WEP Warwick Evans Publishing

Transactions on Economics, Business and Management Research
ISSN: 2960-1789, eISSN: 2960-2254 | Volume 18
GEBM 2026

Green Credit Policies Enhance Firms' Innovation Performance

Zhixiu Li *

International Business School, Dongbei University of Finance and Economics, Dalian, China, 116025

* Corresponding Author Email: leen.li.1@outlook.com

Abstract. Green credit regulation embeds environmental criteria into bank lending decisions and may therefore influence firms' financing conditions and innovation behavior. Based on Chinese A-share listed firms from 2008 to 2023, this study treats the 2012 Green Credit Guidelines as an external policy shock and evaluates their effect on corporate innovation performance. By integrating environmental risks into credit decisions, it improves resource allocation and incentivizes technological innovation. The effect works through three channels: strengthening green orientation, easing financing constraints, and promoting technological upgrading. The innovation effect is stronger in non-competitive industries, eastern and central regions, and state-owned enterprises, suggesting moderation by industry competition, regional finance, and ownership type. Green credit thus serves not only environmental governance but also firm-level technological progress. The findings provide firm-level evidence on how credit-based environmental regulation affects innovation decisions and offer implications for improving the design of green finance policies.

Keywords: Green Credit Policy, Corporate Innovation, Green Finance, Credit Resource Allocation, High-quality Development.

1. Introduction

Under high-quality development and innovation-driven strategies, corporate innovation is crucial for micro-competitiveness, industrial upgrading, and long-term growth. Innovation activities require large investments, long R&D cycles, and face high uncertainty, making them heavily dependent on external financing (Hall and Lerner, 2010) [1]. For listed firms, changes in financing conditions directly affect R&D, technological upgrading, and innovation output. Thus, examining how external financial policies shape innovation is key to understanding firms' innovation decisions and policy consequences.

Green finance has become an important policy instrument for linking environmental objectives with financial resource allocation in China. Among its tools, green credit—anchored in the banking system—has strong policy transmission and resource allocation functions in China's indirect-finance-dominated structure. Unlike general credit, green credit incorporates firms' environmental performance, industry attributes, and project characteristics into lending decisions, using differentiated standards to affect financing availability and costs, thereby potentially altering firms' innovation decisions. The issuance of the 2012 Green Credit Guidelines by the CBRC transformed green credit from a broad policy orientation into a more operational regulatory framework. The Guidelines require banks to strengthen environmental and social risk management, embed green requirements into credit approval and post-loan processes, direct credit to green industries, and tighten constraints on high-pollution, high-energy-consumption sectors. Whether this policy framework can generate measurable innovation responses at the firm level remains an empirical question.

Theoretically, green credit can affect innovation in two ways. On the one hand, by optimizing credit allocation, it eases financing constraints for green-oriented or technology-upgrading firms, boosting R&D and innovation output. On the other hand, stricter credit standards on polluting firms may reduce their available capital, potentially forcing transformation via innovation or crowding out long-term investment. Hence, the net effect is an empirical question requiring micro-level data.

Existing literature on green finance's micro consequences shows mixed results: some find promotion of innovation through better financing and resource allocation; others find a crowding-out effect on constrained firms. Policy outcomes may depend on market competition, regional development, and ownership type.

Using firm-level data from Chinese A-share listed companies during 2008–2023, this paper identifies the effect of the 2012 Green Credit Guidelines through a difference-in-differences framework and further examines whether the effect varies by market competition, region, and ownership type. The main contributions are: (1) providing new micro-level empirical evidence on green credit's innovation effects, and (2) revealing boundary conditions through heterogeneity analysis, offering insights for future green finance policy design.

2. Literature Review

2.1. Green Finance, Corporate Innovation, and the Financing Environment

Innovation is critical for firms to strengthen their core competitiveness, propel industrial upgrading, and realize high-quality development. Unlike conventional investment activities, innovation is characterized by substantial input requirements, prolonged R&D cycles, considerable uncertainty surrounding outcomes, and a high concentration of intangible assets—factors that render it particularly vulnerable to fluctuations in the external financing environment. Hall and Lerner (2010) point out that corporate innovation often encounters higher external financing costs, primarily due to information asymmetry, uncertain returns, and inadequate collateral associated with R&D initiatives. Brown et al. (2009) [2] further validate that corporate R&D investment is strongly shaped by internal cash flows and external financing conditions, underscoring the direct impact of financing environment changes on innovation activities. These studies suggest that external financing conditions and firms' ability to absorb risk are closely related to innovation decisions.

In the process of low-carbon transition, green finance may affect corporate innovation by changing firms' access to external capital and the allocation of financial resources. Distinct from traditional financial instruments, green finance incorporates environmental risks, green development performance, and long-term sustainability into the process of financial resource allocation. Existing scholarly research examines the impact of green finance on corporate innovation primarily through policy tools such as green finance reform and innovation pilot zones, as well as green bonds.

In terms of green finance reform and innovation pilot zones, Liu and Xiong (2022) [3] use the green finance reform and innovation pilot zones as a policy setting and show that such reforms are associated with higher levels of corporate innovation. This effect is primarily achieved by reducing debt financing costs, increasing investment in innovation, and attracting external capital. Jia et al. (2023) [4] reach a similar conclusion, confirming that such reforms enhance firms' green innovation levels through key mechanisms including the alleviation of financing constraints, optimization of credit resource allocation, and guidance provided by government fiscal subsidies. This further illustrates that improving the external financing environment constitutes a key channel through which green finance influences corporate innovation.

