Green Innovation Effect of Policies in Green Finance Pilot Zones

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Abstract. This paper utilizes data from China A-share listed companies from 2010 to 2024 and employs the difference-in-differences method to analyze the impact of green finance pilot zone policies on corporate green innovation, exploring whether they promote substantive innovation or trigger strategic innovation. The study selects 8,481 company-year observations to form an unbalanced panel, estimating the effects using a two-way fixed effects model that controls for firm size, financial leverage, profitability, and other factors. The results show that the policy significantly increased corporate green invention patent applications but had little effect on green utility model patents, indicating that the policy primarily promotes substantive innovation with high technological content rather than merely catering to policy requirements through strategic innovation. Further heterogeneity analysis reveals that state-owned enterprises became more proactive in substantive innovation after policy implementation, which is related to their advantages in resource acquisition and policy execution. Robustness tests, which exclude initial policy-period samples, high-pollution industries, and municipal observations while altering core variable definitions, still yield valid conclusions, demonstrating that green finance pilot zone policies genuinely foster genuine technological innovation rather than superficial compliance.

Keywords: Green finance policy, Corporate innovation, Double difference model, Substantive innovation, Strategic innovation

1 Introduction

Against the backdrop of increasingly severe global climate change and prominent environmental issues, green development has become a shared vision of the international community. As the world's second-largest economy, China faces the arduous task of environmental protection while promoting the transformation of its economic development model, urgently requiring policy guidance to facilitate corporate green transition. Green finance, as a crucial tool for advancing green development, has seen continuous institutional improvements since China became the first country to introduce a green finance policy system in 2016. In 2017, the State Council approved the

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establishment of the first batch of green finance innovation and reform pilot zones, marking the entry of green finance into the local pilot phase. Policies in these pilot zones provide financial and policy support for corporate green innovation through measures such as establishing green finance standards, enriching green financial products and services, and improving incentive and constraint mechanisms. However, the actual effectiveness of these policies—whether they genuinely promote substantive green innovation or merely induce strategic behaviors to meet policy requirements—remains a critical question that needs urgent verification. Theoretically, policy incentives may either stimulate substantive green technological innovation by reducing financing costs and offering tax incentives, or tempt enterprises to adopt "greenwashing" strategies to reap policy dividends. Therefore, systematically evaluating the practical effects of green finance pilot zone policies holds significant theoretical and practical implications for optimizing policy design and enhancing policy precision.

To this end, this paper takes China A-share listed companies from 2010 to 2024 as the research object, constructs a non-equilibrium panel data set containing 8,481 company-year observations, and employs the difference-in-differences (DID) method to empirically test the impact of green finance pilot zone policies on corporate green innovation. In terms of innovation measurement, the study approaches from both aggregate and structural dimensions, using the total number of green patent applications, green invention patent applications, and green utility model patent applications as core dependent variables respectively to distinguish between substantive innovation and strategic innovation. After controlling for characteristic variables such as firm size, financial leverage, and profitability, as well as individual firm fixed effects and year fixed effects, the study evaluates the average treatment effect of policies. Furthermore, heterogeneity analysis is conducted to examine policy differences between state-owned and private enterprises. Robustness tests are also performed by excluding specific years, high-pollution industries, and municipalities to ensure the reliability of research conclusions.

Compared with existing research, the marginal contributions of this paper are mainly reflected in the following three aspects. First, in terms of research perspective, this paper focuses on the heterogeneity of corporate innovation quality, clearly distinguishing between substantive innovation and strategic innovation at the patent type level, addressing the shortcomings of existing literature that often emphasizes innovation quantity while neglecting innovation quality. Second, in terms of research methodology, this paper utilizes green finance pilot zone policies as quasi-natural experiments and employs a two-way fixed effects difference-in-differences model for causal identification, effectively mitigating endogeneity issues that may arise with traditional panel data methods and enhancing the reliability of estimation results. Third, in terms of research context, this paper systematically examines the micro-level transmission mechanisms of green finance policies in emerging market countries based on the institutional background of China, particularly revealing the moderating role of property rights characteristics in policy effects. This provides empirical evidence for understanding how green finance policies can precisely incentivize high-quality corporate

innovation and offers valuable insights for policy optimization and corporate green transition practices.

