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Green Finance and Corporate Green Innovation

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Abstract

Green finance has drawn considerable attention from both academia and policymakers as a key policy instrument for promoting green development and economic transformation in China. Against the backdrop of the central government's strategic efforts to establish a green financial system and a market-oriented green technology innovation system, this paper takes the Pilot Zones for Green Finance Reform and Innovations policy as a point of entry to examine its impact on corporate green innovation. The findings indicate that the pilot zone policy significantly enhances the level of green innovation among enterprises within the pilot regions. Further analysis reveals that the policy effect is more pronounced among firms with lower management ownership, weaker among those with larger pre-existing government green subsidies, and stronger among firms subject to higher levels of media coverage. This study provides empirical evidence for understanding green finance policies. Advancing the Pilot Zones for Green Finance Reform and Innovations policy to drive corporate green innovation is essential for promoting high-quality economic development.

Keywords

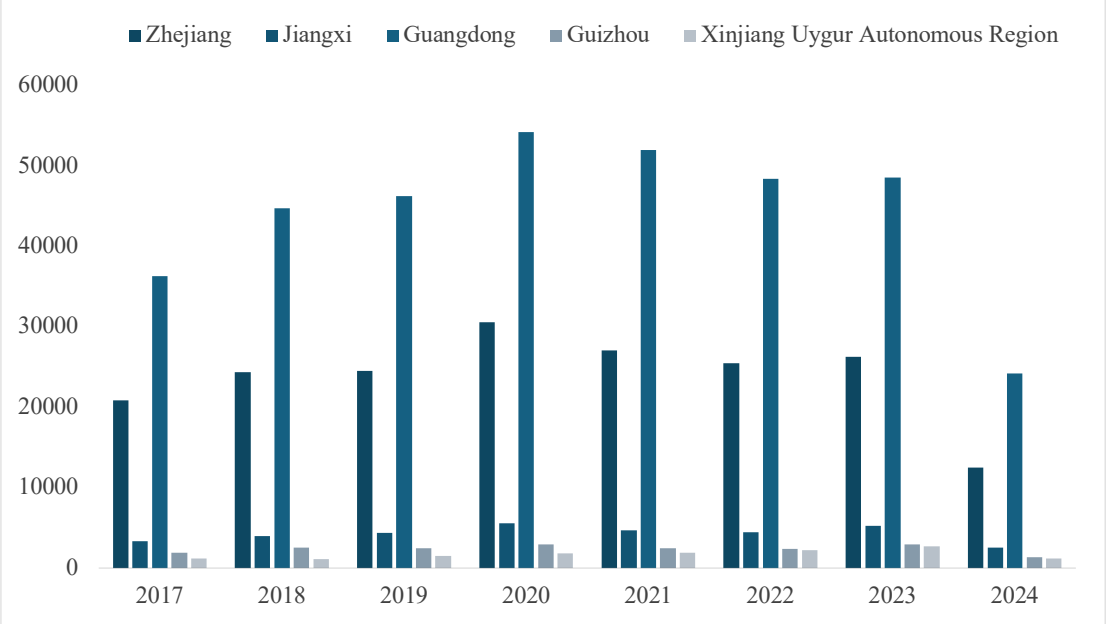
green finance, pilot zones for green finance reform and innovations, green innovation, staggered difference-in-differences

1. Introduction

The report to the 20th National Congress of the Communist Party of China explicitly states that "advancing the green and low-carbon transformation of economic and social development is a key link in achieving high-quality development." Establishing Pilot Zones for Green Finance Reform and Innovation is crucial to realizing the "dual carbon" goals and holds great significance for driving sustainable economic growth and fostering modernization characterized by the harmonious coexistence of humanity and nature. To establish a differentiated policy framework covering areas such as green credit, green bonds, and environmental information disclosure, seven government agencies, including the People's Bank of China, the National Development and Reform Commission, and the Ministry of Finance, have, since 2017, designated specific provinces and regions as pilot zones for green finance reform and innovation, rolling out the initiative in three batches. At present, research on the effects of this policy has proceeded from a macro-regional perspective, revealing that the pilot zone policy can foster the ecological transformation of industrial structures and empower the development of "new quality productive forces" in cities [1, 2]. On the other hand, examining the issue from the perspective of micro-level corporate behavior reveals that the policy can enhance corporate ESG performance and drive a shift in corporate activity from the financial sector to the real economy [3, 4].

As one of the first Pilot Zones for Green Finance Reform and Innovation in China, Huzhou has, from its approval in 2017 through the end of the second quarter of 2025, achieved a total of 74 green finance reform and innovation outcomes that were the first of their kind nationwide. Over the eight years since the pilot zone was established, green loans across the city have grown at an average annual rate of 41%. By the end of the second quarter of 2025, green loans accounted for 33.8% of total loans, far exceeding the national and provincial averages. Take Zhejiang Yikeou Environmental Protection Technology Co., Ltd., located within the pilot zone, as an example: backed by green credit support from the Bank of Huzhou, the company was included in the National Intellectual Property Administration's inaugural list of patent-intensive products in 2024; its "Engineering Laboratory for Pyrolysis Treatment and Resource Utilization of Oily Solid Waste in the Petroleum and Chemical Industry" was certified by the China Petroleum and Chemical Industry Federation in 2023; it was selected as a key "Little Giant" enterprise (specialized, refined, distinctive, and innovative) at the national level in 2021; and in 2020, it won the First Prize for Scientific and Technological Progress in Green Manufacturing from the Chinese Mechanical Engineering Society. Taking the five provinces (regions) covered by the first batch of pilot zones as an example, from the establishment of the pilot zone in 2017 to the end of 2024, the cumulative number of green patent applications in Guangdong Province reached 355,000, Zhejiang Province reached 192,000, Jiangxi Province reached 34,000, Guizhou Province reached 19,000, and Xinjiang Uygur Autonomous Region reached 14,000. The total number of applications in the five provinces (regions) in eight years has exceeded 610,000. Based on this, this article takes Shanghai and Shenzhen A-share non-financial listed companies from 2011 to 2024 as a sample to study the effect, heterogeneity conditions and internal mechanisms of green finance reform and innovation pilot zone policies on corporate green innovation.