As a market-oriented green financial instrument, green bonds also provide important insights into the innovation effects of green finance. Wang and Feng (2022) [5] find that the issuance of green bonds facilitates corporate green innovation by expanding financing channels, thereby enhancing firms' innovation capabilities. Beyond their financing function, green bonds can also drive corporate green transformation through signaling effects and market-based incentives.

Nevertheless, the impact of green finance on corporate innovation is not uniformly positive. On the one hand, green finance can provide financial support for corporate R&D investment and technological upgrading by redirecting financial resources and easing financing constraints. On the other hand, green finance policies may impose financing pressures on high-pollution, high-energy-consumption enterprises through stricter environmental risk assessments and credit constraints, which

could hinder their long-term innovation investment. The Porter Hypothesis, proposed by Porter and van der Linde (1995) [6], posits that appropriate environmental constraints may motivate firms to improve resource efficiency through technological innovation, thereby generating an innovation compensation effect. However, excessively stringent policy constraints may lead to rising financing costs and reduced capital availability, potentially crowding out innovation activities. Therefore, the impact of green finance policies on corporate innovation is dual-sided, and their actual effects require further analysis in conjunction with specific policy instruments and firm characteristics.

2.2. Green Credit Policies and Corporate Innovation

Among various green finance instruments, green credit is particularly relevant to corporate innovation because it directly affects firms' access to bank financing. This is largely because bank credit has long dominated external financing for Chinese enterprises, with the allocation of bank credit resources exerting a profound influence on firms' investment and innovation decisions. Compared with green bonds, green funds, and other instruments, green credit boasts a broader scope and a more direct policy transmission mechanism, enabling it to shape firms' access to financing and financing costs through bank credit standards. As such, green credit policies serve not only as a core component of the green finance system but also as a key institutional context for exploring how financial policies affect corporate innovation.

The Guidelines require banks to consider environmental and social risk factors in credit approval and post-loan management, while encouraging credit support for green projects and tightening lending standards for highly polluting and energy-intensive firms. The introduction of this policy transformed green credit from a voluntary practice into an institutionalized requirement, while also providing a quasi-natural experimental framework for scholars to identify the microeconomic impacts of green credit policies. Previous studies have mainly examined how this policy changes firms' financing decisions and investment activities. For instance, Su and Lian (2018) [7] utilized the Guidelines as a quasi-experiment and found that green credit policies significantly reshape the debt financing and investment decisions of heavily polluting enterprises. Cai et al. (2019) [8] further confirmed, from the perspectives of new bank loans and environmental outcomes, that green credit policies can alter firms' financing structures and environmental behaviors. These findings indicate that green credit policies first modify firms' external financing environments through the bank credit channel, which in turn influences their resource allocation.

Against this backdrop, researchers further investigate the linkage between green credit policies and corporate innovation. Wang and Wang (2021) [9] reveal that green credit can boost green innovation activities of regulated enterprises, whereas it exerts little effect on innovation quality improvement. Existing empirical studies also confirm the obvious heterogeneous characteristics of this policy effect. Overall, green credit reshapes corporate financing conditions and resource allocation and further alters firms' innovative decision-making.

Nevertheless, academic circles have not reached unified views on its innovation influence. Green credit is capable of easing financing constraints for green projects and motivating corporate innovation. Meanwhile, it tightens credit supervision on high-pollution and high-energy-consuming firms, raising their financing costs and restraining long-term innovative investment. Relevant research shows that the policy effect presents obvious duality. Although it helps polluting enterprises cut emissions, increased environmental investment may crowd out funds for innovation, thus dragging down innovation performance and operational efficiency.

Furthermore, green credit policies create an imbalance between innovation quantity and quality. It can effectively raise the number of corporate green innovations but hardly drive high-quality innovation progress. Current evidence indicates that such policies mainly stimulate the output of low-level green patents, with a weak driving effect on core and high-value technological breakthroughs. Hence, whether green credit can effectively promote high-end corporate innovation still needs more in-depth research.

2.3. Research on the Heterogeneity of Green Credit Policy Effects

The impact of green credit policy on innovation may vary across firms because market competition, regional development, and ownership structure affect firms' financing capacity and policy responsiveness.

Market competition, for instance, moderates firms' innovation incentives and resource allocation capabilities. Aghion et al. (2005) [10] proposed an inverted U-shaped relationship between market competition and innovation: moderate competition encourages innovation, while excessive competition compresses profit margins and weakens firms' R&D capacity. Under green credit policies, firms in less competitive industries—endowed with more stable market positions and profit margins—are better able to convert policy support into long-term R&D investment. In contrast, firms in highly competitive industries face greater short-term operational pressure, often diverting funds to working capital and market competition rather than innovation, which in turn influences the transmission efficiency of green credit policies.

