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Green Finance Policy and Corporate Green Innovation: Empirical Evidence from Green Finance Reform and Innovation Pilot Zones

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Abstract

Green innovation is characterized by both dual externalities and long cycles, and generally faces financing constraints and governance deficiencies. Relying solely on market mechanisms is insufficient to fully unleash the vitality of corporate green innovation. Using Shanghai and Shenzhen A-share listed companies from 2014 to 2024 as the research sample and leveraging the staggered establishment of green finance reform and innovation pilot zones as a quasi-natural experiment, this paper constructs a multi-period difference-in-differences (DID) model to systematically examine the micro-level incentive effects and transmission mechanisms of the pilot zone policies, analyzing them through the dual dimensions of innovation intensity and innovation willingness. Empirical results indicate that the policy establishing pilot zones for green finance reform and innovation significantly boosts the level of green innovation among enterprises within these jurisdictions. Specifically, the volume of green patent applications by pilot enterprises increased by an average of 12.92% compared to non-pilot enterprises. The policy exhibits both a corporate governance substitution effect and an information disclosure extension effect, demonstrating a more pronounced promotional impact on innovation among enterprises with weak internal governance foundations or inadequate environmental information disclosure, thereby reflecting a mechanism that addresses and remedies specific weaknesses. The marginal contributions of this paper are threefold: It first replaces the focus on single green financial instruments with comprehensive policy pilots, employs a multi-period difference-in-differences (DID) approach to mitigate endogeneity issues, and refines the measurement system for green innovation across dual dimensions. It also transcends the limitations of existing literature, which largely focuses on the financing constraint channel, by revealing the dual functions of green finance in resource allocation and external governance. Finally, it characterizes the heterogeneous effects of the policy across different types of firms, providing micro-level empirical evidence to support targeted policy implementation and differentiated empowerment of corporate green innovation.

Keywords

green finance reform and innovation pilot zones, green finance, corporate green innovation, multi-period difference-in-differences, corporate governance, information disclosure

1. Introduction

Against the backdrop of cultivating new quality productive forces and advancing a comprehensive green transformation of the economy and society, green technology innovation serves as the core driving force for achieving "dual carbon" goals, overcoming resource and environmental constraints, and upgrading industrial structures. However, green innovation is characterized by dual externalities, namely, technology spillovers and positive environmental externalities, meaning that, under market equilibrium, corporate investment in innovation often falls short of the socially optimal level [1]. At the same time, green R&D is characterized by large-scale investment, long payback periods, and high technical uncertainty. Furthermore, its outputs are primarily intangible assets that lack the physical collateral required for traditional credit, causing enterprises to generally face significant financing and risk constraints [2,3]. It is difficult to fully mobilize the vitality of green innovation by relying solely on spontaneous market regulation. Institutional policy guidance and financial system support are needed.

Green finance is a key lever for supply-side structural reform in the financial sector and a core institutional arrangement for driving green development. Following the 2016 release of the Guidelines on Establishing the Green Financial System, China's green finance entered a stage of systematic advancement driven by top-level design. To explore local practice models that can be replicated and scaled up, the State Council established green finance reform and innovation pilot zones in three batches starting in 2017, creating a policy framework that employs a dual approach of incentives and constraints. It has provided an ideal quasi-natural experiment setting for evaluating the microeconomic effects of green finance.

Existing literature has extensively explored the microeconomic effects of green finance. Regarding policy impact, most studies focus on single policy instruments, such as the Green Credit Guidelines, and find that they exert a significant "forcing effect" on green innovation among heavily polluting enterprises [4, 5]. Some studies have also pointed out that tightening financing constraints may squeeze out corporate R&D resources [6,7]. But there is no consensus on the conclusion. Regarding comprehensive policy pilot programs such as green finance reform and innovation pilot zones, existing studies have largely focused on their impacts on corporate financing costs, pollution emissions, and investment structures [8,9]. However, it remains difficult to accurately capture the marginal impact of these policies on corporate innovation behavior. Regarding transmission mechanisms, most scholars consider financing constraints to play a mediating role [10, 11], yet the governance attributes of green finance policies are often overlooked. Another potential pathway involves mitigating information asymmetry and enhancing the precision of green capital allocation through strengthened information disclosure systems. Yet neither of these transmission pathways has been fully tested or validated.

This paper selects Shanghai and Shenzhen A-share listed companies from 2014 to 2024 as the research sample. Leveraging the staggered establishment of pilot zones as a quasi-natural experiment, it constructs a multi-period difference-in-differences (DID) model to systematically examine the incentive effects of green finance policies on the intensity and willingness of corporate green innovation. Furthermore, it conducts cross-sectional analyses across the dimensions of corporate governance and information disclosure to reveal the policy transmission pathways and stratified characteristics.

This paper makes three primary contributions. By focusing on comprehensive policy pilots and employing a staggered difference-in-differences (DID) approach to mitigate endogeneity, it refines the measurement system for green innovation, incorporating both innovation intensity and willingness, to more accurately identify the policy's causal effects. Moreover, building on existing literature that emphasizes financing constraints, it verifies the dual functions of green finance, namely, resource allocation and external governance, thereby enriching research into the transmission mechanisms through which green finance fosters innovation. Finally, it characterizes the heterogeneity of policy effects across dimensions such as internal governance foundations, environmental management systems, and information disclosure levels. In doing so, it reveals the non-linear nature of the policy's role in "addressing shortcomings," providing micro-level empirical evidence to support the targeted empowerment of corporate green innovation.

The remainder of this paper is organized as follows: Section 2 outlines the institutional background and research hypotheses, reviewing the institutional evolution of the green finance reform and innovation pilot zones and formulating hypotheses based on theoretical analysis. Section 3 details the research design, including sample selection, data sources, model specification, and variable definitions. Section 4 presents the empirical

results and analysis, reporting baseline regression findings, validity tests for the Difference-in-Differences (DID) approach, and a series of robustness checks. Section 5 conducts an analysis of cross-sectional heterogeneity, examining policy transmission channels through the lenses of corporate governance and information disclosure. Section 6 offers research conclusions and policy recommendations.