Figure 1: Number of Green Patent Applications in the Five Pilot Provinces (Regions)



Note: Data sourced from the National Intellectual Property Administration and CNRDS.

This paper first employs a multi-period difference-in-differences model, using the volume of corporate green patent applications as a measure of green innovation performance. After controlling for firm and year fixed effects, the study finds that the pilot zone policy significantly boosts corporate green innovation output. This paper verifies the reliability of the baseline results, and confirms the robustness of the conclusions under various conditions, using multiple methods, including parallel trend tests, placebo tests, propensity score matching, and entropy balancing. Furthermore, this paper examines the sources of heterogeneity in policy effects, finding that the proportion of management shareholding amplifies the policy's innovation-incentivizing effect by mitigating agency conflicts. Pre-existing stocks of government green subsidies diminish the marginal impact of new policies due to resource lock-in; and media attention magnifies the policy's influence by alleviating information asymmetry and strengthening reputational constraints. Finally, the paper offers specific recommendations for optimizing the mix of green finance policy instruments and improving supporting information disclosure mechanisms.

The research contributions of this paper are primarily reflected in the following three aspects. First, this paper expands the research boundaries regarding the economic consequences of green finance. Existing literature largely evaluates green finance policies from the perspectives of macro-regional carbon emissions or aggregate corporate financing constraints [5]. In contrast, this paper focuses on green technological innovation at the firm level and deepens the understanding of the mechanisms through which Pilot Zones for Green Finance Reform and Innovation exert their influence, adopting a tripartite perspective that encompasses internal corporate governance, government resource allocation, and the external information environment.

Secondly, this paper enriches the research on the relationship between industrial policy and corporate innovation. Previous literature on how industrial policy affects corporate innovation has largely focused on direct fiscal subsidies or tax incentives [6, 7], with relatively little discussion regarding the impact of industrial policy in the form of financial market reforms. This paper finds that the green financial reform and innovation pilot zone policy can significantly affect the green innovation behavior of enterprises, supplementing the channels through which industrial policies affect corporate innovation.

Finally, this article has strong practical guidance significance. On one hand, the findings regarding heterogeneity suggest that regulators, when expanding green finance pilot zones, should consider the policy's suitability for enterprises with varying levels of governance and resource endowments, and leverage external information sources, such as the media, to amplify the policy's positive guiding effect. On the other hand, this paper identifies dimensions for market investors to assess corporate green innovation capabilities and offers a novel perspective on the effective alignment between capital markets and industrial policy.

The remainder of the paper is organized as follows: Section 2 outlines the institutional background; Section 3 details the research design; Section 4 presents the main empirical results; Section 5 conducts heterogeneity analysis; and the final section summarizes the study and offers policy recommendations.

2. Institutional Background

In September 2015, the CPC Central Committee and the State Council issued the Overall Plan for the Reform of the Ecological Civilization System, proposing for the first time the establishment of a green financial system. In August 2016, seven government agencies, including the People's Bank of China, the National Development and Reform Commission, the Ministry of Finance, the Ministry of Environmental Protection, and the regulatory commissions for banking, securities, and insurance, issued the Guiding Opinions on Establishing a Green Financial System, which defined green finance and outlined the policy framework. In June 2017, an executive meeting of the State Council decided to establish Pilot Zones for Green Finance Reform and Innovation in five provinces and autonomous regions: Zhejiang, Jiangxi, Guangdong, Guizhou, and Xinjiang. Seven government departments later jointly issued master plans for five provinces (and regions), designating the Ganjiang New Area in Jiangxi, the Gui'an New Area in Guizhou, Huzhou and Quzhou in Zhejiang, the Huadu District of Guangzhou in Guangdong, and the cities of Hami, Karamay, and Changji Prefecture in Xinjiang as the first batch of pilot zones. These zones aim to explore pathways for regional green transformation through financial mechanism innovation, accumulate replicable experience for the nation's ecological civilization development, and foster the coordinated and sustainable development of regional economies and the ecological environment. In November 2019, Lanzhou New District of Gansu Province was approved to join, further strengthening the team of the pilot area, helping to verify the effectiveness of green finance policies on a wider scale, and injecting new financial vitality into the green revitalization and ecological protection of the western region. In August 2022, Chongqing City was approved for establishment, which has important demonstration significance in promoting the green and high-quality development of the Yangtze River Economic Belt and realizing the modernization of harmonious coexistence between man and nature. As of the end of 2024, the pilot zone covered ten locations across seven provinces (and regions). In April 2024, seven ministries and commissions issued the Opinions on Further Strengthening the Construction of Green Financial Reform and Innovation Pilot Zones and proposed 21 specific measures, marking the policy's shift from pilot exploration to in-depth promotion, which will help promote the comprehensive, coordinated and sustainable development of the economy and society.