Beyond market competition, regional development levels also play a pivotal role in shaping policy implementation effectiveness. Significant disparities exist across China in terms of economic development, financial resource supply, marketization levels, and innovation foundations. The eastern region, with a well-developed financial system, solid green finance foundation, and concentrated corporate innovation resources, can more effectively translate green credit policies into innovation inputs and outputs. The central region, with continuous improvements in its industrial base and financial service capabilities, possesses moderate policy implementation capacity, whereas the western region—constrained by scarce financial resources, low marketization, and weak corporate innovation foundations—sees limited policy transmission efficiency. Wu et al. (2025) [11] further supported this regional variation, noting that the Guidelines have a more pronounced promotional effect on green technological innovation among manufacturing enterprises in the eastern region.

Ownership structure also exerts a notable impact on the transmission of green credit policies. State-owned enterprises often have easier access to bank loans and stronger connections with policy-oriented financial resources, which may help them transform green credit support into long-term innovation investment. In contrast, non-SOEs, despite their greater market vitality and innovation incentives, often face higher credit barriers and tighter financing constraints, which weaken the promotional effect of green credit on their innovation activities. Liu and Xiong (2022) confirmed that green finance reforms, a core component of green credit policy, have a more pronounced promotional effect on innovation in local state-owned enterprises, underscoring the role of ownership in shaping policy responses.

Existing literature has comprehensively discussed the microeconomic consequences of green finance and green credit policies from the perspectives of financing constraints, resource allocation, external governance, and environmental constraints, yet three key limitations remain. Most studies focus on green innovation and green transformation while neglecting the impact on firms' total innovation. The conclusions on innovation effects are still inconsistent, and the heterogeneous performance across industries, regions, and ownership types has not been fully analyzed. Therefore, this paper focuses on overall corporate innovation and further examines how the policy effect differs across firms with different characteristics.

3. Theoretical Analysis and Research Hypotheses

3.1. The Theoretical Mechanism Through Which Green Credit Policies Influence Corporate Innovation

The Guidelines incorporate environmental performance into banks' lending decisions, which may alter firms' access to credit, financing costs, and investment allocation. Given the long-cycle and high-uncertainty features of innovation activities, changes in financing conditions will further affect corporate R&D investment and innovation output. Green credit may promote innovation through

financing support, resource allocation, and external supervision, but it may also exert a crowding-out effect by tightening constraints on polluting enterprises.

On the one hand, corporate innovation relies heavily on external financing due to its large input, high uncertainty, and lack of effective collateral. Hall and Lerner (2010) point out that information asymmetry and collateral shortage make innovation more vulnerable to financing constraints. By tilting credit resources toward green and technology-upgrading projects, green credit eases financing pressure and enables firms to expand R&D investment. Conversely, tighter credit standards may raise the financing burden of highly polluting firms and reduce the funds available for innovation activities. Nevertheless, according to the Porter Hypothesis, appropriate environmental constraints can stimulate technological innovation to improve efficiency, producing an innovation compensation effect (Porter and van der Linde, 1995).

Overall, green credit policy may generate both promotion and restrictive effects on innovation. Given the policy emphasis on environmental upgrading and technological improvement, this paper expects the positive incentive effect to be stronger. We therefore propose Hypothesis 1.

Hypothesis 1: Green credit policies can significantly promote corporate innovation.

3.2. Heterogeneous Effects of Green Credit Policy on Corporate Innovation

The innovation effects of green credit are not identical across firms, because of market competition, regional development, and ownership shape firms' financing capacity, resource allocation, and policy responsiveness.

Market competition affects profit stability and innovation willingness. As suggested by Aghion et al. (2005), market competition and innovation present an inverted U-shaped relationship. Firms in non-competitive industries have more stable profits and can better convert green credit support into long-term R&D investment, whereas firms in highly competitive industries tend to prioritize short-term operations over innovation.

Regional development also matters. The eastern and central regions have more mature financial systems, abundant innovation resources, and stronger policy implementation capacity, which strengthens the transmission of green credit. By contrast, the western region lacks financial resources and foundation innovation, weakening policy effects.

Ownership structure further leads to heterogeneity. State-owned enterprises have more stable financing channels and stronger policy responsiveness, enabling them to better capture the benefits of green credit. Non-state-owned enterprises face tighter financing constraints, which dampen the innovation incentive effect.

Based on the above analysis, we propose Hypothesis 2.

Hypothesis 2: The impact of green credit policies on corporate innovation exhibits heterogeneity, with their promotional effects being more pronounced in non-competitive industries, the eastern and central regions, and state-owned enterprises.

To illustrate the logical framework more clearly, Figure 1 depicts the theoretical mechanism and research hypotheses of this paper, covering the policy shock, influence channels, heterogeneity conditions, and final innovation outcomes.