2. Institutional Background and Research Hypotheses

2.1 Institutional Evolution of Pilot Zones for Green Finance Reform and Innovation

In August 2016, seven government agencies, including the People's Bank of China, jointly issued the Guiding Opinions on Establishing a Green Financial System. This marked the first time the concept of green finance was defined, an institutional framework established, and core tasks clarified at the national level, signaling the entry of China's green finance development into an institutionalized phase guided by top-level design.

To overcome bottlenecks in the local implementation of green finance, China adopted a reform strategy characterized by phased piloting and a tiered rollout. In June 2017, the State Council approved the establishment of the first batch of pilot zones in Huzhou and Quzhou (Zhejiang), Ganjiang New Area (Jiangxi), Guangzhou (Guangdong), Gui'an New Area (Guizhou), and Hami, Changji, and Karamay (Xinjiang), with each location exploring approaches tailored to its specific industrial characteristics and resource endowments. In November 2019, Lanzhou New Area (Gansu) was approved as a second-batch pilot zone, focusing on ecological protection in the Yellow River Basin and new energy industry clusters. In August 2022, the entirety of Chongqing was designated as a third-batch pilot zone, which marks the first province-level pilot covering an entire administrative region, thereby advancing the reform from isolated cities toward regional coordination.

2.2 Theoretical Analysis and Research Hypotheses

Green innovation is characterized by long cycles, high uncertainty, and pronounced dual externalities. Corporate investment in innovation is constrained by both the external financing environment and the quality of internal corporate governance. Green projects involve complex technical pathways and long timelines for realizing returns. Significant information friction exists between enterprises and financial institutions, and green R&D has long faced a shortage of financing [12]. Green innovation entails long-term strategic investment. However, pressure from short-term performance evaluations and agency conflicts can foster short-sighted behavior, such as the voluntary reduction of green R&D budgets, while internal governance deficiencies further diminish the efficiency of innovation resource allocation [13].

Green finance reform and innovation pilot zones serve as comprehensive policy instruments capable of empowering corporate green innovation through two pathways: first, by broadening low-cost financing channels, such as green credit and green bonds, to alleviate funding gaps; and second, by leveraging environmental credit assessments and mandatory information disclosure to establish external oversight, thereby compelling enterprises to increase investment in green R&D. Based on this, the following baseline hypothesis is proposed:

H1: Holding other factors constant, the policies for green finance reform and innovation pilot zones can significantly enhance the intensity of and willingness for green innovation among enterprises within the jurisdiction.

From the perspective of internal governance, enterprises with robust internal controls and ISO 14001 certification have established mature green operational mechanisms and possess strong momentum for independent innovation. In contrast, enterprises with weak governance suffer from issues such as the misuse of funds and a lack of environmental management. The pilot zones link credit resources with environmental compliance, use external constraints to make up for internal governance shortcomings, and have a stronger incentive effect on companies that address shortcomings. It is therefore proposed that:

H2: Policies for green finance reform and innovation pilot zones exhibit a corporate governance substitution effect, exerting a stronger promoting influence on green innovation in enterprises with lower levels of internal governance.

From the perspective of information disclosure, companies with comprehensive disclosure regarding environmental principles and social responsibility exhibit lower levels of information asymmetry, making it easier for their green projects to secure funding. It is difficult for financial institutions to recognize the green value of enterprises with weak information disclosure. By standardizing disclosure norms and establishing a green credit system, the pilot zones have significantly improved the financing environment for enterprises with low disclosure levels, yielding a stronger marginal effect in boosting innovation; thus, the following hypothesis is proposed:

H3: The green finance reform and innovation pilot zone policy has an information disclosure extension effect and has a stronger promotion effect on green innovation of enterprises with a weak information disclosure foundation.

3. Research Design

3.1 SAMPLE Selection and Data Sources

This study focuses on Shanghai and Shenzhen A-share listed companies from 2014 to 2024. Samples were selected based on the following criteria: excluding companies in the finance, insurance, and real estate sectors; excluding those subject to special treatment (ST/SZ) or abnormal trading status; and removing observations with abnormal operating conditions or missing key data. To mitigate the impact of extreme values on empirical results, all continuous variables were winsorized at the 1% level (two-tailed). Firm- and city-level data were obtained from the CSMAR database and the CNRDS platform, resulting in a balanced panel dataset for subsequent analysis.

3.2 Model Specification and Variable Definitions

To identify the causal effect of green finance policies on corporate green innovation, this paper constructs a multi-period difference-in-differences (Multi-period DID) model, leveraging the quasi-natural experiment created by the phased establishment of green finance reform and innovation pilot zones. The baseline model is specified as follows:

$$Inno_{i,t}=\beta_0+\beta_1 DID_{i,t}+\gamma X_{i,t}+\delta_i+\lambda_t+\varepsilon_{i,t} \quad (1)$$

The core explanatory variable, the treatment effect variable ($DID_{i,t}$) associated with the implementation of the green finance reform and innovation pilot zone policy, is used to reflect the net impact of green finance policies. The assignment rule for this variable is as follows: it is assigned a value of 1 if the enterprise is registered in a green finance reform and innovation pilot zone and the observation year is subsequent to the year the policy was approved; otherwise, it is assigned a value of 0. In the model, $X_{i,t}$ represents firm-level control variables used to account for the effects of individual firm characteristics, such as firm size, leverage ratio, profitability, growth potential, and ownership structure. δ_i is used as a firm-level fixed effect to capture the inherent characteristics of firms that remain constant over time across the various stages. λ_t represents an individual-specific fixed random effect that captures common time trends resulting from nationwide macroeconomic shocks and cyclical fluctuations across industries. $\varepsilon_{i,t}$ is the firm-specific random disturbance term. The coefficient β_1 represents the average treatment effect of the green finance reform and innovation pilot zone policy on corporate green innovation. If β_1 is significantly positive, it indicates that the green finance policy exerts a significant promoting effect on green innovation among enterprises within the pilot zones.