Innovative products and services are one of the core tasks of the overall plan of each pilot zone. The Implementation Rules for Building a Green Finance Reform and Innovation Pilot Zone in Ganjiang New Area outline 46 tasks across 14 areas. The rules place special emphasis on fostering green industrial development

by supporting energy-saving and consumption-reducing technical upgrades for enterprises in sectors such as iron and steel, non-ferrous metals, papermaking, and printing and dyeing, while accelerating the cultivation of green products and demonstration projects for green factories. Key priorities include supporting the listing and public trading of green enterprises and establishing green industry development funds, thereby using financial instruments to incentivize companies to implement source-based pollution control and process innovation. Huzhou City released the Catalogue of Financial Support Economic Activities for Textile Industry Transformation in 2022, covering 106 low-carbon transformation technology paths in 37 sub-sectors in 9 categories. It includes "energy-saving technical transformation equipment update", "energy efficiency improvement" and "clean energy substitution" into the scope of support, and guide enterprises to invest credit resources in the research and development and transformation of green production processes. The Implementation Rules for Building Pilot Zones for Green Finance Reform and Innovation in Guangzhou, Guangdong Province explicitly propose "expanding the scope of eligible collateral and pledges for green enterprises and projects." By exploring the use of environmental rights, such as carbon emission allowances, pollutant discharge rights, and energy consumption rights, along with their associated revenue rights, as qualified collateral, the rules open up new financing channels for green technology enterprises, effectively resolving the challenge of securing financing for asset-light green innovation companies. Quzhou City has established a "1+6+N" policy framework centered on carbon account finance and introduced digital tools, such as the "Carbon Emissions e-Ledger" and "Carbon Credit e-Report", to provide targeted financing support for green technology R&D. Gui'an New Area has allocated special incentive funds to provide rewards and subsidies to financial institutions that develop green credit, green bonds, and green insurance. In 2019, the People's Bank of China issued a document supporting enterprises within the pilot zones in issuing green debt financing instruments, establishing "green channels," and encouraging product innovation. By employing market-based mechanisms to alleviate financing constraints on corporate green innovation and reduce the R&D risks associated with green products and services, the policy demonstrates China's strong determination to reform and unleash the vitality of enterprises as key drivers of green innovation.

Existing literature has evaluated the economic consequences of policies regarding Pilot Zones for Green Finance Reform and Innovation. At the macro level, existing research indicates that policies in pilot zones effectively facilitate the eco-friendly transformation of industrial structures and drive the real economy to shift away from "fictitious" activities and toward the real sector [1, 4]. At the micro level, existing literature confirms that the establishment of pilot zones can improve corporate ESG performance [3]. Research on the drivers of green innovation has long examined the subject from the perspectives of industrial policy and macroeconomic regulation. Dong Zhaoyingzi et al. found that energy-saving and emission-reduction policies can promote both the quantity and quality of green innovation [8]. Liu Jinke et al. found that environmental protection taxes can significantly enhance corporate green innovation capabilities [9]. Yu Zhimai found that government environmental subsidies exert a significant negative moderating effect on corporate green innovation [10]. Furthermore, from the perspective of the transmission of environmental practices among firms, Yu xinguo found that the greater the pressure of environmental competition from peers, the more inclined firms are to engage in green innovation [11]. Thus, existing research focuses, on the one hand, on the impact of policies regarding green finance reform and innovation pilot zones on aspects such as corporate environmental investment, ESG performance, and the alleviation of financing constraints; on the other hand, it largely explores the drivers of corporate green innovation from perspectives such as environmental regulation, government subsidies, and corporate strategy. Few studies have analyzed the two in an integrated manner, creating an opportunity for this paper to explore the effects and boundary conditions of policies establishing green finance reform and innovation pilot zones on corporate green innovation.

Policies for Pilot Zones for Green Finance Reform and Innovation internalize environmental externalities through market-based mechanisms, guiding the allocation of financial resources toward green innovation. Existing research perspectives on green finance policies and corporate green innovation can be broadly categorized into two types. Some scholars believe that green finance policies promote green innovation. Wang Xin and Wang Ying point out that green credit policies significantly promote green innovation in industries subject to green credit restrictions by reducing agency costs and enhancing investment efficiency [5]. Lu Jing and others found that green credit policies function by fostering technological innovation among polluting enterprises, driving the reallocation of credit resources from polluting industries to clean industries, and thereby achieving optimal resource allocation at the industry level [12]. Policies regarding Pilot Zones for Green Finance Reform and Innovation are regional in nature. They further integrate diverse financial

instruments, such as green bonds, green insurance, and pledges or collateral based on environmental rights and interests, and grant localities greater scope for institutional innovation, thereby providing an opportunity to re-examine the innovation effects of green finance.

However, some scholars have also expressed cautious views regarding macro-industrial policies such as green finance. Research by Li Shihui and others indicates that credit constraints leave enterprises in a predicament where they lack the means to act despite the willingness to do so, resulting in a crowding-out effect on their green innovation [13]. Li Wenjing and Zheng Manni point out that macroeconomic industrial policies may incline enterprises to engage in strategic innovations, such as utility model patents, which are less demanding, to cater to regulatory requirements, rather than pursuing substantive green invention patent innovations [6]. Guo Junjie et al. found that when green credit policies lack sufficient tolerance for short-term innovation failure, they inhibit innovation through crowding-out effects and resource constraints [14]. Wang Shiqi and Wang Yongqiao found that green innovation induced by green credit policies acts as a leverage effect superimposed on existing innovation activities. While it does not crowd out other forms of technological innovation, it is essentially a continuation of existing innovation paths rather than a breakthrough [15].