2 Theoretical Analysis and Research Hypotheses

2.1 Theoretical Analysis

The impact mechanism of green financial policies on corporate innovation behavior can be understood from multiple perspectives. From the perspective of resource dependence theory, enterprises require substantial financial support and resource investment for innovation activities. Green financial policies provide diversified financing channels such as preferential loans, green bonds, and environmental protection funds, effectively alleviating financing challenges faced by companies during green technology R&D. When enterprises gain easier access to low-cost funding, their motivation for long-term green technological innovation significantly increases. The application of policy-based financial instruments has also substantially reduced financing costs for green projects, making previously unfeasible green innovation initiatives possible due to extended investment return periods, thereby encouraging enterprises to intensify green technology development efforts. Extensive empirical studies have validated this mechanism. Zhang et al. [1] conducted a quasi-natural experiment based on green credit policies, demonstrating that green financial policies significantly enhance green innovation levels among heavily polluting enterprises, particularly through alleviating financing constraints. Hu et al. [3] similarly employed the difference-in-differences method to confirm that green credit policies effectively incentivize green innovation activities by reducing corporate financing costs. Furthermore, Li et al. [4] research further indicates that green financial policies not only directly promote corporate green innovation but also indirectly improve innovation performance through optimized resource allocation.

From the perspectives of signaling theory and institutional theory, green finance policies not only convey positive signals of government support for green development to markets but also influence corporate innovation behaviors through institutional design. Policy implementation releases clear market signals, enabling enterprises to anticipate future trends and profit potential in green technologies, thereby adjusting their innovation strategies. Under institutional pressures and incentives, companies must balance short-term strategic responses with long-term substantive innovation. Qin et al. [10] directly addressed this core issue in their research, noting that green finance policies may either guide enterprises toward long-term value-driven innovations or incentivize low-quality strategic innovations to capture policy dividends. Yang et al. [6] further revealed significant policy effect variations across enterprises, with state-owned enterprises demonstrating more proactive innovation responses due to their greater social responsibilities. Kang and Geng [7] demonstrated at the urban level that green financial reforms promote high-quality economic development through optimized resource allocation and environmental governance, a transmission mechanism equally applicable to corporate innovation activities.

In studies examining innovation types and quality, scholars have begun focusing on whether green finance policies genuinely drive substantive corporate innovation. Guo et al. [11], adopting a policy tool combination perspective, investigated the heterogeneous impacts of different green financial instruments on corporate green innovation novelty, revealing that rational policy tool combinations enhance innovation quality. Liu et al. [9], grounded in regional financial reform contexts, demonstrated that financial reform pilot policies significantly boost corporate green innovation, with this effect being more pronounced in industries with higher marketization levels and pollution intensity. Li et al. [8] expanded their research framework to incorporate the novel concept of "new quality productivity," validating the positive role of green finance pilot zone policies in improving innovation quality. These studies collectively indicate that green finance policies influence corporate innovation through multidimensional mechanisms, exhibiting distinct quality-oriented characteristics.

This institutional guidance effect exhibits significant variations across enterprises with different ownership structures. State-owned enterprises, burdened with greater social responsibilities and policy implementation mandates, typically demonstrate higher enthusiasm and sustained commitment to green finance policies, whereas private enterprises may respond differently due to financing constraints and short-term performance pressures. Yang et al. [2] revealed the macro-level promoting effect of green credit policies on green innovation, while Wang et al. [5] analyzed the trade-off between "scale" and "efficiency" in corporate environmental investment behaviors at the micro level. These studies provide crucial foundations for understanding heterogeneous responses across enterprises with distinct characteristics.