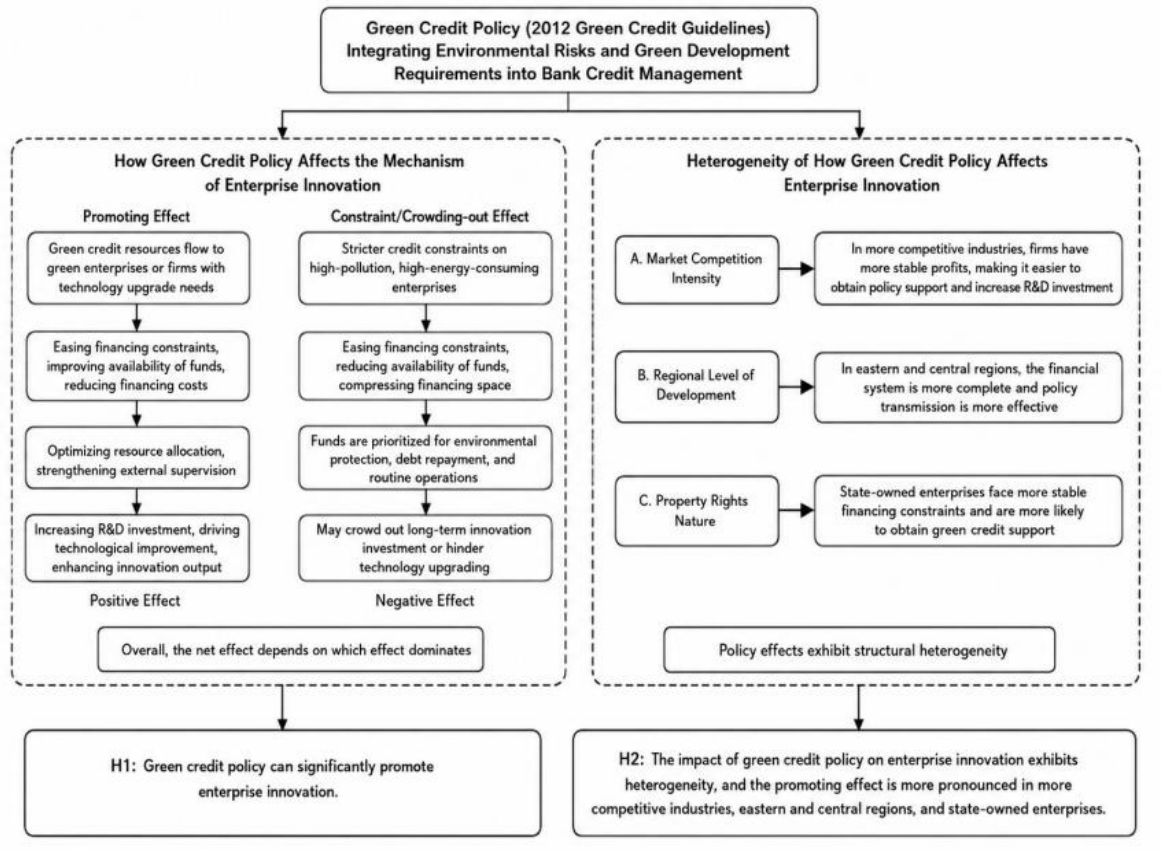

Figure 1. Diagram of Theoretical Analysis and Research Hypotheses.

4. Research Design

4.1. Sample Selection and Data Sources

The initial sample for this study consists of data from Chinese A-share listed companies from 2008 to 2023. The following methods were used to screen and process the sample: (1) Exclude companies subject to ST or *ST designations, as well as delisted companies; (2) Exclude financial and real estate companies; (3) Exclude samples with severe missing values. To avoid the influence of outliers, the main continuous variables were Winsorized at the 1% level. After the above processing, a final set of 18,016 valid observations was obtained.

4.2. Model Construction and Variable Selection

To estimate the policy effect, this study constructs a difference-in-differences model based on the implementation of the 2012 Green Credit Guidelines. Specifically, this study first constructs the policy-period dummy variable. If the yeart falls after the implementation of the Guidelines, i.e., 2012 or later, then $post_t$=1; if the yeart falls before the policy implementation, then $post_t$=0.

Second, we construct the treatment group dummy variable $treat_i$. Drawing on the research by Wang and Wang (2021) and incorporating the classification of key industries affected by green credit from the “Key Evaluation Indicators for the Implementation of Green Credit”, this paper defines industries significantly affected by green credit policies as the treatment group, including nuclear power generation, hydropower generation, water conservancy and inland river port construction, coal mining and washing, oil and natural gas extraction, ferrous metal mining and beneficiation, non-ferrous metal mining and beneficiation, non-metallic mineral mining and beneficiation, and other mining industries. If a firm belongs to the aforementioned industries, then $treat_i = 1$; otherwise, $treat_i = 0$.

Based on this, this paper constructs a difference-in-differences core explanatory variable:

$$DID_i=post_t \times treat_i \quad (1)$$

Where$DID_{i,t}$ represents the green credit policy shock variable. This variable takes a value of 1 only when the firm belongs to the treatment group and the year falls after the policy implementation; otherwise, it takes a value of 0. Therefore, $DID_{i,t}$ indicates the policy impact on firms in the treatment group relative to those in the control group following the implementation of the Guidelines, serving as the core explanatory variable for identifying the effects of the green credit policy in this study.