This paper argues that the positive impact of pilot zone policies on corporate green innovation is dominant. Policies in the pilot zone require financial institutions to innovate green credit products and broaden the scope of collateral and pledges, incorporating assets such as carbon emission rights, pollutant discharge rights, and energy-use rights, thereby lowering financing thresholds and costs for green innovation projects. Policies in the pilot zone leverage market-based mechanisms, such as green credit incentives and environmental regulatory constraints, to compel enterprises to improve their internal governance. Adjusting internal governance processes in this way is more conducive to sustained research and development of green technologies. By incorporating corporate environmental information disclosure into credit rating systems, the policy subjects enterprises to reputational consequences and the risk of penalties for non-compliance. This compels them to optimize their internal governance structures, thereby enhancing their level of green innovation. Furthermore, under the traditional policy framework, certain enterprises, due to factors such as scale, ownership structure, or ties between government and business, find it easier to secure government subsidies, thereby creating implicit barriers. Policies in the pilot zones have reduced corporate reliance on direct government subsidies through market-based financing mechanisms, providing more equal green financing opportunities for small and medium-sized enterprises (SMEs) and non-state-owned enterprises. Media coverage extends the reach of policy transmission and alleviates information asymmetry between enterprises and financial institutions, ensuring that policy signals more effectively reach corporate decision-makers. Based on this, this paper proposes the following hypotheses:

H1: The implementation of policies for green finance reform and innovation pilot zones can significantly promote corporate green innovation.

3. Research Design

3.1 SAMPLE Selection and Data Sources

This study uses Shanghai and Shenzhen A-share listed companies from 2011 to 2024 as the initial research sample. Pilot Zones for Green Finance Reform and Innovation were established in three batches, in 2017, 2019, and 2022, ensuring the sample period fully covers the stages before and after policy implementation. To ensure the representativeness of the sample, the following screening procedures were applied: (1) excluding firms in the finance and insurance sectors; (2) excluding firms with abnormal trading statuses (such as ST and *ST) and samples with severe missing data for key variables; and (3) winsorizing all continuous variables at the 1st and 99th percentiles. Financial and green patent data for listed companies were obtained from the CSMAR database, while the list of enterprises in the pilot zones and the timing of relevant policies were manually compiled based on official documents released by the People’s Bank of China and other government agencies.

3.2 Model Design and Variable Selection

To examine the impact of the construction of Pilot Zones for Green Finance Reform and Innovation on the green transformation of enterprises, this paper constructs the following multi-period difference-in-differences model (1):

$$Patent_{i,t}=\alpha+\beta\cdot Did_{i,t}+\gamma\cdot Controls_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (1)$$

The main variables included in Model (1) are as follows:

3.2.1 Dependent Variable: Corporate Green Transformation (Patent)

Drawing on the work of Wang Yao et al. and Li Wenjing et al., this paper uses the number of corporate green patent applications to measure the degree of green transformation [4, 6]. Compared to the number of granted patents, the volume of patent applications reflects enterprises' willingness to innovate more promptly and is less affected by the examination cycle. Given that the distribution of this variable is right-skewed, the natural logarithm was taken after adding 1 to the raw application count.

3.2.2 Core Explanatory Variable: Multi-period DID (DID)

This paper treats the establishment of green finance reform and innovation pilot zones as a quasi-natural experiment and employs a multi-period difference-in-differences (DID) method. The variable is assigned values based on the specific year (2017, 2019, or 2022) in which the pilot zone where the enterprise is located was approved: it takes a value of 1 if the enterprise is registered in a pilot zone and the time period is the year of policy implementation or later, and 0 otherwise.

3.2.3 Control Variables

In order to alleviate the omitted variable bias, this article selects two types of control variables: the first type is enterprise characteristic variables, including asset-liability ratio (*Lev*), return on net assets (*Roe*), operating cash flow (*Cfo*), growth (*Growth*), enterprise size (*Size*) and enterprise age (*Age*); the second category is corporate governance variables, including ownership concentration (*Top1*), board size (*Board*), proportion of independent directors (*Indep*) and nature of property rights (*SOE*).

Table 1: Description of Key Variables

Variable Type	Variable Name	Symbol	Definition and Measurement
Dependent Variable	Green Patent Applications	*Patent*	Ln(1 + number of green patent applications)
Core Explanatory Variable	Multi-period DID	*Did*	1 if the firm's registered location is in a pilot zone and the year is the policy implementation year or later; 0 otherwise
Control Variables	Firm Size	*Size*	Ln(total assets)
	Leverage	*Lev*	Total liabilities / total assets
	Return on Equity	*Roe*	Net profit / net assets
	Operating Cash Flow	*Cfo*	Net cash flow from operating activities / total assets
	Growth	*Growth*	Operating revenue growth rate
	Firm Age	*Age*	Ln(current year − listing year + 1)
	Board Size	*Board*	Ln(number of board members)
	Independent Director Ratio	*Indep*	Number of independent directors / total number of board members × 100
	Ownership Nature	*SOE*	1 if state-owned enterprise; 0 if non-state-owned enterprise
	Largest Shareholder Ownership	*Top1*	Shares held by the largest shareholder / total shares × 100

4. Empirical Results and Analysis

4.1 Descriptive Statistics

Table 2 reports the descriptive statistics for the main variables. The mean value of green patent applications is 0.920, with a standard deviation of 1.204, indicating that the overall level of green innovation among the sample firms is relatively low and that there are significant disparities between them. The mean value of the multi-period DID variable is 0.040, indicating that approximately 4% of the observations in the full sample fall into the treatment group category following policy implementation. This aligns with the policy context of the green finance reform and innovation pilot zones being rolled out in three batches across 2017, 2019, and 2022. Regarding the control variables, the mean values are 22.273 for firm size (*Size*), 0.427 for the asset-liability ratio (*Lev*), 0.044 for return on equity (*Roe*), and 0.339 for ownership nature (*SOE*). The distributions

of these variables fall within reasonable ranges, with no extreme outliers, indicating that the sample data quality is high and suitable for subsequent regression analysis.