The dependent variable, the intensity of corporate green innovation, is used to measure the strength of green innovation. The enterprise's willingness to engage in green innovation is a binary dummy variable used to measure whether the enterprise conducts green innovation activities. This study also selects other key factors potentially influencing the intensity of corporate green innovation as control variables; these include firm-level variables such as asset size, asset-liability ratio, growth capacity, return on net assets, cash flow ratio, years since listing, and the shareholding ratio of the largest shareholder.

Table 1: Variable Names and Definitions

Variable Type	Variable Name	Symbol	Measurement / Definition
Dependent Variables	Corporate Green Innovation Intensity	*Inno*	ln (number of green patent applications by the firm in the year + 1)
	Corporate Green Innovation Willingness	*PatentH*	1 if Inno ≠ 0; 0 if Inno = 0
Explanatory Variable	Treatment effect of the Green Finance Reform and Innovation Pilot Zone policy	*DID*	1 if the firm's registered location is in a Green Finance Reform and Innovation Pilot Zone and the observation year is after the policy approval year; 0 otherwise
Control Variables	Firm Size	*Size*	ln (year-end total assets)
	Leverage	*Lev*	Year-end total liabilities / year-end total assets
	Return on Equity	*Roe*	Net profit / year-end net assets
	Cash Flow	*Cfo*	Net cash flow from operating activities / total assets
	Operating Revenue Growth Rate	*Growth*	Current year's operating revenue / previous year's operating revenue − 1
	Years Listed	*Age*	Current year − listing year
	Board Size	*Board*	ln (number of board members)
	Independent Director Ratio	*Indep*	Number of independent directors / total number of directors
	Ownership Nature	*SOE*	1 if the firm is a state-owned enterprise; 0 otherwise
	Largest Shareholder Ownership	*Top1*	Shares held by the largest shareholder / total shares

4. Empirical Results and Analysis

4.1 Descriptive Statistical Results and Analysis

Table 2 shows the descriptive statistical results of the main variables in this article. In terms of explained variables, the mean value of corporate green innovation intensity is 0.985, and the standard deviation is 1.231, indicating that there are certain differences in the level of green patent applications among sample companies The average value of corporate green innovation willingness is 0.520, indicating that approximately 52.0% of the sample companies have carried out green patent application activities. In terms of explanatory variables, the mean value of the policy interaction term (DID) in the Green Finance Reform and Innovation Pilot Zone is 0.047, and the standard deviation is 0.211, which is basically consistent with the statistical characteristics of related policy impact studies.

Among the control variables, the average company size is 22.339, the average asset-liability ratio is 0.424, the average return on net assets is 0.040, the average operating cash flow is 0.048, and the average operating income growth rate is 0.133. The average listing years is 11.729 years, the average board size is 2.102, the average proportion of independent directors is 37.885%, the average property rights nature is 0.320, and the average shareholding ratio of the largest shareholder is 34.622%. The distribution characteristics of the above variables are basically consistent with the statistical results of Chinese listed companies in the existing literature, indicating that the sample in this article is well representative.

Table 2: Descriptive Statistics

	N	Mean	SD	Min	p25	Median	p75	Max
Inno	37010	0.985	1.231	0.000	0.000	0.693	1.792	4.787
PatentH	37010	0.520	0.500	0.000	0.000	1.000	1.000	1.000
DID	37010	0.047	0.211	0.000	0.000	0.000	0.000	1.000
Size	37010	22.339	1.287	19.964	21.419	22.145	23.067	26.206
Lev	37010	0.424	0.207	0.060	0.260	0.413	0.571	0.947
Roe	37010	0.040	0.167	-0.927	0.020	0.062	0.108	0.411
Cfo	37010	0.048	0.067	-0.156	0.010	0.047	0.087	0.242
Growth	37010	0.133	0.389	-0.614	-0.054	0.078	0.232	2.335
Age	37010	11.729	8.181	0.942	4.597	9.722	18.497	29.569
Board	37010	2.102	0.197	1.609	1.946	2.197	2.197	2.639
Indep	37010	37.885	5.371	33.330	33.330	36.360	42.86	57.14
SOE	37010	0.320	0.466	0.000	0.000	0.000	1.000	1.000
Top1	37010	34.622	15.022	7.020	23.220	32.690	44.929	74.34

4.2 Univariate Statistical Results and Analysis

Table 3 shows the T-test results of the mean differences of each variable before and after the implementation of the Green Finance Reform and Innovation Pilot Zone policy. It can be seen from the figure that after the implementation of the policy, the average value of corporate green innovation intensity and corporate green innovation willingness are higher than before the policy implementation, and they are both significant at the 1% level, indicating that the level of corporate green innovation has been improved after the implementation of the policy. In addition, before and after the implementation of the policy, the asset-liability ratio, return on net assets, operating cash flow, operating income growth rate, board size, proportion of independent directors, nature of property rights and shareholding ratio of the largest shareholder are also different, which means that certain attributes of the company have changed significantly before and after the implementation of the policy. Univariate test results show that there are significant differences in the asset-liability ratio, profitability level, operating cash flow, ownership structure and other characteristics of enterprises before and after the implementation of the policy, indicating that the above time-varying factors may be related to policy impact and corporate innovation behavior. Therefore, subsequent benchmark regressions will include these time-varying control variables to alleviate omitted variable bias. This article will control year fixed effects, industry fixed effects and company fixed effects in regression analysis to reduce the interference of other omitted variables.

Table 3: Univariate Statistics

Variable	Before Policy		After Policy		Mean Difference
	Observations	Mean	Observations	Mean	
Inno	35284	0.980	1726	1.081	-0.101***
PatentH	35284	0.517	1726	0.574	-0.056***
Size	35284	22.337	1726	22.382	-0.045
Lev	35284	0.424	1726	0.416	0.009*
Roe	35284	0.040	1726	0.048	-0.007*
Cfo	35284	0.048	1726	0.057	-0.009***
Growth	35284	0.135	1726	0.105	0.030***
Age	35284	11.740	1726	11.514	0.226
Board	35284	2.103	1726	2.089	0.013***
Indep	35284	37.865	1726	38.298	-0.432***
SOE	35284	0.318	1726	0.362	-0.044***
Top1	35284	34.532	1726	36.457	-1.926***

4.3 Benchmark Regression Results and Analysis

Table 4 shows the baseline regression results of this article. The explained variables in columns (1) and (2) are corporate green innovation intensity, and the explained variables in columns (3) and (4) are corporate green innovation intentions.