Based on the above variable construction, this paper specifies the following difference-in-differences model:

$$lnPatent_{i,t}=\alpha_0+\alpha_1 DID_{i,t}+\phi X_{i,t}+\mu_i+\gamma_t+\varepsilon_{i,t} \quad (2)$$

The dependent variable "$lnPatent_{i,t}$" is used to measure firm-level innovation output. Following the research of Kong Dongmin (2017) [12] and others, we take the natural logarithm of the number of invention patent applications filed by the firm plus one. i denotes the firm; t denotes the year; X denotes a set of control variables; ϕ denotes the coefficient of the control variables' effect on firm innovation; μ_i and γ_t denote firm and year fixed effects, respectively; $\varepsilon_{i,t}$ denotes the random error term; and α denotes the coefficient to be estimated. $DID_{i,t}$ represents the green credit policy shock variable, and its coefficientα_1 is the key estimated coefficient of focus in this study, used to measure the change in the innovation levels of firms in the treatment group relative to those in the control group following the implementation of the Guidelines. A positive and statistically significant α_1 indicates that the policy is associated with an increase in innovation output among treated firms. Conversely, it suggests that the green credit policy does not significantly promote firm innovation.

To control for other economic characteristics that may influence corporate innovation, and drawing on existing research on corporate green innovation, green finance, and innovation (Su and Lian, 2018), this study introduces control variables such as debt-to-asset ratio (lev), return on assets (roa), board size (board), proportion of independent directors (indep), Tobin's Q (tobinq), and dual-role directors (dual); Additionally, considering corporate profitability, we further control for gross profit margin (grossprofit) and net profit margin (netprofit). These variables primarily control factors that may influence corporate innovation across three dimensions: financial characteristics, governance structure, and growth potential.

4.3. Descriptive Statistics of Variables

Table 1 reports the summary statistics of the variables used in the empirical analysis. Regarding the dependent variable, the level of corporate innovation (lnpatent) has a mean of 1.684, a median of 1.386, a standard deviation of 1.722, a minimum value of 0, and a maximum value of 11.778. These statistics show considerable cross-firm variation in innovation output, with some firms exhibiting significantly higher innovation levels than others, suggesting strong heterogeneity in corporate innovation. This characteristic suggests that there are significant differences among firms in terms of R&D foundations, technological accumulation, and the ability to commercialize innovation outcomes, and it also provides a solid sample foundation for subsequently identifying the impact of green credit policies on firm innovation.

Regarding the control variables, the mean debt-to-asset ratio (LEV) is 0.470, indicating that the overall leverage level of the sample enterprises is within a relatively moderate range; the mean return on assets (ROA) was 0.033, suggesting that the overall profitability of the firms was average; the mean gross profit margin and net profit margin were 0.271 and 0.058, respectively, but the standard deviation of the net profit margin was large, reflecting significant fluctuations in the profitability of different firms. Regarding corporate governance variables, the mean for board size (board) is 2.140, the mean for the proportion of independent directors (indep) is 0.376, and the mean for dual roles

(dual) is 0.224, indicating that approximately 22.4% of the sample firms have situations where the chairman and general manager hold dual roles. For growth indicators, the mean value of the Tobin's Q ratio (tobinq) was 1.824, with a relatively high standard deviation, indicating significant differences among firms in terms of growth opportunities and market valuation. Overall, the distribution of key variables for the sample firms is generally reasonable and supports the following empirical analysis.

Table 1. Descriptive Statistics.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Number of observations	Mean	Standard Deviation	Minimum	Median	Maximum
lnpatent	18,016	1.684	1.722	0.000	1.386	11.778
lev	18,016	0.470	0.209	0.008	0.472	0.998
ROA	18,016	0.033	0.079	-2.834	0.034	0.974
grossprofit	18,016	0.271	0.177	-3.253	0.247	3.764
netprofit	18,016	0.058	0.734	-54.273	0.065	20.907
board	18016	2.140	0.204	1.099	2.197	2.890
indep	18016	0.376	0.058	0.000	0.364	0.800
tobinq	18016	1.824	1.466	0.611	1.421	45.140
dual	18016	0.224	0.417	0.000	0.000	1.000

5. Empirical Results and Analysis

5.1. Baseline Regression

The baseline regression estimates the effect of the Green Credit Guidelines on corporate innovation using the DID specification described above, with the results reported in Table 2. Column (1) reports the estimate using only the DID variable, whereas Column (2) adds firm-level controls as well as firm and year fixed effects.

The regression outcomes indicate that the estimated coefficient of DID remains significantly positive regardless of whether control variables are added. In particular, the coefficient of DID is 0.504 in Column (1) and 0.479 in Column (2), both of which are statistically significant at the 1% level. These results indicate that treated firms experienced a greater increase in innovation output after the policy implementation after controlling for firm heterogeneity and time-varying shocks. That is, firms affected by green credit policies experience a more substantial increase in innovation output relative to unaffected firms after policy implementation, suggesting that green credit regulation may create innovation incentives for affected firms.

Moreover, the sign and significance of the DID coefficient remain stable after controlling firm characteristics, which verifies the robustness of the baseline conclusion. Regarding control variables, leverage (LEV) and return on assets (ROA) both present significantly positive coefficients, implying that enterprises with stronger financing capacity and profitability tend to engage in more innovation activities. Board size and the proportion of independent directors (indep) also promote corporate innovation, reflecting that sound corporate governance helps improve innovation capabilities. By contrast, the coefficients of Tobin's Q (tobinq) and CEO duality (dual) are significantly negative, meaning that overly high market valuation may induce firms to prioritize short-term performance, and excessive managerial power may restrain long-term innovation investment. Gross profit margin and net profit margin show no significant impact on corporate innovation.

Overall, the baseline results are consistent with Hypothesis 1 and show a positive association between green credit regulation and corporate innovation.