Table 2: Descriptive Statistics

	N	*Mean*	*SD*	*Min*	*p25*	*Median*	*p75*	*Max*
Patent	43182	0.920	1.204	0.000	0.000	0.000	1.609	4.787
Did	43182	0.040	0.196	0.000	0.000	0.000	0.000	1.000
Size	43182	22.273	1.303	19.141	21.355	22.082	23.010	26.206
Lev	43182	0.427	0.211	0.051	0.259	0.416	0.579	0.967
Roe	43182	0.044	0.163	-0.927	0.022	0.063	0.109	0.439
Cfo	43182	0.047	0.069	-0.176	0.009	0.046	0.086	0.255
Growth	43182	0.143	0.409	-0.614	-0.048	0.084	0.238	2.625
Age	43182	11.434	7.975	0.608	4.386	9.707	17.602	29.569
Board	43182	2.111	0.198	1.609	1.946	2.197	2.197	2.639
Indep	43182	37.738	5.403	14.290	33.333	36.363	42.860	57.140
SOE	43182	0.339	0.473	0.000	0.000	0.000	1.000	1.000
Top1	43182	35.123	15.169	7.020	23.490	33.333	45.360	75.460

4.2 Univariate Analysis

Table 3 reports the results of mean difference tests grouped by policy implementation (*Did*=0 and *Did*=1). Regarding the core variable, the mean number of green patent applications (*Patent*) for enterprises in the treatment group was 1.081 following policy implementation, significantly higher than the pre-implementation figure of 0.913, with the difference being significant at the 1% level. This indicates that the implementation of green finance policies led to a significant increase in green innovation output among the treated enterprises. Regarding the control variables, firm size (*Size*), operating cash flow (*Cfo*), growth (*Growth*), board size (*Board*), and the shareholding ratio of the largest shareholder (*Top1*) all showed significant differences before and after the policy implementation, while the differences in the asset-liability ratio (*Lev*) and the nature of property rights (*SOE*) were significant at the 5% and 1% levels, respectively. The above results indicate significant differences across multiple dimensions between the treatment and control groups before and after policy implementation. Therefore, it is necessary to control for these variables in the multiple regression analysis.

Table 3: Univariate Tests

Variable	Before Policy		After Policy		Mean Difference
	Observations	Mean	Observations	Mean	
Patent	41456	0.913	1726	1.081	-0.168***
Size	41456	22.27	1726	22.38	-0.112***
Lev	41456	0.427	1726	0.416	0.012**
Roe	41456	0.0440	1726	0.0480	-0.00400
Cfo	41456	0.0460	1726	0.0570	-0.011***
Growth	41456	0.144	1726	0.106	0.038***
Age	41456	11.43	1726	11.51	-0.0820
Board	41456	2.112	1726	2.089	0.023***
SOE	41456	0.338	1726	0.362	-0.024**
Top1	41456	35.07	1726	36.48	-1.411***

*Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.*

4.3 Regression Analysis

Table 4 reports the baseline regression results. Column (1) controls only for firm and year fixed effects without including additional control variables. The *Did* coefficient is 0.1497 and significant at the 5% level, preliminarily indicating that the policy has a positive impact on corporate green innovation. Column (2) incorporates control variables, such as firm characteristics and corporate governance, into the model used in Column (1). The *Did* coefficient is 0.1366 and remains significant at the 5% level. Although the coefficient decreases slightly, its sign and significance remain consistent, indicating that while the control variables explain a portion of the positive effect, the core conclusion remains unchanged. Column (3) further controls

for year-industry joint fixed effects to absorb industry-level time-varying shocks. The *Did* coefficient is 0.1143, remaining significant at the 5% level. In terms of control variables, the coefficients of enterprise size (*Size*) and the proportion of independent directors (*Indep*) are both significantly positive, indicating that larger enterprises with better corporate governance structures are more inclined to green innovation, consistent with theoretical expectations.

Table 4: Baseline Regression Results

	Patent		
	(1)	(2)	(3)
Did	0.1497**	0.1366**	0.1143**
	(0.0649)	(0.0615)	(0.0571)
Size		0.3555***	0.3630***
		(0.0184)	(0.0176)
Lev		-0.0466	-0.0305
		(0.0522)	(0.0503)
Roe		0.0280	0.0085
		(0.0286)	(0.0279)
Cfo		0.0111	0.0482
		(0.0665)	(0.0641)
Growth		-0.0009	-0.0088
		(0.0091)	(0.0090)
Age		0.0118	0.0534*
		(0.0269)	(0.0275)
Board		0.0866	0.1094*
		(0.0618)	(0.0574)
Indep		0.0040**	0.0044***
		(0.0018)	(0.0017)
SOE		0.0082	0.0090
		(0.0351)	(0.0339)
Top1		0.0012	0.0013
		(0.0009)	(0.0009)
Cons	0.9138***	-7.4979***	-8.2141***
	(0.0026)	(0.5359)	(0.5191)
Firm FE	YES	YES	YES
Year FE	YES	YES	
Year*Industry			YES
N	43182	43182	43163
adj. R^2	0.704	0.721	0.732