Research on the impact of green finance policies on corporate innovation has made significant progress both domestically and internationally, achieving notable breakthroughs in theoretical exploration and empirical testing. However, existing studies still exhibit certain limitations and room for expansion. First, in terms of research content, most studies focus on the overall promoting effect of green finance policies on corporate innovation, with relatively insufficient attention to the heterogeneity of innovation quality, particularly the unclear distinction between substantive innovation and strategic innovation. Although Qin et al. [10] and Guo et al. [11] have begun addressing this issue, systematic research remains to be strengthened. Second, regarding research methods, some studies employ traditional panel data approaches that may encounter endogeneity issues in causality identification. While difference-in-differences methods [1][3][9] enhance causal identification reliability, specialized studies targeting policies in green finance pilot zones remain relatively limited. Third, from a contextual perspective, existing research predominantly focuses on macro or industry levels, leaving room for further exploration in micro-level corporate innovation analysis, especially regarding the differentiation of corporate innovation motivations. Building on these findings, this study will further investigate the differential impacts of green finance policies on substantive and strategic innovation, aiming to provide more targeted empirical evidence for policy optimization.

It should be noted that the aforementioned analysis focuses on theoretical mechanism exploration to provide a logical foundation for empirical research. The empirical analysis in this paper primarily examines the overall relationship between green fi-

nance policies and corporate green innovation, as well as their heterogeneous manifestations across different patent types and corporate characteristics. The study does not conduct direct causal identification regarding the specific transmission pathways of these theoretical mechanisms.

2.2 Research Hypothesis Formulation

Based on the theoretical mechanisms and literature review outlined above, this study proposes corresponding research hypotheses. From the perspective of innovation-driven theory, green financial policies can effectively alleviate funding pressures faced by enterprises during green technology innovation through measures such as reducing financing costs for green projects, providing dedicated funding support, and establishing green financial product systems. According to Porter's hypothesis, appropriate environmental regulations and policy incentives help stimulate corporate innovation motivation, encouraging the development of advanced green technologies that achieve a win-win balance between economic and environmental benefits. As a market-oriented environmental policy tool, green financial pilot zone policies utilize financial market mechanisms for resource allocation, demonstrating greater incentive compatibility compared to traditional command-and-control policies, thereby facilitating substantive technological innovation. Studies by Zhang et al. [1], Hu et al. [3], and Li et al. [4] have all confirmed that green financial policies significantly promote green innovation among heavily polluting enterprises. Moreover, green invention patents exhibit higher technical sophistication and innovation capacity compared to green utility model patents, better reflecting enterprises' substantive innovation capabilities. Qin et al. [10] explicitly noted differences in the impact of green financial policies on substantive versus strategic innovation, while Guo et al. [11] further revealed heterogeneity in how different policy instruments affect innovation novelty. Integrating these theoretical foundations with empirical evidence, this study proposes the hypothesis that green financial pilot zone policies significantly enhance substantive green innovation, primarily manifested through increased applications for green invention patents rather than strategic green utility model patents.

3 Research Design

3.1 Sample Selection and Data Processing

3.1.1 Sample Screening Process.

This study initially selected China A-share listed companies from 2010 to 2024 as the sample, and further conducted sample selection based on scientific and rational principles. On the basis of the initial sample, financial listed companies were first excluded due to their distinct characteristics compared to traditional manufacturing enterprises, as their financial indicators and operational methods may influence the research findings. Next, companies labeled as ST, ST, or PT were removed, as they typically face special financial conditions or abnormal operations that significantly impact green innovation investment behaviors. Finally, observations with substantial

missing data in key variables were eliminated to ensure the completeness and accuracy of critical metrics such as green patent applications and corporate financial status. After rigorous screening, a total of 8,481 company-year observations were obtained, constituting the unbalanced panel data used in this study.

3.1.2 Data Preprocessing.

After completing sample screening, this study conducted appropriate data preprocessing to ensure reliable research conclusions. For continuous variables, tail-trimming was performed at the 1% and 99% quantiles to mitigate the impact of outliers on regression results. Count-type variables such as green patent applications underwent logarithmic transformation using ln(1+X), which not only improved data skewness distribution but also prevented zero-value-induced data loss. Continuous variables including firm size and total assets were similarly transformed to reduce effects from dimensionality differences and heteroscedasticity. Standardization tests were applied to all variables to ensure comparability and model estimation validity, laying a solid foundation for subsequent empirical research.