Table 2. Baseline Regression Results.

Variable Name	(1)	(2)
	lnpatent	lnpatent
did	0.504***	0.479***
	(0.054)	(0.055)
lev		0.226***
		(0.078)
ROA		0.522***
		(0.141)
gross profit		-0.131
		(0.083)
net profit		0.011
		(0.012)
Board		0.155*
		(0.085)
indep		0.590**
		(0.248)
tobinq		-0.029***
		(0.008)
dual		-0.079***
		(0.029)
Corporate fixed	Yes	Yes
Fixed by year	Yes	Yes
N	18016	18016
adj. R^2	0.662	0.662

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.2. Parallel Trends Test

DID identification requires that treated and control firms follow similar innovation trends before the policy shock. To this end, this study employs event study methods to test the dynamic effects before and after the implementation of the green credit policy, with the results shown in Figure 2.

The estimation results indicate that, prior to policy implementation, the coefficients of the interaction terms for all periods did not deviate significantly from 0, and their 95% confidence intervals all included 0. This suggests that, before the policy shock occurred, there were no systematic differences in the trends of innovation levels between firms in the treatment and control groups, meaning the parallel trends assumption holds. This implies that, in the absence of external policy shocks, the innovation trajectories of firms in both groups were essentially consistent, thereby providing the necessary conditions for the identification of the difference-in-differences model.

After policy implementation, the coefficients of the relevant interaction terms turned positive overall, indicating that following the implementation of the green credit policy, the innovation levels of firms in the treatment group showed a significant increase relative to those in the control group. This result suggests that the promotional effect of the green credit policy on firm innovation was not caused by pre-existing differences between the treatment and control groups, but rather emerged gradually after policy implementation. Thus, the pre-policy pattern supports the validity of the DID identification strategy.

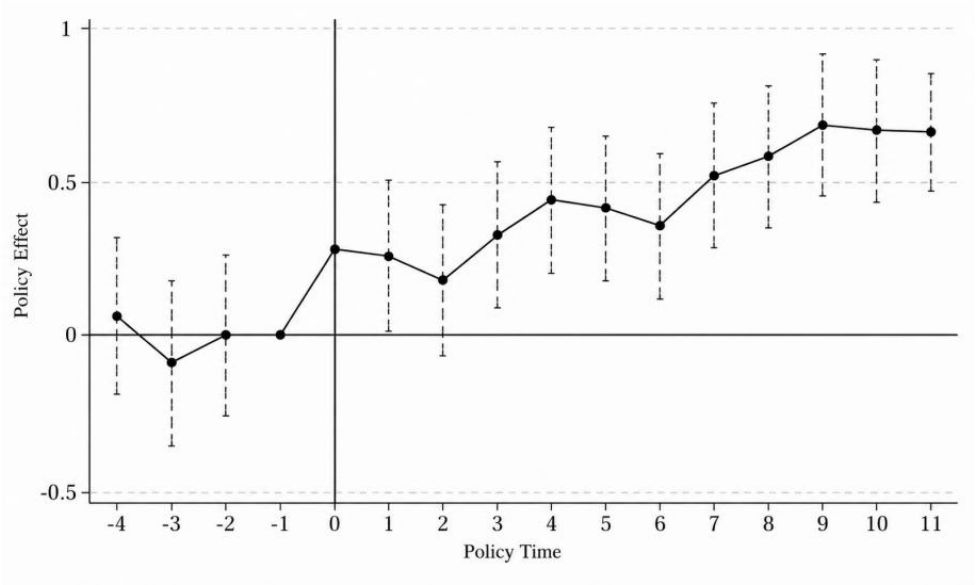

Figure 2. Parallel Trends Test.

5.3. Placebo Test

A placebo test is conducted to examine whether the baseline result is driven by random shocks or unobserved factors following the methodology of Ye Yongwei and Li Zengfu (2020) [13]. Specifically, firms are randomly assigned to pseudo-treatment groups, and the DID regression is repeated 1,000 times using a simulated policy variable to examine the distribution characteristics of the estimated coefficients of the dummy policy variable. The test results are shown in Figure 3.

The results show that the estimated coefficients obtained from the random regressions are mostly concentrated around zero, and the corresponding significance levels are generally low; most results do not pass conventional statistical significance tests. This indicates that, in the absence of a real policy shock, difference-in-differences estimation typically does not yield significant positive results. In other words, the significant positive effect of green credit policies on firm innovation observed in the baseline regression of this paper does not stem from sample randomness or model specification bias, but rather has a strong empirical basis and statistical reliability. The placebo test further reinforces the finding that the estimated policy effect is unlikely to be explained by random assignment.