*Note: ***, **, and * indicate that the coefficients are significant at the 1%, 5%, and 10% levels, respectively; t-values are in parentheses.*

4.4 Robustness Tests

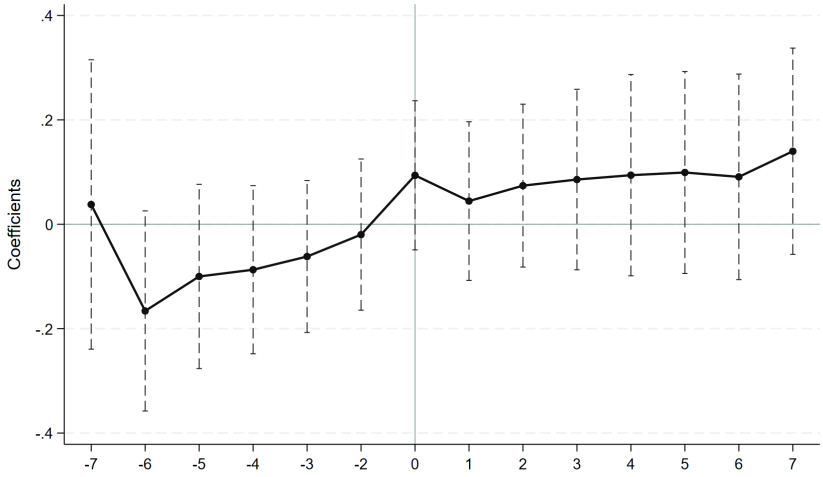
4.4.1 Parallel Trends Test

Drawing on the methods of Kong Lingcheng et al. [16], this paper constructs the following dynamic DID model (2):

$$Patent_{i,t}=\alpha+\sum_{k=-7}^{-2}\beta_k D_{i,t}^{k}+\beta_0 D_{i,t}^{0}+\sum_{k=1}^{7}\beta_k D_{i,t}^{k}+\gamma\cdot Controls_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (2)$$

Figure 2 reports the estimated coefficients and 95% confidence intervals for each period. Looking at the periods prior to policy implementation (k = -7 to k = -2), none of the estimated coefficients passed the significance test at the 10% level, and all confidence intervals spanned the zero line. This indicates that prior to the implementation of the green finance pilot zone policy, there was no significant difference in the trends of green patent application volumes between the treatment group and the control group, and the parallel trend test was satisfied.

Figure 2: Parallel Trends Test



Starting from the period of policy implementation (k=0), the estimated coefficient turned positive and maintained a positive trend throughout the subsequent periods (k=1 to k=7). The policy effect began to intensify gradually from the second period following implementation, and the confidence interval narrowed significantly. This indicates that the policy's role in promoting the green transformation of enterprises is sustained and stable, further validating the findings of the baseline regression analysis.

4.4.2 Placebo Test

In the real-world economic environment, random factors unrelated to policy may interfere with corporate green innovation, leading to biased estimates of policy effects. To rule out this possibility, this paper conducts a placebo test.

Figure 3: Placebo Test

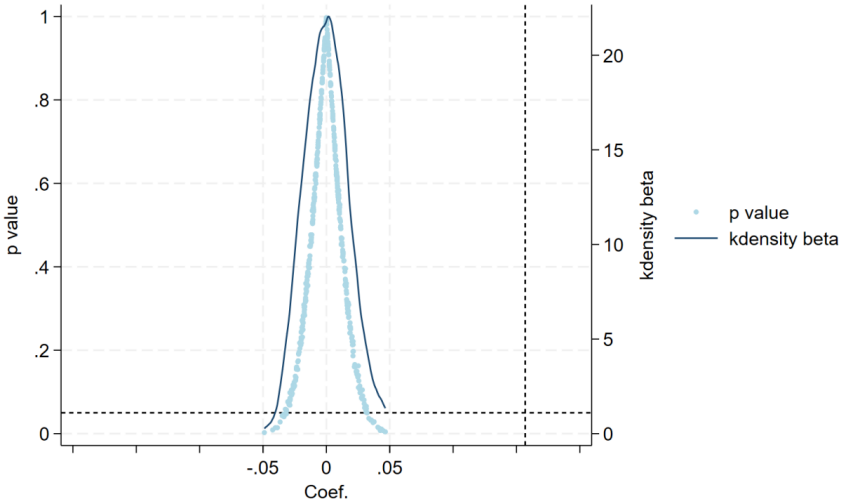


Figure 3 reports the results of the placebo test. An analysis of the coefficient distribution reveals that, following 500 iterations of random matching, the mean of the pseudo-*Did* coefficients approaches 0.000, with a maximum value of only 0.0465; in contrast, the true *Did* coefficient from the baseline regression is 0.1366, a figure far exceeding any of the random estimation results. This means that the true policy effect differs significantly from effects that might arise from random factors. In 500 random estimations, the pseudo-coefficient was significant at the 5% level in only 27 instances, a figure close to the level expected by chance (25 instances). Based on the above results, the impact of unobserved random factors on corporate green innovation is negligible. The promoting effect of green finance policies is not driven by chance, and the placebo test is passed.