3.2 Research Methodology Design

3.2.1 Construction of Double Difference Model.

To examine the impact of policies in green finance pilot zones on corporate green innovation, this study constructs the following two-way fixed-effects difference-in-differences model:

$$\mathbf{Green\_Pat_{it}} = \alpha + \beta \cdot DID_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

The model $\mathbf{Green\_Pat_{it}} DID_{it} X_{it} \mu_i \lambda_t \varepsilon_{it}$ represents the green innovation level of firm i in year t, where the interaction term between treatment group dummy variable and post-policy implementation time dummy variable captures policy effects. Control variables include firm fixed effects and year fixed effects, while random error terms are included. The treatment group consists of listed companies registered in green finance pilot zones, with the control group comprising non-pilot zone listed companies from their respective provinces. Policy implementation timelines were determined by State Council approvals: the first pilot zones began in June 2017, Gansu Lanzhou New Area in December 2019, and Chongqing Metropolitan Area in August 2022. This design effectively mitigates sample selection bias and missing variable bias, enabling identification of net policy effects through comparative analysis of green innovation dynamics between treatment and control groups before and after policy implementation.

3.3 Variable Definition

3.3.1 Dependent Variable.

In distinguishing the various dimensions of green innovation, the paper draws upon the classical analytical framework of "substantive innovation" and "strategic innova-

tion." This framework posits that substantive innovation aims to achieve breakthroughs at the technological frontier, building long-term competitive advantages for enterprises through high-quality technological progress. In contrast, strategic innovation primarily responds to external institutional pressures or seeks policy support, with the goal of increasing the quantity of innovation outputs.

Based on this framework, the study employs green invention patent applications as a proxy variable for corporate "substantive green innovation." Compared to other patent types, green invention patents typically require higher R&D investments and demonstrate greater technical complexity, better reflecting enterprises' exploration and breakthroughs in core technologies. Conversely, green utility model patents serve as a proxy for "strategic green innovation." With lower authorization thresholds and shorter examination cycles, they are more susceptible to policy incentives, leading to strategic application behaviors. This makes them widely used in existing literature to measure corporate strategic innovation tendencies. Numerous English empirical studies have adopted this metric classification method, applying it across diverse institutional contexts and industry samples to validate its effectiveness and replicability. Research by Tan et al. [10], Zhao et al. [12], and Li et al. [13] respectively utilized green invention patents and utility model patents to measure substantive and strategic green innovation. To eliminate zero values and smooth data distribution, all patent variables underwent ln(1+X) logarithmic transformation to ensure robust regression results and interpretability.

3.3.2 Core Explanatory Variables.

This study employs a difference-in-differences (DID) design to identify the impact of green finance policies on corporate innovation behavior, with the core explanatory variable being the interaction term of treatment group dummy variable (Treat) and time dummy variable (Post). The treatment group is defined based on whether the company's registration location is within a nationally approved green finance innovation and reform pilot zone: if the company is registered in any batch of pilot zones, Treat is assigned a value of 1; otherwise, it is 0. The time dummy variable Post is strictly set according to the official implementation timeline of each policy batch—values of 1 are assigned to the first batch of pilot zones (including Huzhou and Quzhou in Zhejiang, Ganjiang New Area in Jiangxi, Guangzhou in Guangdong, Guian New Area in Guizhou, and Hami, Changji, and Karamay in Xinjiang) in June 2017 and subsequent years. For Lanzhou New Area in Gansu added in December 2019 and Chongqing in August 2022, Post is also set to 1 for their corresponding years and thereafter. This design ensures comparability between treatment and control groups before policy shocks and accurately captures temporal differences in policy implementation. The coefficient of the Treat×Post interaction term reflects the average treatment effect of green finance policies on corporate green innovation, constituting the core focus of empirical analysis. Given the insufficient identification hypothesis testing in existing literature on DID designs, this study particularly emphasizes the exogeneity of treatment group assignment and precise temporal definition of policies. Clustering is performed at the individual firm level within standard error clusters to

control for potential intra-group correlation and heteroscedasticity, thereby enhancing the robustness and credibility of estimation results.