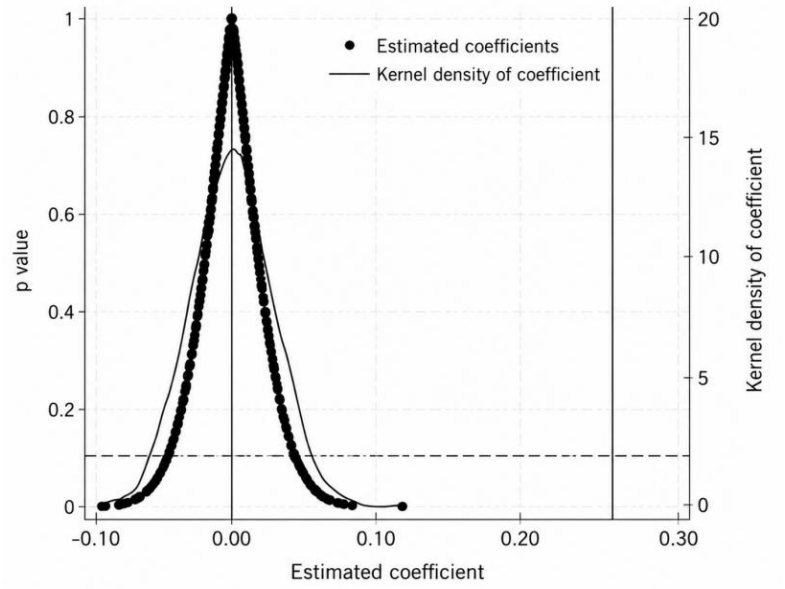

Figure 3. Placebo Test.

5.4. Robustness Tests

To further confirm the reliability of the baseline regression results, this paper carries out two robustness tests by adjusting the sample period and employing robust standard errors, with the corresponding results reported in Table 3.

To reduce the influence of the COVID-19 period, observations from 2019 to 2022 are excluded and the baseline model is re-estimated. The pandemic has imposed extensive shocks on corporate operations, financing conditions, and innovation strategies, aggravating financing constraints and increasing uncertainty, which may distort the identification of green credit policy effects (Zeng and Tang, 2023) [14]. In addition, considering the possible existence of heteroskedasticity in the panel data model, this paper also adopts robust standard errors to ensure the accuracy of statistical inference.

The DID coefficient remains positive and statistically significant after this adjustment. after using robust standard errors, which is highly consistent with the baseline regression. The sign, magnitude, and significance of the core explanatory variable remain stable in both robustness tests.

Overall, the robustness tests produce results consistent with the baseline regression, suggesting that the main conclusion is not sensitive to sample-period adjustment or standard-error treatment.

Table 3. Robustness Tests.

Variable Name	(1)	(2)
	lnpatent	lnpatent
did	0.455***	0.479***
	(0.058)	(0.060)
Control variables	Yes	Yes
Firm-level fixed	Yes	Yes
Fixed year	Yes	Yes
N	13170	18016
adj. R2	0.653	0.662

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.5. Heterogeneity Test

The results of the baseline regression reflect the average impact of green credit policies on corporate innovation. However, due to differences in the competitive environment of their industries, the level of regional financial development, and the nature of property rights, different firms may respond to policy shocks in markedly different ways. Therefore, this paper further examines the heterogeneity of the impact of green credit policies on corporate innovation from three dimensions: the degree of market competition, regional distribution, and the nature of property rights

5.5.1. Heterogeneity in Market Competition

Table 4 shows that the estimated policy effect is positive and significant only for firms in less competitive industries. We classify industries by market concentration and measure competition intensity using the Herfindahl–Hirschman Index (HHI). The coefficient of DID is 0.489 and significant at the 1% level in non-competitive industries, but is −0.230 and insignificant in competitive industries.

Firms in non-competitive industries have more stable profits and can better convert credit support into long-term R&D investment. In competitive markets, firms face tighter profit margins and tend to allocate resources to short-term operations rather than innovation. Therefore, green credit policies exert a stronger innovation incentive effect in non-competitive industries.

Table 4. Heterogeneity Test 1.

Variable Name	Non-competitive	Competitive
	lnpatent	lnpatent
did	0.489***	-0.230
	(0.075)	(0.231)
Control variable	Yes	Yes
Fixed	Yes	Yes
Fixed by year	Yes	Yes
N	6243	11773
adj. R^2	0.680	0.671

Standard errors in parentheses

* p < 0.10, ** p < 0.05, *** p < 0.01

5.5.2. 5Regional Heterogeneity

The sample is further divided into eastern, central, and western regions to examine regional differences in the policy effect. As shown in Table 5, the DID coefficients are 0.531, 0.371, and 0.313, significant at the 1%, 1%, and 5% levels, respectively. Green credit policies exert significant innovation promotion effects across all regions, but with obvious heterogeneity. The estimated effect is largest in the eastern region, smaller in the central region, and weakest in the western region. The eastern and central regions feature more developed economies and financial systems, enabling more effective policy transmission. In contrast, the western region is constrained by insufficient financial resources and a weak innovation foundation, limiting firms' ability to translate policy support into innovation investment. Accordingly, regional economic and financial development levels shape the innovation effects of green credit policies.

Table 5. Heterogeneity Test 2.

Variable Name	Eastern	Central	West
	lnpatent	lnpatent	lnpatent
did	0.531***	0.371***	0.313**
	(0.075)	(0.129)	(0.125)
Control variables	Yes	Yes	Yes
Fixed	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes
N	11529	3774	2713
adj. R^2	0.681	0.625	0.615

Standard errors in parentheses

* p < 0.10, ** p < 0.05, *** p < 0.01

5.5.3. Heterogeneity by Ownership Type

Table 6 presents the ownership-based heterogeneity results. The estimated coefficient is positive and significant for state-owned enterprises, whereas the coefficient for non-state-owned enterprises is smaller and statistically insignificant. Green credit policies therefore significantly promote innovation in state-owned enterprises, while the effect on non-state-owned enterprises is weak and insignificant. A possible explanation is that state-owned enterprises have more stable access to bank financing and stronger policy responsiveness, which helps them translate green credit support into innovation investment. In contrast, non-state-owned enterprises may be more constrained by financing pressure and market competition, limiting their ability to respond through innovation investment.

