corporate ESG performance. In practice, however, policy effects exert

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differentiated impacts on corporations conditional upon ownership categories and industrial traits, as well as regional conditions. To explore these heterogeneous effects, we follow Lu and Cheng (2024) and Li et al. (2024) and conduct subsample analyses along three dimensions: ownership type, pollution intensity, and region.

6.1. Ownership Type

Ownership structure is a key factor shaping corporate behavior. Firms of different ownership types differ substantially in their business objectives, social responsibility orientation, and access to external resources-all of which can influence how green finance policies play out at the firm level. We therefore split the full sample into SOEs and private enterprises, then re-run our baseline regression separately for the two subgroups.

As reported in Table 6, the coefficient on did is 1.9344 and significant at the 1% level for the SOE subsample, but statistically insignificant for non-SOEs. This comparison shows that the ESG improvement effect of the policy is mainly concentrated in state-owned enterprises.

One possible explanation is that state-owned enterprises have a closer relationship with the government and respond more quickly to national policy directives, so it is more conducive to transforming green financial policy incentives into practical green transformation actions. As a backbone of the domestic economy, state-owned corporations shoulder heavier social and environmental obligations, driving their more proactive engagement in policy initiatives. Non-state-owned enterprises have stricter profit restrictions and more serious financing frictions than state-owned enterprises. In terms of green investment - such investments are characterized by high uncertainty and long return cycles - they tend to be more conservative and give priority to short-term financial returns, which may explain why the policy effect is not immediate in this group.

6.2. Industry Heterogeneity

We classify firms as heavily polluting based on the 16 industries required to disclose annual environmental reports under the Guidelines for Environmental Information Disclosure of Listed Companies. Firms in these 16 industries are categorized as heavily polluting, while the rest are classified as non-heavily polluting.

Columns (3) and (4) of Table 6 present the results. The coefficient on did is 1.7786 and statistically meaningful at the 1% level for firms outside heavy pollution sectors, whereas no significant effect emerges within heavily polluting industries. This indicates that the pilot zone policy effectively improves ESG performance among non-heavily polluting firms-an outcome broadly consistent with the policy's goal of using green finance tools to ease financing constraints and stimulate green innovation in cleaner industries. However, the complementary objective of raising financing costs for polluting firms to force green innovation-whereby innovation compensation offsets compliance costs, as suggested by the Porter hypothesis-has not yet materialized. The Porter effect has yet to emerge significantly, which explains why the policy has not lifted ESG performance among heavily polluting firms.

6.3. Regional Heterogeneity

The pilot zones established in 2017 (eight localities across five provinces), along with Lanzhou New Area in Gansu (added in 2019) and Chongqing (added in 2022), are concentrated primarily in the eastern and western regions of China. We therefore expect policy effects to be more pronounced in these regions relative to central China. The full sample is split into eastern, central, and western regional subsamples based on firm location, and the model is re-estimated accordingly. Table 6, columns (5) to (7), present the estimation outcomes. Eastern and western corporations yield positive and statistically significant DID estimates, whereas the coefficient loses significance for central businesses. This suggests that the Green Finance Reform and

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Innovation Pilot Zone policy has a more pronounced effect on ESG performance among firms in the eastern and western regions compared with those in the central region.