3.3.3 Control Variables.

To control factors influencing corporate green innovation, this study selects a series of firm characteristic variables as control variables. Firm size (Size) is represented by the natural logarithm of total assets, reflecting a company's resource allocation and R&D capabilities. Financial leverage (Lev) is measured by the debt-to-asset ratio, indicating how corporate debt burdens affect innovation investment. Profitability (ROA) is expressed as return on total assets, showing net profit as a percentage of total assets to demonstrate profitability and financial strength. Growth potential (Growth) is measured by revenue growth rate, indicating organizational development capacity. Shareholder concentration (Top1) is quantified by the proportion of shares held by the largest shareholder, revealing how ownership structure impacts innovation decision-making. Firm age (Age) is calculated as the natural logarithm of the listing years plus 1 to control lifecycle factors. Independent director ratio (Indep) measures the proportion of independent directors in the board of directors, reflecting corporate governance independence. Dual leadership (Dual) is coded as a dummy variable with a value of 1 when the chairman and CEO hold concurrent positions. All continuous variables underwent tail-trimming at the 1st and 99th percentiles to mitigate extreme value effects.

4 Interpretation of Result

4.1 Benchmark Regression Results

The benchmark regression results based on a difference-in-differences (DID) model demonstrate that green finance policies significantly increase the total number of green patent applications by enterprises. The estimated coefficient of the core explanatory variable DID is 0.430, which remains significantly positive at the 5% significance level, corresponding to an average increase of approximately 43.0% in total green patent applications. This finding preliminarily reveals that green finance policies exhibit a pronounced positive effect on corporate innovation behavior, with this impact being neither accidental nor driven by confounding factors. Further analysis distinguishing patent types to identify innovation quality disparities reveals that the DID coefficient for green invention patent applications is 0.396, also statistically significant at the 5% level, while the DID coefficient for green utility model patent applications is 0.232, showing no statistical significance. This indicates distinct heterogeneity in policy effects across different types of green patents. Considering that invention patents typically represent higher technical barriers, longer R&D cycles, and stronger originality, with more pronounced substantive innovation characteristics, whereas utility model patents—due to lower examination standards and shorter authorization periods—are often used by enterprises to rapidly respond to external incentives or meet short-term compliance requirements, demonstrating stronger strate-

gic motivations, the significant promotion effect of green finance policies on invention patents contrasts sharply with their insignificant impact on utility model patents. This suggests that policy incentives may more effectively guide enterprises to allocate resources toward substantive green innovation activities with long-term value and genuine technological breakthroughs, rather than merely serving as strategic behaviors aimed at complying with regulations or obtaining policy dividends. All regression analyses strictly controlled for key variables potentially influencing innovation decisions, including firm size, financial leverage, and profitability. Fixed effects were incorporated to account for time-invariant firm characteristics, while year-specific fixed effects were introduced to mitigate potential confounding effects from macroeconomic fluctuations, industry cycles, or shared temporal trends on the overall innovation environment. This approach effectively addressed omitted variable bias and enhanced causal identification reliability. Model goodness-of-fit R^2 values reached 0.812 (invention patents), 0.788 (utility models), and 0.825 (aggregate metrics), demonstrating strong explanatory power for dependent variable variations and robust regression results. With 8,481 observed cases spanning diverse samples and reasonable temporal spans, the study further ensures representativeness and extrapolability of empirical conclusions. Overall, under green finance policy implementation, corporate green innovation exhibits distinct quality-oriented characteristics. Policy design and execution have successfully mitigated risks of inducing low-quality or strategic innovations, instead incentivizing deep investments and substantive breakthroughs in green technology R&D. These findings provide empirical evidence for understanding how green finance policies guide micro-level entities toward high-quality sustainable development through market mechanisms, while offering critical references for optimizing green incentive mechanisms, accurately identifying corporate innovation motivations, and preventing "greenwashing" practices in policy implementation.

Table 1. Results of Green Policy Effect Regression

variable	Types of Green Patents		
	Number of invention patent applications	Number of Utility Model Applications	Total patent applications
DID	0.396**	0.232	0.430**
	(0.026)	(0.110)	(0.016)
controlled variable	Yes	Yes	Yes
firm fixed effect	Yes	Yes	Yes
year fixed effect	Yes	Yes	Yes
observed value	8481	8481	8481
R^2	0.812	0.788	0.825

4.2 Heterogeneity Analysis

The impact of green financial policies on corporate green innovation exhibits significant heterogeneity due to differences in property rights structures. To examine how

property rights characteristics moderate policy effects, this study categorizes sample firms into state-owned enterprises and private enterprises. It should be noted that the baseline regression analysis incorporates 8,481 company-year observations, including not only state-owned and private enterprises but also a limited number of foreign-funded enterprises, collective enterprises, and other ownership types (totaling 950 observations). Given the small sample size and substantial property rights disparities among these enterprises, meaningful intergroup comparisons were deemed impractical and thus excluded from the heterogeneity analysis. The final sample comprises 2,719 private enterprise observations and 4,812 state-owned enterprise observations, totaling 7,531 company-year observations.