In column (1), when only controlling for firm and year fixed effects, the coefficient of the green finance reform and innovation pilot zone policy interaction term DID is 0.1409, which is significantly positive at the 5% level. In Column (2), after including all control variables, the DID coefficient remains 0.1292 and is significantly positive at the 5% level, indicating that the implementation of the green finance reform and innovation pilot zone policy has significantly boosted corporate green innovation efforts.

In column (3), when only company and year fixed effects are controlled, the coefficient of DID is 0.0489, which is significantly positive at the 5% level. After adding control variables to column (4), the coefficient of DID is 0.0461, which is significantly positive at the 10% level, indicating that policy implementation also significantly increases the willingness of enterprises to carry out green innovation activities.

As can be seen from column (2) in the table, the coefficient of the policy interaction term DID is 0.1292, indicating that compared with similar companies in non-pilot areas, the green patent application level of enterprises in pilot areas has increased by approximately 12.92% on average, which has relatively strong economic implications. The above results prove that the research hypothesis of this article is correct, that is, the policies of the green financial reform and innovation pilot zone can improve the green innovation of enterprises.

Table 4: Benchmark Regression Results

	Inno		PatentH	
	(1)	(2)	(3)	(4)
DID	0.1409**	0.1292**	0.0489**	0.0461*
	(2.34)	(2.23)	(1.96)	(1.85)
Size		0.3802***		0.1180***
		(19.28)		(16.72)
Lev		-0.0799		-0.0161
		(-1.47)		(-0.63)
Roe		-0.0004		-0.0158
		(-0.01)		(-1.06)
Cfo		-0.0175		0.0166
		(-0.24)		(0.43)
Growth		0.0019		0.0086
		(0.18)		(1.54)
Age		-0.0049		-0.0042
		(-0.18)		(-0.28)
Board		0.1144*		0.0560**
		(1.74)		(1.98)
Indep		0.0049**		0.0008
		(2.49)		(1.00)
SOE		-0.0316		0.0030
		(-0.91)		(0.18)
Top1		0.0022**		0.0011**
		(2.12)		(2.56)
Cons	0.9785***	-7.9156***	0.5176***	-2.2520***
	(348.98)	(-13.84)	(444.07)	(-9.14)
Firm FE	*YES*	*YES*	*YES*	*YES*
Year FE	*YES*	*YES*	*YES*	*YES*
N	37010	37010	37010	37010
adj.R^2	0.73	0.74	0.48	0.49

*Note: The t values are in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively. Clustering standard errors are adjusted at the enterprise level. Same as the tables below.*

4.4 Validity Analysis and Robustness Test of DID Estimation

4.4.1 Parallel Trend Test

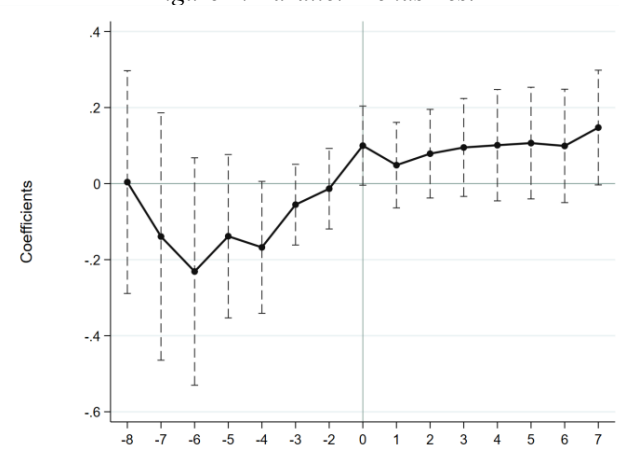
When employing the difference-in-differences model to evaluate policy effects, the parallel trends assumption is a prerequisite. Specifically, there must be no significant difference in the level of green innovation between enterprises in pilot regions and those in non-pilot regions prior to the implementation of the green finance reform and innovation pilot zone policy. This paper employs the event study method to conduct a parallel trend test, based on established standards in the literature. The results indicate that the regression coefficients for the periods prior to the pilot program were not statistically significant and the 95% confidence intervals included zero. Thus, it can be inferred that the trends in green innovation development were essentially consistent before the pilot, satisfying the prerequisites for the difference-in-differences model. Starting from the period of policy implementation (Period 0), the level of green innovation among enterprises in the pilot zones exhibited a clear upward trend. The coefficients for all periods following implementation were positive and relatively stable, indicating that the green finance policy has a sustained, positive impact on corporate green innovation. It is consistent with the results of the baseline regression analysis in this study.

4.4.2 Propensity Score Matching and Entropy Balancing Tests

To mitigate sample self-selection bias, this paper employs the PSM-DID method to conduct robustness tests. Enterprises covered by the pilot zone policies were designated as the treatment group, while the remaining enterprises served as the control group. Covariates selected included firm size, debt-to-asset ratio, return on net assets, operating cash flow, revenue growth rate, years since listing, board size, proportion of independent directors, nature of property rights, and the shareholding ratio of the largest shareholder. Sample matching was conducted using one-to-one nearest neighbor matching, K-nearest neighbor matching, radius

matching, and kernel matching. The results in Column (1) of Table 5 show that the post-matching DID coefficient is 0.1198, which is significantly positive at the 10% level; the ATT is significantly positive across various matching methods, consistent with the baseline regression findings.

Figure 1: Parallel Trends Test



To circumvent the reliance of traditional matching methods on functional forms and weight specifications, this paper employs the entropy balancing method. By adjusting weights to achieve balance in covariate moment conditions between the treatment and control groups, it mitigates sample selection bias. As shown in Column (2) of Table 5, the DID coefficient after entropy balancing is 0.1249, remaining significantly positive at the 10% level. The sign and magnitude of the coefficient are similar to those of the baseline regression. The above results indicate that, after controlling for differences in observable individual characteristics, the effect of green finance policies in driving corporate green innovation remains robust, confirming the reliability of the baseline findings.