4.4.3 Propensity Score Matching

To mitigate the endogeneity issue arising from sample selection bias, this paper employs the Propensity Score Matching combined with Difference-in-Differences (PSM-DID) method to conduct a robustness test. The variable *Treat* is defined based on whether a firm is affected by the policy: it takes a value of 1 if the firm is registered in the pilot zone, and 0 otherwise. Matching variables include firm size (*Size*), return on equity (*Roe*), operating cash flow (*Cfo*), board size (*Board*), proportion of independent directors (*Indep*), nature of property rights (*SOE*), and the shareholding ratio of the largest shareholder (*Top1*). A Logit model is used to estimate propensity scores, and 1:1 nearest-neighbor matching without replacement is employed, with a caliper set at 0.05.

Before matching, the kernel density curves of the treatment and control groups exhibited certain differences; after matching, the curves largely overlapped, satisfying the common support assumption. Post-matching, the maximum absolute standardized bias for any variable was 3.1%, well below the 20% threshold; t-test p-values exceeded 0.1, indicating no significant differences between the two groups regarding the matching variables and demonstrating effective matching.

4.4.4 Entropy Balancing Matching Test

As a supplementary test, this paper employs the entropy balancing matching method. Entropy balancing weighting is performed using the same matching variables as those used for PSM. Table 5 reports the regression results obtained using PSM-DID and entropy balancing matching. The *Did* coefficient is 0.1312 in Column (1) (PSM-DID) and 0.1257 in Column (2) (entropy balancing matching); both are significant at the 5% level. The results indicate that the core conclusions remain robust after employing various matching methods to mitigate sample selection bias.

Table 5: Robustness Test (PSM-DID and Entropy Balancing Matching)

	PSM Matching	Entropy Balancing Matching
	(1)	(2)
Did	0.1312**	0.1257**
	(2.02)	(2.20)
Controls	YES	YES
Firm FE	YES	YES
Year FE	YES	YES
N	4174	43182
adj. R^2	0.71	0.71

*Note: ***, **, and * indicate that the coefficients are significant at the 1%, 5%, and 10% levels, respectively; t-values are in parentheses.*

4.4.5 4.4.5 Other Robustness Tests

Table 6: Other Robustness Tests

	Differentiating Policy Timing (First)	Differentiating Policy Timing (Second)	Differentiating Policy Timing (Third)	Replacing the Dependent Variable
	(1)	(2)	(3)	(4)
Did	0.1542**	0.1345	0.0783	0.0516**
	(2.01)	(0.72)	(0.66)	(2.09)
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	42383	40571	40932	43182
adj. R2	0.72	0.72	0.72	0.49

*Note: ***, **, and * indicate that the coefficients are significant at the 1%, 5%, and 10% levels, respectively; t-values are in parentheses.*

(1) Distinguishing Policy Timing

Given that the pilot zones were established and rolled out in batches, pooling all batches for regression analysis might mask the heterogeneity of the policy effects. To this end, this paper excludes samples from the other batches and re-estimates the DID model by retaining only the pilot enterprises from a single batch and the enterprises that were never affected by the policy. Columns (1) through (3) of Table 6 show that the *Did*

coefficient for the first batch is 0.1542 (significant at the 5% level), while the coefficients for the subsequent two batches are 0.1345 and 0.0783, respectively; neither of the latter two reaches the level of statistical significance. This indicates that the first batch of policies yielded the most significant results, while the effects of the subsequent two batches were relatively weaker, a pattern that may be attributable to policy transmission lags or diminishing marginal effects.

(2) Replacing the Explained Variable

To avoid potential bias in the estimation results arising from the measurement method of the dependent variable, this paper converts the continuous patent count into a dummy variable (*patentdummy*), indicating whether a firm held a patent in a given year, to examine the marginal impact of the policy. Column (4) of Table 6 shows a *Did* coefficient of 0.0516, significant at the 5% level, indicating that the policy significantly increased the probability of firms engaging in innovation activities. This is consistent with the baseline regression results.

5. Heterogeneity Analysis

5.1 Governance Effect: Management Shareholding Ratio

Different levels of internal corporate governance will have different responses to policy effects. Existing research has shown that management ownership concentration will inhibit the green innovation of enterprises. Management shareholding can alleviate agency conflicts between large shareholders and small and medium shareholders, thereby promoting enterprises to carry out more green technology innovations [17]. Referring to its approach, this article puts the management shareholding ratio (*Mngmhldn*) and its cross-product term *Did* × *Mngmhldn* with Did into model (1) for regression. The results are shown in column (1) of Table 7.

It can be seen from column (1) of Table 7 that the coefficient of the cross-multiplication term of *Did* × *Mngmhldn* is significantly negative at the 10% level (estimated coefficient = -0.005, t value = -1.86). The green finance reform and innovation experimental zone policy will have a weaker promotion effect on green innovation in companies with a high management shareholding ratio. This may be because the green finance reform and innovation pilot zone policy forces companies to standardize environmental behavior, increase investment in green innovation, and improve corporate governance through market-oriented mechanisms such as green credit guidance and environmental protection regulatory constraints. For companies with low management shareholding ratios and weak internal governance, the effect of policies on improving governance levels is more prominent, which is in line with the expectations of this article.