Table 6. Mediation Analysis

	Ownership Type		Industry Type		Region		
	Non-SOEs	SOEs	Non-Heavily Polluting	Heavily Polluting	Eastern	Central	Western
	ESG	ESG	ESG	ESG	ESG	ESG	ESG
did	0.7999	1.9344***	1.7786***	0.4222	1.0291**	0.1856	1.6141**
	(0.5384)	(0.4390)	(0.5173)	(1.1110)	(0.4744)	(0.4447)	(0.7092)
lngdp	-0.1241	1.7183	0.5505	-0.5525	-0.2348	1.7844**	0.8694
	(0.6685)	(1.3339)	(0.6218)	(1.6158)	(0.9104)	(0.8666)	(1.9363)
indus	-0.3094	0.1071	-0.1073	-0.2627	-0.3567	-0.1053	-0.5411
	(0.3058)	(0.4013)	(0.2441)	(1.1923)	(0.3251)	(0.8914)	(0.8187)
Boardsize	0.1816	-0.2214	0.3836	-1.3428	0.7195	-0.8055	-2.6606**
	(0.7353)	(0.8681)	(0.5213)	(1.3884)	(0.5545)	(1.3857)	(1.1492)
Dual	-0.3088	-0.6490	-0.3886**	-0.5009	-0.5144**	0.0832	-0.1933
	(0.2151)	(0.5574)	(0.1958)	(0.5532)	(0.2185)	(0.5136)	(0.6499)
Size	1.2597***	0.2353	0.8562***	1.6956***	0.8998***	1.5386***	1.1255***
	(0.1982)	(0.3206)	(0.1828)	(0.4923)	(0.1943)	(0.4327)	(0.3860)
Loss	-0.2877	0.4420	-0.0784	0.5791	-0.1691	0.7906**	0.4054
	(0.2189)	(0.3131)	(0.1916)	(0.3811)	(0.1916)	(0.3276)	(0.4603)
TobinQ	0.0091	0.1630**	0.0046	0.3735**	0.1694***	0.1711	-0.0035
	(0.0117)	(0.0798)	(0.0110)	(0.1496)	(0.0455)	(0.1081)	(0.0043)
Age	5.3995***	1.0592	3.6842***	6.9538	4.0431***	-0.1616	6.4895
	(1.9307)	(2.8958)	(1.2697)	(4.3161)	(1.1828)	(4.4868)	(4.9520)
_cons	-14.3597	-0.9496	-11.1070	-16.6797	-3.1851	-24.1373	-19.0417
	(9.7176)	(21.9703)	(9.2447)	(23.5785)	(12.3897)	(15.5551)	(28.5412)
Firm & year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustering level	City	City	City	City	City	City	City
N	16979	8640	20953	5360	18909	4097	3201
adj. R2	0.6833	0.6136	0.6330	0.6375	0.6610	0.6447	0.6540

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

7. Conclusion and Policy Implications

Taking the Green Finance Reform and Innovation Pilot Zones-established in batches across China since 2017-as a quasi-natural experiment, this paper constructs a multi-period difference-in-differences model using panel data on Shanghai and Shenzhen A-share listed companies from 2014 to 2022. The influence of the regional pilot policy on corporate ESG performance and its potential transmission channels has been empirically tested.

The estimation outcomes indicate the pilot policy generates marked improvements in local firms' ESG ratings, a result that survives multiple robustness examinations, including parallel trend tests and placebo tests. Further mechanism analysis indicates that the policy enhances corporate ESG performance along three transmission channels: driving digital transformation, motivating green-technology innovation, and strengthening corporate environmental

disclosure quality. Heterogeneity analysis shows that the policy has a more significant impact on state-owned enterprises, non-heavy pollution industries and enterprises in the eastern and western regions, while the benefits to enterprises and private enterprises in the central region are relatively limited.

In general, the pilot area for green financial reform and innovation has played a positive role in promoting the green transformation of enterprises, but its results are still subject to the characteristics of enterprises and regional development conditions. Looking to the future, we should further improve green financial instruments, strengthen the coordination of digitalization and innovation, and better combine policy implementation with the actual local situation.

Based on the above research results, we put forward the following suggestions:

First of all, the government should steadily expand the scope of the pilot and adopt more targeted, differentiated and local policies. For enterprises in industries with severe pollution, green technology innovation subsidies and research and development support should be increased to help them reduce the cost of transformation. For small and medium-sized enterprises with weak digital foundation, more digital transformation incentives and technical guidance should be provided to help them improve their green development capabilities.

Secondly, financial institutions should broaden the scope of green financial products and optimize the allocation of credit resources. Commercial banks and related financial institutions should develop more low-cost green financial instruments suitable for the transformation of the traditional manufacturing industry with a long investment payback period in view of the actual difficulties faced in the transformation process of enterprises.

Third, enterprises should grasp the policy dividends and achieve balanced development in all dimensions of ESG. Listed companies in pilot areas, especially non-state-owned enterprises and heavily polluting enterprises facing the pressure of transformation, should actively use pressure as a driving force, take the initiative to connect green financial resources, and use the credit obtained for digitalization and green technology research and development.

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