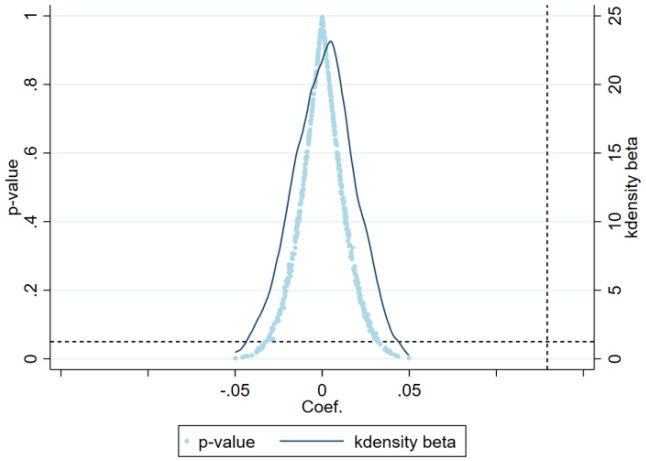
Table 5: Robustness Checks (Propensity Score Matching and Entropy Balancing)

	(1)	(2)
DID	0.1198*	0.1249*
	(1.89)	(1.95)
Size	0.3422***	0.3460***
	(6.07)	(5.97)
Lev	-0.0097	-0.0300
	(-0.05)	(-0.15)
Roe	-0.0650	-0.0626
	(-0.51)	(-0.46)
Cfo	-0.2460	-0.2543
	(-0.91)	(-0.92)
Growth	-0.0321	-0.0242
	(-0.82)	(-0.61)
Age	-0.0637	-0.0701
	(-0.64)	(-0.69)
Board	0.1428	0.1355
	(0.63)	(0.60)
Indep	0.0131**	0.0140**
	(2.15)	(2.28)
SOE	-0.0799	-0.0604
	(-0.67)	(-0.51)
Top1	0.0068*	0.0067*
	(1.94)	(1.86)
Cons	-6.9237***	-6.9533***
	(-3.93)	(-3.88)
Firm FE	*YES*	*YES*
Year FE	*YES*	*YES*
N	3429	3429
adj.R^2	0.72	0.72

4.4.3 Placebo Test

To rule out the influence of random factors on policy effects and ensure that the baseline results were not obtained by chance, this paper employs a placebo test by randomly selecting a pseudo-treatment group. Keeping the policy implementation timing unchanged, a number of enterprises were randomly selected to form a pseudo-treatment group, and the random sampling and regression processes were repeated 500 times. The results indicate that, after 500 random regressions, most estimated coefficients cluster around zero and follow a normal distribution; furthermore, the majority of p-values exceed 0.05, meaning they are not significant at the 5% level. The baseline regression coefficients and p-valuesdeviate significantly, and far exceed, the levels associated with a random distribution. This indicates that the baseline results cannot be explained by random factors, thereby indirectly demonstrating the robustness of the conclusions.

Figure 2: Placebo Test



4.4.4 Test Using an Alternative Dependent Variable

To avoid estimation bias arising from measurement using a single indicator, this paper conducts robustness checks by replacing the dependent variable with measures based on two dimensions: innovation willingness and innovation quality. The baseline regression measures green innovation using the number of green patent applications. This study re-runs the regression using green innovation intention and patent citation counts as alternative proxies, while keeping the model specification, explanatory variables, control variables, and two-way fixed effects unchanged. Column (1) of Table 6 shows that when the willingness to engage in green innovation is the dependent variable, the DID coefficient is 0.0461, which is significantly positive at the 10% level. In column (2), when the number of patent citations is used as the dependent variable, the DID coefficient is 0.0936, which is significantly positive at the 5% level. Using two alternative indicators, the coefficients of the core variables align in direction and significance with the baseline results, and the results for control variables show no systematic changes. This indicates that the policy incentive effect is significant regardless of whether innovation willingness or innovation quality is measured, and the core conclusions remain robust to the choice of measurement for the dependent variable.

Table 6: Robustness Check (Replacing the Dependent Variable)

	Enterprises' Willingness to Engage in Green Innovation	Corporate Patent Citation Count
	(1)	(2)
DID	0.0461*	0.0936**
	(1.85)	(2.07)
Size	0.1180***	0.0083
	(16.72)	(0.63)
Lev	-0.0161	0.0218
	(-0.63)	(0.54)
Roe	-0.0158	0.0439*
	(-1.06)	(1.90)
Cfo	0.0166	-0.0013

	Enterprises' Willingness to Engage in Green Innovation	Corporate Patent Citation Count
	(0.43)	(-0.02)
Growth	0.0086	-0.0026
	(1.54)	(-0.34)
Age	-0.0042	-0.0754***
	(-0.28)	(-3.37)
Board	0.0560**	0.0025
	(1.98)	(0.05)
Indep	0.0008	0.0009
	(1.00)	(0.51)
SOE	0.0030	-0.0407
	(0.18)	(-1.12)
Top1	0.0011**	0.0010
	(2.56)	(1.36)
Cons	-2.2520***	0.9673**
	(-9.14)	(2.32)
Firm FE	*YES*	*YES*
Year FE	*YES*	*YES*
N	37010	37010
adj.R2	0.49	0.57

4.4.5 Test by Policy Type

To further enhance the credibility of the baseline findings, this paper categorizes the sample into three time periods based on the policy implementation years of 2017, 2019, and 2022, and employs a three-period difference-in-differences (DID) model to examine the trend of policy effects. Columns (1) through (3) of Table 7 show that the DID coefficient for the first batch of policies (2017) is 0.1279, which is significantly positive at the 10% level. The coefficients for the 2019 and 2022 batches are 0.1694 and 0.1176, respectively, both positive but failing to pass conventional tests of statistical significance. This result is attributable to the broader scope, more comprehensive policy tools, and more robust market response associated with the first batch of pilots, reflecting the more pronounced early effects of the policies. Batch-based testing did not overturn the baseline conclusions but revealed temporal heterogeneity in policy effects, effectively validating the robustness of the baseline results. Among the control variables, firm size is consistently positive and significant at the 1% level; the signs and significance of the other variables remain largely consistent, indicating stable model performance. The adjusted R^2 values range from 0.74 to 0.75, reflecting a good model fit.