The panel regression analysis based on enterprise ownership structures reveals systematic policy effect differentiation between state-owned and private enterprises. In terms of total green patent applications, the state-owned enterprises' difference-in-differences (DID) estimation coefficient reached 0.447 at the 5% significance level, whereas private enterprises showed only 0.258, failing conventional significance tests. This disparity demonstrates that state-owned enterprises exhibit more proactive and effective responses to green finance policies.

Further categorization of innovation types reveals clearer differentiation between substantive and strategic innovations. Regarding green invention patent applications, state-owned enterprises demonstrated a DID coefficient of 0.427 at the 5% significance level (standard error 0.047), indicating substantial breakthroughs in high-value, original green technology fields. In contrast, private enterprises showed a statistically insignificant coefficient of 0.240, suggesting limited motivation or capability in core green technology R&D. For green utility model patent applications, neither enterprise type exhibited significant policy effects: private enterprises had a DID coefficient of 0.002 while state-owned enterprises recorded 0.241. Although the latter showed positive directionality, its statistical reliability was lacking. These findings indicate that policies failed to effectively incentivize enterprises to increase low-barrier, easily imitable strategic green patent applications, with virtually no impact observed among private enterprises.

These findings are closely related to corporate resource endowments and institutional environments. State-owned enterprises, leveraging their advantages in credit access, policy coordination, and long-term strategic planning, are more likely to direct green financial resources toward high-cost, high-risk yet socially valuable substantive innovation activities. In contrast, private enterprises constrained by financing limitations and short-term performance pressures find it difficult to make large-scale investments in foundational green R&D even with policy support. Notably, all regression models controlled for firm fixed effects and year fixed effects, incorporating a series of firm-level covariates to ensure estimation results remain unaffected by unobservable individual heterogeneity or time trends. The model goodness-of-fit (R^2) ranged between 0.786 and 0.839, indicating strong explanatory power of the dependent variables.

In conclusion, the role of green finance policies in promoting green innovation is primarily reflected in the substantial progress made by state-owned enterprises in green invention patents, rather than encouraging widespread strategic reliance on low-

quality utility model patents. The nature of property rights thus serves as a critical dimension for understanding policy transmission mechanisms.

Table 2. Property Rights Heterogeneity

type	private enterprise	state-owned enterprises	private enterprise	state-owned enterprises	private enterprise	state-owned enterprises
variable	Number of Green Invention Patent Applications	Number of Green Invention Patent Applications	Total number of green patent applications	Total number of green patent applications	Number of Green Utility Model Patent Applications	Number of Green Utility Model Patent Applications
DID	0.240	0.427**	0.258	0.447**	0.002	0.241
	(0.531)	(0.047)	(0.439)	(0.044)	(0.985)	(0.205)
controlled variable	yes	yes	yes	yes	yes	yes
firm fixed effect	yes	yes	yes	yes	yes	yes
year fixed effect	yes	yes	yes	yes	yes	yes
observed value	2719	4812	2719	4812	2719	4812
R^2	0.786	0.828	0.811	0.839	0.789	0.794

4.3 Robustness Test

4.3.1 Parallel Trend Test.

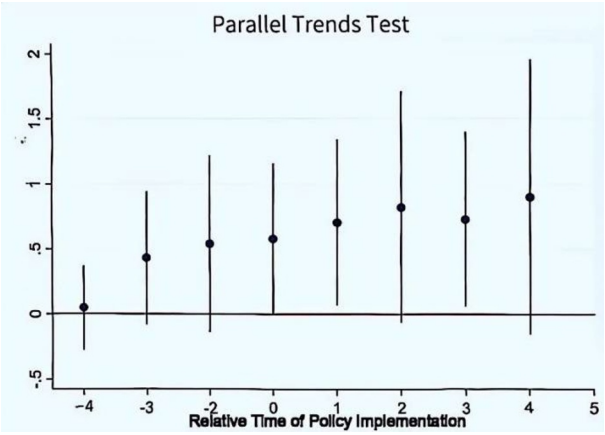

Fig. 1. Parallel Trend Test.

