

The Impact of Green Credit on Green Innovation in Chinese Renewable Energy Listed Companies

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ABSTRACT: Leveraging the promulgation of the Green Credit Guidelines as a quasi-exogenous policy shock, this study establishes a rigorous quasi-natural experimental framework to empirically examine the causal nexus between green credit policy and green innovation outcomes in renewable energy enterprises. Employing a Difference-in-Differences (DID) methodology on a comprehensive panel dataset spanning 2016–2025, complemented by systematic heterogeneity analyses, mediation effect examinations, and an extensive battery of robustness tests, we uncover several salient findings. The green credit policy exerts a statistically significant and economically meaningful positive effect on green innovation among renewable energy enterprises. The other is promotional effect manifests pronounced heterogeneity: it is substantially amplified in state-owned enterprises relative to their private counterparts, and in enterprises headquartered in the eastern coastal region compared to those in central and western China. Third, financing constraints operate as a significant mediating channel, partially transmitting the policy effect through the alleviation of capital access limitations. These findings yield important policy implications for optimizing the structural design of green credit instruments and accelerating green innovation transitions in the renewable energy sector.

KEYWORDS: Green credit; Renewable energy enterprises; Green innovation; Difference-in-Differences; Financing constraint

I. INTRODUCTION

Against the backdrop of global warming and energy transition, the development of renewable energy and green energy has become a core strategy for countries worldwide to achieve carbon neutrality goals and sustainable development. The Intergovernmental Panel on Climate Change points out that the window of opportunity for achieving an orderly transition is rapidly closing, and transformation pathways consistent with the goals of the Paris Agreement require a substantial increase in renewable energy deployment. Data from the International Energy Agency shows that to achieve the global temperature control target of 1.5°C, renewable energy needs to account for more than 40% of the global energy structure by 2030, requiring at least \$2.8 trillion in new investment annually, creating a huge funding gap^[1]. To fulfill the commitment made at COP28 to triple renewable energy installed capacity by 2030, there is an annual investment gap of approximately \$400 billion globally, meaning current annual investment levels need to increase by about 60%. The financial system plays an irreplaceable and crucial role in bridging this financing gap^[1]. China, as the world's largest energy consumer and carbon emitter, has accelerated its energy structure transformation in recent years, proposed the "Dual Carbon" strategic goals, and introduced a series of policy tools to support green energy development. Among these, green credit policy has become a core means of financial support for green development, and its impact on corporate innovation has become a research hotspot in the fields of business administration and energy economics. According to data from the People's Bank of China, as of the fourth quarter of 2022, green loans to the electricity, heat, gas, and water production and supply industries reached 5.62 trillion yuan, accounting for approximately 25.52% of total green credit, with a year-on-year growth of 27.44%. This indicates that green credit has become an important source of funding to support renewable energy development.

By the end of 2022, the new energy industry, represented by wind power and photovoltaics, obtained 1,587 green patents, a year-on-year increase of 34.8%, of which green invention patents increased by 58.4% year-on-year, and green utility model patents increased by 25.6% year-on-year. This data intuitively reflects the rapid growth trend of green innovation in renewable energy enterprises against the backdrop of green finance development, and also highlights the practical necessity of in-depth research into the mechanism of green credit. Renewable energy development is characterized by large investment scale, rapid technological updates, and long investment return cycles. Corporate innovation activities generally face strong financing constraints. Due to risk-

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return considerations, the traditional financial system finds it difficult to meet the huge funding needs of renewable energy enterprises, seriously hindering the process of green technology innovation. Since low-carbon energy technologies are often more capital-intensive than existing high-carbon solutions, the cost of capital and accessibility set in financial markets are key factors determining investment, energy structure, and decarbonization speed^[1]. In the Chinese context, green credit policy has been continuously improved since the introduction of the Green Credit Guidelines in 2012, and has formed a relatively systematic policy framework. In practice has this policy effectively alleviated the financing constraints of renewable energy enterprises, thereby promoting green innovation? Are there differences in policy effects among different types of enterprises? What role does financing constraint play in the policy transmission process?

II. LITERATURE REVIEW

Research supporting the promotion theory believes that green credit policy can promote corporate green innovation through multiple channels. Wang Xin and Wang Ying (2021) used the Green Credit Guidelines as a quasi-natural experiment and employed the difference-in-differences method for empirical research. They found that green credit policy can promote green innovation in constrained industries, but its effect on improving innovation quality is not obvious. This research achievement has been widely cited in academia and is a representative study supporting the promotion theory^[2]. Hou Xinshuo and Li Pei (2026), based on data from Chinese listed companies from 2011 to 2022 and using text analysis to identify enterprises' access to green credit, found that obtaining green credit can effectively promote the improvement of sustained green innovation levels. The mechanism lies in alleviating debt financing costs, improving green management innovation levels, and incentivizing environmental protection investment, further supporting the promotion theory^[4]. Other studies have also found that green credit policy can promote green innovation through channels such as alleviating corporate financing constraints and promoting green transformation. Most research supporting the promotion theory recognizes the positive role of green credit policy.