4.4.6 Test Excluding Provinces Unaffected by the Policy

To eliminate confounding factors arising from the absence of pilot zones, this paper selects only those provinces that have established pilot zones as the sample for regression analysis. In Column (4) of Table 7, the coefficient of the core explanatory variable (DID) is 0.1405 and is significantly positive at the 5% level. This result is entirely consistent with, and even more significant than, the baseline positive incentive effect, indicating that the policy outcome is not attributable to systematic differences between the groups. The coefficient for the control variable "firm size" is 0.3919 (significant at the 1% level), and the coefficient for the asset-liability ratio is -0.1589 (significant at the 10% level); both align with the results of the baseline regression. The model continues to control for firm and year fixed effects; the adjusted R^2 is 0.73, indicating a high goodness of fit and suggesting that the conclusions are robust.

Table 7: Robustness Tests (Differentiating Policy Types and Excluding Provinces Unaffected by the Policy)

	Impact of the 2017 Policy	Impact of the 2019 Policy	Impact of the 2022 Policy	Excluding Provinces Unaffected by the Policy
	(1)	(2)	(3)	(4)
DID	0.1279*	0.1694	0.1176	0.1405**
	(1.76)	(0.93)	(1.02)	(2.35)
Size	0.3843***	0.3848***	0.3790***	0.3919***
	(19.28)	(18.82)	(18.64)	(12.78)
Lev	-0.0747	-0.0913*	-0.0840	-0.1589*
	(-1.38)	(-1.66)	(-1.52)	(-1.76)
Roe	0.0043	0.0076	0.0078	-0.0729

	Impact of the 2017 Policy	Impact of the 2019 Policy	Impact of the 2022 Policy	Excluding Provinces Unaffected by the Policy
	(0.14)	(0.25)	(0.26)	(-1.46)
Cfo	-0.0137	-0.0114	0.0037	-0.1069
	(-0.19)	(-0.15)	(0.05)	(-0.88)
Growth	0.0005	0.0017	0.0038	0.0061
	(0.05)	(0.16)	(0.36)	(0.32)
Age	-0.0083	-0.0015	-0.0004	-0.0398
	(-0.31)	(-0.06)	(-0.02)	(-0.85)
Board	0.0891	0.0970	0.1282*	0.2025*
	(1.35)	(1.44)	(1.90)	(1.72)
Indep	0.0044**	0.0040*	0.0047**	0.0066*
	(2.22)	(1.95)	(2.29)	(1.74)
SOE	-0.0312	-0.0313	-0.0313	-0.0430
	(-0.89)	(-0.88)	(-0.88)	(-0.72)
Top1	0.0019*	0.0021*	0.0018*	0.0026
	(1.81)	(1.95)	(1.68)	(1.44)
Cons	-7.8850***	-7.9736***	-7.9411***	-8.0329***
	(-13.64)	(-13.44)	(-13.50)	(-9.27)
Firm FE	*YES*	*YES*	*YES*	*YES*
Year FE	*YES*	*YES*	*YES*	*YES*
N	36340	34754	35064	12611
adj.R^2	0.74	0.75	0.75	0.73

4.4.7 Test of Alternative Fixed Effects

To control for the confounding effects of multidimensional unobservable factors and to test the sensitivity of the findings to various fixed-effects specifications, this paper sequentially introduces fixed effects for province, industry, year-by-industry, and year-by-province into the regression models. Table 8 shows that the DID coefficient is 0.1290 (significant and positive at the 5% level) when province fixed effects are included in column (1), and 0.1257 (significant and positive at the 5% level) when industry fixed effects are included in column (2). When year-industry and year-province interaction fixed effects are included in columns (3) and (4), the DID coefficients are 0.1052 and 0.1515, respectively, both significant and positive at the 10% level. The DID coefficients remain significantly positive across various fixed-effect specifications. Their magnitudes are close to the baseline, and their significance is stable, indicating that the baseline findings are not driven by the choice of fixed effects. The results for the control variables are highly consistent with the baseline. The firm size coefficients are significantly positive at the 1% level, and the adjusted R^2 values range from 0.74 to 0.75, indicating a good model fit. The results remain stable and reliable after controlling for regional, industry, and temporal heterogeneity.

Table 8: Robustness Check (Alternative Fixed Effects)

	(1)	(2)	(3)	(4)
DID	0.1290**	0.1257**	0.1052*	0.1515*
	(2.20)	(2.21)	(1.92)	(1.96)
Size	0.3808***	0.3786***	0.3899***	0.3832***
	(19.94)	(20.01)	(20.74)	(19.96)
Lev	-0.0831	-0.0734	-0.0310	-0.0727
	(-1.55)	(-1.38)	(-0.58)	(-1.35)
Roe	0.0035	-0.0010	-0.0070	0.0078
	(0.12)	(-0.03)	(-0.23)	(0.26)
Cfo	-0.0133	-0.0084	0.0494	-0.0094
	(-0.19)	(-0.12)	(0.70)	(-0.13)
Growth	0.0017	0.0010	-0.0039	0.0010
	(0.16)	(0.10)	(-0.38)	(0.10)
Age	0.0005	-0.0025	0.0448	-0.0111
	(0.02)	(-0.09)	(1.64)	(-0.39)
Board	0.1100*	0.1137*	0.1246**	0.1096*
	(1.72)	(1.76)	(1.98)	(1.70)
Indep	0.0051***	0.0048**	0.0049**	0.0054***