Table 6. Heterogeneity Test 3.

Variable Name	State-owned enterprises	Non-state-owned enterprises
	lnpatent	lnpatent
did	0.545***	0.190
	(0.064)	(0.118)
Control variable	Yes	Yes
Fixed	Yes	Yes
Fixed by year	Yes	Yes
N	8523	9493
adj. R^2	0.711	0.680

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In summary, the heterogeneity analysis indicates that the promotional effect of green credit policies on corporate innovation is not uniformly distributed but is more concentrated in non-competitive industries, the eastern and central regions, and state-owned enterprise samples; Hypothesis 2 is supported.

6. Research Conclusions and Policy Recommendations

6.1. Research Conclusions

The Green Credit Guidelines have significantly boosted corporate innovation. As a core instrument guiding green financial allocation, the policy improves corporate financing conditions, optimizes resource distribution, and strengthens external constraints, thereby motivating firms to prioritize technological upgrading and long-term development. Moreover, the policy presents clear structural heterogeneity: the innovation promotion effect is more prominent in non-competitive industries, eastern and central regions, and state-owned enterprises, since market stability, regional financial development, and ownership endowment affect policy transmission efficiency. Overall, green credit effectively stimulates corporate innovation, but its impact varies with industry competition, regional development, and ownership structure. Future policy implementation should maintain the green orientation while accounting for firm-level differences in financing capacity, innovation foundation, and policy responsiveness to improve targeting and incentive efficiency.

6.2. Policy Recommendations

The empirical findings lead to several policy implications. First, the green credit framework should be improved to better connect environmental assessment with firms' innovation incentives. On the basis of environmental risk constraints, more credit resources should be guided to enterprises with transformation and innovation demands by improving evaluation standards and approval procedures. Second, differentiated credit support should be strengthened for firms that face greater financing pressure, particularly those in competitive industries, western regions and non-state-owned sectors., so as to expand the inclusiveness of green finance. Third, coordination between green credit and innovation-related policies should be strengthened, such as fiscal subsidies, tax incentives, and intellectual property protection, to form a joint incentive for enterprises to convert financial support into innovation investment. Fourth, financial institutions should improve environmental information screening and risk assessment so that banks can allocate green credit resources more efficiently, thus enhancing the allocation efficiency of green credit resources.

References

[1] Hall B H, Lerner J. The financing of R&D and innovation [J]. Handbook of the Economics of Innovation, 2010, 1: 609-639.

[2] Brown J R, Fazzari S M, Petersen B C. Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom [J]. Journal of Finance, 2009, 64(1): 151-185.

[3] Liu C, Xiong M. Green finance reform and corporate innovation: Evidence from China [J]. Finance Research Letters, 2022, 48: 102993.

[4] Jia J, He X, Zhu T, Zhang E. Does green finance reform promote corporate green innovation? Evidence from China [J]. Pacific-Basin Finance Journal, 2023, 82: 102165.

[5] Wang Y., Feng J.H. A Study on How Green Bonds Promote Corporate Green Innovation [J]. Financial Research, 2022(06): 171-188.

[6] Porter M E, van der Linde C. Toward a new conception of the environment-competitiveness relationship [J]. Journal of Economic Perspectives, 1995, 9(4): 97-118.

[7] Su Dongwei, Lian Lili. Does Green Credit Affect the Investment and Financing Behavior of Heavy Polluters? [J]. Financial Research, 2018(2): 123-137.

[8] Cai Haiqing, Wang Xiangyao, Tan Chao. Green Credit Policies, Firms' New Bank Borrowing, and Environmental Effects [J]. Accounting Research, 2019(03): 88-95.

[9] Wang Xin, Wang Ying. A Study on How Green Credit Policies Promote Green Innovation [J]. Management World, 2021, 37(06): 173-188+11.

[10] Aghion P, Bloom N, Blundell R, Griffith R, Howitt P. Competition and innovation: An inverted-U relationship [J]. Quarterly Journal of Economics, 2005, 120(2): 701-728.

[11] Wu Anbing, Zhou Yueheng, Wang Yinglong, Huang Huan, Pan Lin: "Green Finance Policies, Financing Constraints, and Green Technological Innovation in Manufacturing Enterprises," Journal of Technology and Economy, Issue 12, 2025, pp. 52–63.

[12] Kong Dongmin, Xu Mingli, Kong Gaowen. Internal Wage Gaps and Innovation [J]. Economic Research Journal, 2017, 52(10): 144-157.

[13] Ye Yongwei and Li Zengfu, 2020, "Loan Renewal Restrictions and Corporate Technological Innovation," *Financial Research*, No. 11, pp. 151–169.

[14] Zeng Rong and Tang Song, "The Role of State-Owned Enterprises in Providing Financing Support to Private Enterprises During the COVID-19 Pandemic: A Supply Chain Perspective," *Financial Research*, No. 2, 2023, pp. 125–137.