5.2 Equity Effect: Government Green Subsidies

Under the traditional policy framework, certain enterprises, due to factors such as scale, ownership structure, or ties between government and business, find it easier to secure government subsidies, creating implicit barriers for small and medium-sized enterprises. Yu Zhimai found that government environmental subsidies exert a significant negative moderating effect on policy effectiveness; specifically, the lower the subsidy level, the stronger the policy's role in promoting corporate green innovation [10]. Drawing on the research approach of those studies, this paper introduces a variable, government green subsidy (*Green_Subsidy*), defined as the amount of government subsidies related to environmental protection received by the firm during the year. Government green subsidies (*Green_Subsidy*) and their interaction term with DID (*DID* × *Green_Subsidy*) were included in Model (1) for regression analysis. The results are presented in Column (2) of Table 7.

Column (2) of Table 7 reports that the interaction term *Did* × *Green_Subsidy* is significant at the 10% level (estimated coefficient = -0.096, t-value = -1.71). The results indicate that for enterprises that had already received substantial green subsidies, the policy's role in promoting their green innovation was actually weaker. It can therefore be inferred that the policy has, to some extent, enhanced market fairness and lowered the implicit barriers for enterprises to access green financial resources. By accommodating marginalized entities, such as small and medium-sized enterprises (SMEs) and non-state-owned enterprises, it has provided them with more equitable opportunities for green financing.

5.3 The Amplification Effect of Media Attention: Media Attention Level

As important information intermediaries in the capital market, the media play a corporate governance role by influencing the reputations of managers [18]. Media attention plays a significant supervisory and governance role across various aspects of the behavior of listed companies in China [19]. Drawing on the approaches of Li Peigong and Shen Yifeng, Xu Liping and Li Yu, and Huang Jun and Guo Zhaorui [20–22], this study measures media attention (*Media*) as the natural logarithm of (1 plus) the number of headlines featuring the firm in newspapers and online media during the year. We incorporate *Media* and the interaction term *Did*×*Media* into Model (1) for regression analysis The results are presented in Column (3) of Table 7.

The results show that the *Did*×*Media* interaction term is significant at the 5% level (estimated coefficient = 0.184, t-value = 1.99). This indicates that media coverage amplifies the impact of policies by mitigating information asymmetry between firms and financial institutions, as well as by strengthening external oversight and reputational constraints. The higher the level of media attention, the more fully policy information is disseminated, the more actively enterprises respond to policies, and the greater the output of green innovation.

Table 7: Heterogeneity Analysis

	(1)	(2)	(3)
	Patent	*Patent*	*Patent*
Did	0.156**	0.157**	0.112*
	(2.20)	(2.53)	(1.65)
Mngmhldn	0.002**		
	(2.36)		
Did×*Mngmhldn*	-0.005*		
	(-1.86)		
Green_Subsidy		0.029**	
		(2.41)	
Did×*Green_Subsidy*		-0.096*	
		(-1.71)	
Media			0.021
			(1.43)
Did×*Media*			0.184**
			(1.99)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	43021	43182	42602
adj.R²	0.7209	0.7212	0.7210

6. Conclusions and Policy Recommendations

Since 2017, the People's Bank of China and six other government departments have established pilot zones for green finance reform and innovation across selected provinces and regions in three batches, using market-based mechanisms to channel financial resources toward green innovation. Using a sample of non-financial A-share listed companies on the Shanghai and Shenzhen stock exchanges from 2011 to 2024, this paper employs a multi-period difference-in-differences model to empirically examine the impact of pilot zone policies on corporate green innovation. Research finds that the policies in the pilot zones have significantly boosted the green innovation levels of enterprises within their jurisdictions, as evidenced by an increase in the number of green patents. Further research reveals that enterprises with low management shareholding ratios are more significantly affected by the policy, indicating that the policy can compensate for governance deficiencies. Enterprises that received substantial green subsidies beforehand were less affected by the policy, demonstrating the policy's equitable effect. Enterprises attracting greater media attention are more strongly affected by policies, confirming that the media may exert an amplifying effect by mitigating information asymmetry and reinforcing reputational constraints.

Based on the above conclusions, this article makes the following suggestions. From a policy perspective, first, the innovation of green financial products and services should be continuously deepened. Pilot zones should further expand the scope of financing secured by environmental rights, such as carbon emission allowances and pollution

discharge rights, lower financing thresholds for green R&D by small and medium-sized enterprises (SMEs), and more fully realize the equitable effects of these policies. Second, improve environmental information disclosure and media supervision mechanisms. Regulatory authorities should accelerate the establishment of a mandatory disclosure system for corporate environmental information, use media reports to reduce information asymmetry between companies and financial institutions, and strengthen reputation constraints and social supervision, thereby amplifying the market transmission effect of policies. Third, establish a mechanism for the dynamic assessment of policy effects and for feedback. Given that the impact was most significant in the first batch of pilot zones, with diminishing returns observed in subsequent batches, regulatory authorities should periodically evaluate the effectiveness of policies and the industrial structures within each zone, as well as the actual needs for green transformation, in order to dynamically adjust the policy mix and intensity.

At the corporate level, the first step is to optimize management incentives and internal governance structures. Enterprises should proactively refine mechanisms for management shareholding and incentive-constraint systems, foster management recognition of the long-term strategic value of green innovation, and leverage the institutional dividends and financing conveniences offered by policies. Secondly, enterprises should proactively tap into market-based financing channels. Corporate management should proactively enhance the quality of environmental information disclosure and capabilities in green technology R&D, leveraging strong green performance to secure greater credit support and actively drive the green transition. Finally, enterprises should formulate differentiated strategic plans for green innovation. They should objectively assess their own conditions, such as governance standards, resource endowments, and the information environment, to select targeted green innovation pathways and effectively translate policy dividends into sustainable green competitive advantages.

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