	(1)	(2)	(3)	(4)
	(2.64)	(2.48)	(2.57)	(2.78)
SOE	-0.0220	-0.0329	-0.0257	-0.0194
	(-0.63)	(-0.95)	(-0.73)	(-0.55)
Top1	0.0023**	0.0022**	0.0015	0.0020*
	(2.26)	(2.13)	(1.44)	(1.92)
Cons	-7.9973***	-7.9059***	-8.7342***	-7.9170***
	(-14.23)	(-14.19)	(-15.66)	(-13.77)
Firm FE	*YES*	*YES*	*YES*	*YES*
Year FE	*YES*	*YES*	*NO*	*NO*
Province FE	*YES*	*NO*	*NO*	*NO*
Industry FE	*NO*	*YES*	*NO*	*NO*
Year×Industry FE	*NO*	*NO*	*YES*	*NO*
Year×Province FE	*NO*	*NO*	*NO*	*YES*
N	37010	37010	36997	37008
adj.R^2	0.74	0.75	0.75	0.74

5. Cross-sectional Difference Analysis

The impact of policies establishing pilot zones for green finance reform and innovation on corporate green innovation exhibits significant cross-sectional divergence at the firm level. A company's internal governance foundation and its basis for environmental information disclosure directly moderate the strength of the policy incentives. This section analyzes the subject from two dimensions, the substitutive role of corporate governance and the spillover effects of information disclosure, to clarify the logic behind the differentiated impact of policy incentives on enterprises with varying endowments.

5.1 The Substitutive Role of Corporate Governance

Internal controls and a standardized environmental management system together form a comprehensive internal green governance system. The two complement and check each other, establishing an internal mechanism of constraint.

On one hand, the effectiveness of internal control constitutes a crucial foundation for a firm's internal governance, directly influencing the management of R&D funds, the constraint of agency costs, and the soundness of innovation decision-making. For enterprises with deficiencies in internal controls, the use of R&D funds lacks constraints, which hinders the pursuit of green innovation. This paper uses the effectiveness of internal control (IsValid) as a measure of a firm's internal governance quality, assigning a value of 1 if internal control is effective and 0 otherwise, and incorporates an interaction term between this variable and the difference-in-differences (DID) term into the baseline model for empirical testing. The results in Column (1) of Table 9 show that the baseline DID coefficient is significantly positive at the 1% level, indicating that green innovation in firms with weak internal controls significantly increased following the policy shock. The coefficient of the interaction term between policy and internal control effectiveness is significantly negative, demonstrating that green finance policies exert a stronger incentive effect on green innovation for enterprises with weak internal controls.

On the other hand, ISO 14001 environmental management system certification reflects a company's specialized environmental governance capabilities. It complements internal controls and further validates the logic of governance substitution. Enterprises that have obtained this certification possess mature mechanisms for environmental risk prevention and control as well as green operations, with stable institutional support for green innovation. In contrast, enterprises that have not yet obtained the certification tend to have fragmented environmental management and lack institutional safeguards for green R&D. This paper uses ISO14001 certification status (IsPassISO14001) to measure the level of corporate environmental governance; a value of 1 is assigned for certification and 0 otherwise. Firms scoring above the annual median are classified into the high internal governance group (IsPassISO14001 = 1), while the remainder are assigned to the low internal governance group (IsPassISO14001 = 0). The results in Column (2) of Table 9 show that the baseline DID coefficient is significantly positive at the 5% level, indicating that enterprises with imperfect environmental management systems experienced a significant improvement in their green innovation performance driven by the policy. The coefficient of the interaction term between policy and certification is significantly negative,

indicating that the marginal incentive effect of the policy on enterprises with mature environmental management systems is relatively limited.

Synthesizing the empirical findings regarding internal control effectiveness and ISO 14001 environmental management certification, it is evident that for enterprises suffering from internal control failures or lacking standardized environmental management systems, external policy constraints can compensate for the absence of internal governance mechanisms, thereby generating stronger incentives for green innovation. In contrast, for enterprises with robust internal governance and comprehensive environmental control systems, which already possess mature operational mechanisms for innovation, the incremental gains resulting from such policies are relatively limited.

Table 9: Cross-sectional Regression Results of Corporate Governance Substitution Effect

	(1)	(2)
Did	0.6120***	0.1498**
	(2.99)	(2.52)
IsValid	0.1558***	
	(3.53)	
c.Did#c.IsValid	-0.4806**	
	(-2.42)	
IsPassISO14001t		0.0116
		(0.86)
c.DID#c.IsPassISO14001		-0.1005**
		(-2.10)
Size	0.3774***	0.3803***
	(19.53)	(19.28)
Lev	-0.0750	-0.0797
	(-1.36)	(-1.47)
Roe	-0.0114	-0.0003
	(-0.37)	(-0.01)
Cfo	-0.0375	-0.0176
	(-0.52)	(-0.24)
Growth	0.0012	0.0018
	(0.11)	(0.17)
Age	-0.0018	-0.0044
	(-0.07)	(-0.16)
Board	0.1110*	0.1142*
	(1.74)	(1.74)
Indep	0.0045**	0.0049**
	(2.38)	(2.50)
SOE	-0.0343	-0.0318
	(-0.98)	(-0.92)
Top1	0.0021**	0.0022**
	(2.05)	(2.11)
Cons	-8.0151***	-7.9241***
	(-14.27)	(-13.85)
Firm FE	*YES*	*YES*
Year FE	*YES*	*YES*
N	36091	37010
adj. R^2	0.74	0.74

5.2 Extended Effect of Information Disclosure

Corporate environmental information disclosure encompasses the disclosure of environmental philosophies at the fundamental strategic level and the disclosure of social responsibility reports at the comprehensive operational level. The quality of these two types of disclosure collectively determines the enterprise's endogenous drive for green transformation and the transparency of its information to external stakeholders.