The core premise for DID estimation of effectiveness is that the treatment group and control group exhibit consistent change trends prior to policy implementation. This study employs event study methodology to conduct parallel trend tests, using the period preceding policy implementation as the baseline to examine coefficient changes between pre-and post-policy years. As shown in Figure (or as described based on

your provided table data), the estimated coefficients of dummy variables remain insignificant and relatively small (fluctuating between 0.1 and 0.55 with confidence intervals containing 0) across periods prior to policy implementation (e.g., periods-4 to-1). This indicates no systematic differences in green innovation levels between treatment and control groups before policy rollout, satisfying the parallel trend assumption. During policy implementation and subsequent periods (0 to 4), the estimated coefficients become significantly positive and progressively increase (rising from 0.55 to 0.9), demonstrating the policy's delayed and sustained effects. Over time, the incentive mechanism for green innovation gradually manifests and intensifies through policy implementation.

4.3.2 Placebo Test.

To validate the robustness of the benchmark regression results and eliminate interference from unobservable random factors, this study further employs a placebo test using the placebo test method. Specifically, the treatment group dummy variable DID undergoes 500 random sampling allocations, with the benchmark regression process repeated for each iteration. The estimated coefficients from each simulated regression are extracted and plotted as kernel density distributions. As shown in Figure 1, the coefficients obtained through random permutation cluster around the zero value, exhibiting an approximately normal zero-centered distribution. The absolute values of most coefficients are significantly smaller than the true estimated coefficients from the benchmark regression (marked by black dashed lines, coefficient value 0.1031). The true coefficients are positioned in the extreme right tail of the permutation coefficient distribution, exceeding over 95% of random sampling results. This indicates that the observed green innovation promotion effect in this study is not driven by conventional random factors or missing variables, demonstrating strong robustness and statistical significance in the benchmark regression results.

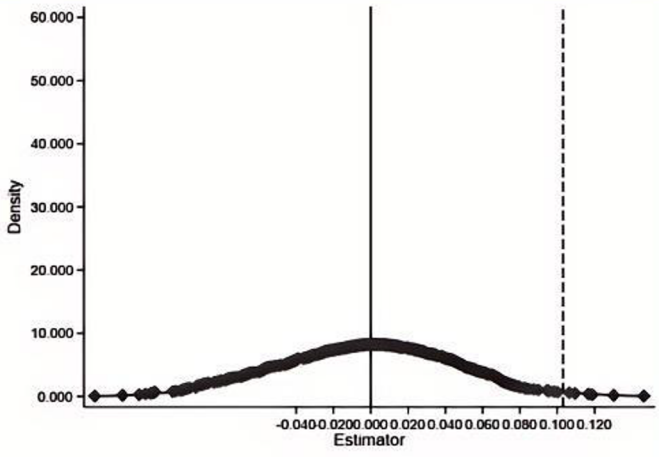

Fig. 2. Placebo Test.

4.3.3 Excluded Samples.

To test the robustness of baseline regression results, this study sequentially removes samples from specific years, pollution-intensive industries, and municipalities directly under the central government, then reestimates the impact of green finance policies on corporate innovation behavior. First, considering that 2017 marked the initial implementation year of green finance reform pilot policies, there may be lingering effects from policy implementation. Additionally, 2020 was significantly impacted by the global COVID-19 pandemic, which likely introduced substantial non-policy factors disrupting corporate innovation activities. Therefore, in the first robustness test, observations from 2017 and 2020 were excluded, with regression analysis conducted using remaining data. Results show that the estimated coefficient of the green finance policy variable is 0.359, demonstrating significant positivity at the 5% significance level. This indicates that after excluding potential interference years, the policy still exerts a substantial positive effect on substantive green innovation in enterprises.

Secondly, given that enterprises in high-pollution industries may prioritize strategic innovation to meet compliance requirements under environmental regulations rather than genuinely investing in green technology R&D, this study further excludes samples classified as heavy-pollution industries according to the "Industry Classification Guidelines for Listed Companies." This adjustment reduces the sample size to 4,958 observations. The regression results show a policy coefficient of 0.399, which remains statistically significant and marginally higher than the baseline regression results. This indicates that even after accounting for potential strategic response biases in pollution-intensive industries, the incentive effect of green finance policies on high-quality green innovation remains robust.

Third, given the systemic disparities among municipalities (Beijing, Shanghai, Tianjin, and Chongqing) in financial resource concentration, policy enforcement intensity, and innovation infrastructure compared to other regions, their sample data may exert abnormal influence on overall estimates. To address this, regression analysis of the remaining 6,135 samples after excluding corporate observations from these four municipalities revealed a policy variable coefficient of 0.409, with unchanged significance levels and enhanced effect strength. All three robustness tests controlled for firm fixed effects and year fixed effects while incorporating full set control variables, yielding model goodness-of-fit (R^2) values of 0.810,0.827, and 0.785 respectively, demonstrating stable explanatory power of the models.

The aforementioned results consistently demonstrate that green finance policies maintain robust positive impacts on corporate green innovation across various sample selection criteria. Notably, policy effects show no attenuation when excluding samples potentially inducing strategic behavior (e.g., polluting industries) or special regions (e.g., municipalities), instead exhibiting slight enhancement. This indicates that corporate responses primarily reflect genuine investments in substantive green technology R&D rather than short-term compliance motives or regional peculiarities. As a core indicator of substantive innovation, invention patents demonstrate significant positive correlations across all regression analyses, further corroborating the intrinsic alignment between policy guidance directions and improvements in corporate innovation quality.

Table 3. Robustness test results

Robustness test results			
process mode	Exclude specific years	Eliminate polluting industries	Excluding municipalities directly under the central government
DID	0.359*	0.399*	0.409*
	(0.054)	(0.088)	(0.057)
controlled variable	yes	yes	yes
firm fixed effect	yes	yes	yes
year fixed effect	yes	yes	yes
observed value	6526	4958	6135
R^2	0.810	0.827	0.785

5 Conclusion and Implications

Based on the unbalanced panel data of annual observations from 8,481 China A-share listed companies from 2010 to 2024, this paper employs the difference-in-differences method to explore the impact of green finance pilot zone policies on corporate green innovation. Corporate green innovation is evaluated from both aggregate and structural perspectives, with the total number of green patent applications, green invention patent applications, and green utility model patent applications selected as primary indicators to measure policy effectiveness. Empirical results show that green finance pilot zone policies have a positive impact on corporate green innovation, particularly significantly boosting green invention patent applications, indicating that the policy primarily incentivizes substantive technological innovation rather than strategic compliance, thereby addressing the research question. Heterogeneity analysis reveals that the policy exerts a stronger promoting effect on state-owned enterprises, suggesting their advantages in policy implementation and resource allocation. Robustness tests conducted by excluding specific years, high-pollution industries, and municipal samples confirm the reliability and validity of the conclusions, providing insights into how green finance policies facilitate corporate green innovation.

The research findings on the impact of green finance pilot zone policies on corporate green innovation provide valuable insights for policymakers and practitioners. Green finance policies should prioritize the effectiveness of incentive mechanisms, utilizing diverse policy tools to encourage enterprises to invest in R&D of truly technologically groundbreaking green invention patents rather than blindly pursuing patent quantity. Policymakers need to establish scientifically sound quality evaluation standards for green innovation, incorporating factors such as patent technological content and market commercialization rates to prevent enterprises from engaging in strategic innovation solely to meet policy requirements. Additionally, given the policy sensitivity and resource advantages of state-owned enterprises, they should take the lead in demonstrating green technology innovation through industry-academia-research collaboration and technology spillover mechanisms, thereby enhancing private enterprises' green innovation capabilities. Furthermore, the implementation of

green finance policies requires supportive external environments and institutional frameworks, including establishing effective technology transfer mechanisms to ensure that genuine innovation investments receive appropriate market returns, ultimately creating a virtuous cycle of green innovation incentives.

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