From the perspective of strategic disclosure, companies that proactively disclose their environmental policies and green development models have integrated environmental goals into their daily operations, with green innovation driven by internal momentum. Conversely, companies that do not disclose their

environmental philosophies show a weaker willingness to undergo a green transition, relying more on external policy drivers for green R&D. This study employs the disclosure of environmental protection concepts (EPtConcept) to measure the strategic orientation of corporate environmental protection; a value of 1 is assigned if a company discloses information such as environmental protection concepts, environmental policies, or green development models (0 otherwise), and the sample is divided into high and low groups based on the annual median for analysis. The results in Column (1) of Table 10 show that the baseline DID coefficient is significantly positive at the 5% level, indicating a significant increase in green innovation among enterprises that did not disclose environmental philosophies following the policy's implementation. The coefficient for the interaction term between the policy and environmental philosophy disclosure is significantly negative, suggesting that the policy has a stronger effect on boosting innovation in enterprises with insufficient disclosure of environmental philosophies.

From the perspective of integrated business operations, enterprises that consistently provide high-quality social responsibility disclosures demonstrate greater information transparency and find it easier to secure credit for green projects. Conversely, enterprises with low levels of disclosure fail to adequately communicate green-related information to the outside world and face tighter financial constraints regarding green R&D. This paper uses the disclosure level of corporate social responsibility (CSR) reports to measure the extent of corporate information disclosure. Based on the upper quartile of disclosure quality for the sample years, firms with disclosure levels exceeding the annual upper quartile are classified into the high-disclosure group (IsPublishCSRRep = 1), while the remainder are classified into the low-disclosure group (IsPublishCSRRep = 0). When the grouping variable and its interaction term with the DID variable are incorporated into the baseline model to examine the information disclosure mechanism, the results in Column (2) of Table 10 show that the baseline DID coefficient is significantly positive at the 5% level, indicating that green innovation among firms with low disclosure levels increased significantly following the policy intervention. Meanwhile, the coefficient for the interaction term between the policy and the high-disclosure group is significantly negative, implying that the policy's marginal effect on promoting innovation among firms with high information disclosure is relatively limited.

By synthesizing the empirical findings regarding environmental philosophy disclosure and social responsibility reporting, it can be concluded that policies aimed at addressing information disclosure deficiencies are more effective for enterprises that previously lacked environmental philosophy disclosures, driving greater green innovation. Conversely, for enterprises that already possess robust information disclosure mechanisms, the scope for incremental improvement resulting from such policies is more limited, given the already low level of information asymmetry.

Table 10: Cross-sectional Regression Results for the Spillover Effect of Information Disclosure

	(1)	(2)
DID	0.1429**	0.1393**
	(2.41)	(2.36)
EPtConcept	-0.0153	
	(-1.12)	
c.DID#c.EPtConcep	-0.0984*	
	(-1.81)	
IsPublishCSRReport		0.1064***
		(4.50)
c.did#c.IsPublishCSRReport		-0.2122**
		(-2.51)
Size	0.3806***	0.3802***
	(19.32)	(19.31)
Lev	-0.0788	-0.0843
	(-1.45)	(-1.56)
Roe	-0.0005	-0.0000
	(-0.02)	(-0.00)
Cfo	-0.0180	-0.0200
	(-0.25)	(-0.28)
Growth	0.0016	0.0021
	(0.15)	(0.20)
Age	-0.0045	-0.0055

	(1)	(2)
	(-0.17)	(-0.21)
Board	0.1152*	0.1159*
	(1.75)	(1.76)
Indep	0.0049**	0.0049**
	(2.49)	(2.52)
SOE	-0.0311	-0.0341
	(-0.90)	(-0.99)
Top1	0.0022**	0.0023**
	(2.09)	(2.18)
Cons	-7.9279***	-7.9173***
	(-13.86)	(-13.91)
Firm FE	*YES*	*YES*
Year FE	*YES*	*YES*
N	37010	37010
adj. R^2	0.74	0.74

6. Conclusions and Policy Recommendations

Green finance reform and innovation pilot zones represent a significant institutional exploration of China's financial supply-side structural reform within the realm of green development. The policy outcomes of these zones not only determine the practical success of local green transitions but also shape the strategic path for the financial system to empower the high-quality development of the real economy in the context of the "dual carbon" goals.

Taking Shanghai and Shenzhen A-share listed companies from 2014 to 2024 as the research subjects, and leveraging the quasi-natural experiment created by the phased establishment of green finance reform and innovation pilot zones, this paper constructs a multi-period difference-in-differences (DID) model to systematically evaluate the policy effects from the perspectives of innovation intensity and innovation willingness. Research indicates that policies in the pilot zones can significantly boost the level of corporate green innovation; the volume of green patent applications by pilot-zone enterprises is approximately 12.92% higher than that of enterprises in non-pilot areas. The policy effects are more pronounced in companies characterized by weak internal controls, a lack of environmental management mechanisms, low transparency regarding environmental philosophies, and poor-quality social responsibility reports. Meanwhile, in companies with higher asset operational efficiency, the policy dividends were more effectively translated into tangible R&D outcomes.

Based on the above findings, the following policy recommendations are proposed:

It is recommended to systematically scale up the experience gained in pilot zones and refine the green finance framework based on "unified standards plus local characteristics." Elevate core rules, such as the certification of proven green projects and environmental credit assessments, from the pilot zones to national standards to reduce cross-regional institutional friction. At the same time, allow space for local innovation by enabling the design of tailored toolkits based on distinct industrial structures and resource endowments. This fosters deep alignment between green finance, the cultivation of "new quality productive forces," and "dual carbon" goals, while channeling medium- and long-term capital toward key areas of green technology breakthroughs.

It is also recommended to strengthen external governance and information transparency, and to implement targeted support based on classification. On one hand, it is necessary to refine the differentiated credit mechanism that rewards excellence and penalizes poor performance by incorporating both environmental compliance and innovation incentives into credit assessments. This involves formulating unified detailed rules for environmental information disclosure by listed companies, establishing an inter-departmental information-sharing platform, and reducing the costs associated with screening green projects for financing. On the other hand, for enterprises lagging in their transition, efforts should be intensified to lower entry barriers while applying pressure to compel change, accompanied by the provision of transition finance instruments and compliance guidance services. Meanwhile, high-quality enterprises should receive robust support to enhance

their capabilities, enabling them to secure long-term, low-interest capital through mechanisms such as green bonds and the pledging of carbon assets.

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