Research supporting the inhibition theory or misallocation theory warns of potential resource misallocation issues in green credit and questions the innovation promotion effect of green credit policy. Some studies have found that green credit enhances strategic green innovation in heavily polluting enterprises but significantly suppresses substantive innovation, thus there is no Porter effect. This inhibitory effect is attributed to increased financing constraints and reduced R&D investment, challenging the promotion theory from the perspective of innovation type differentiation. Other scholars point out that one-size-fits-all credit tightening may deprive highly polluting enterprises of the funds needed for transformation, hindering green innovation. When credit constraints cross a certain threshold, excessive and drastic capital flight can trigger systematic vicious cycles, which not only fail to promote green transformation but may also lead enterprises into liquidity crises, hindering the overall green transformation of the economy^[5]. Some studies indicate that green credit policy exhibits ownership preference and scale preference, with state-owned enterprises and large enterprises more easily obtaining green credit funds, private enterprises and small and medium-sized enterprises are more likely to face credit constraints. This credit misallocation reduces the efficiency of green credit fund allocation and may inhibit overall innovation efficiency. The inhibition theory emphasizes the potential negative effects of green credit policy, reminding scholars and policymakers to pay attention to possible flaws in policy design.

III. RESEARCH HYPOTHESES

A. Overall Effect of Green Credit on Green Innovation in Renewable Energy Enterprises

As a core policy financial tool for the Chinese government to support green industry development, green credit was designed to guide financial resources toward green and low-carbon sectors such as renewable energy, promoting green industrial development through differentiated credit conditions. Compared with traditional credit, the logic of green credit's impact on green innovation in renewable energy enterprises has distinct targeted support characteristics rather than coercive pressure on heavily polluting enterprises. This targeted support promotes green innovation in renewable energy enterprises mainly through two dimensions: capital supply and signal transmission. From the capital supply dimension, renewable energy development and innovation activities inherently feature large investment scales, rapid technological updates, long investment return cycles, and high uncertainty. According to financial constraint theory, due to information asymmetry, agency problems, and the high uncertainty of innovation activities, the external financing cost of enterprises is significantly higher than internal financing cost.

From the signal transmission dimension, the introduction of green credit policy sends a clear signal to the market that the state supports the development of the renewable energy industry. This can reduce investors' risk expectations regarding renewable energy projects and help enterprises attract more social capital, further broadening the sources of funding for corporate innovation and providing more adequate financial security for green innovation activities. Before the introduction of green credit policy, although renewable energy development aligned with long-term trends, many market-oriented investors maintained a wait-and-see attitude toward renewable energy projects due to technological immaturity and high investment risks. This resulted in

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renewable energy enterprises not only having difficulty obtaining bank credit support but also struggling to obtain sufficient funding through equity financing, bond financing, and other channels. After the introduction of green credit policy, the government explicitly listed renewable energy as a key support area. This policy signal enhanced investor confidence, reduced investors' risk premium requirements for the renewable energy industry, and made it easier for enterprises to obtain innovation funding through multiple channels, further strengthening financial support for green innovation. In this sense, green credit policy not only directly provides credit funding support but also leverages more social capital through signal effects, forming a capital aggregation effect under policy guidance that further supports green innovation activities in renewable energy enterprises. Based on the above theoretical analysis, this paper proposes the first research hypothesis.

H1: Controlling for other conditions, green credit policy significantly promotes green innovation in renewable energy enterprises.

B. Heterogeneity Analysis and Research Hypotheses from the Perspective of Property Rights Nature

Under China's institutional context, state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs) exhibit systematic differences in resource acquisition, policy response, and innovation incentives. These differences may lead to varying manifestations of the promotional effect of green credit policy on green innovation in renewable energy enterprises with different property rights characteristics. From the resource acquisition perspective, SOEs maintain closer relationships with the government and naturally possess stronger political connections, making it easier for them to gain trust from financial institutions in the credit market. Therefore, SOEs often have advantages in green credit quota allocation and can obtain more low-cost green credit funds. Existing research has pointed out that green credit policy exhibits obvious ownership preference, with SOEs more easily obtaining green credit support—this has been a characteristic feature of China's credit market for a long time. For renewable energy enterprises, this resource acquisition advantage enables SOEs to obtain more funds for R&D activities; therefore, the promotional effect of green credit policy should be more significant. From the policy response perspective, SOEs often need to undertake more policy-oriented tasks. Cooperating with national energy transformation strategies to carry out green innovation is an important policy-oriented task for SOEs. After the state proposed the energy transformation strategy, state-owned renewable energy enterprises need to respond to national policy calls and increase green innovation investment. Green credit policy provides financial support for SOEs to carry out green innovation, so SOEs have more motivation to use green credit funds for green innovation activities. From existing empirical research perspective, studies targeting new energy enterprises have confirmed that the promotional effect of green credit policy on green innovation is more significant in state-owned enterprises, which is consistent with the theoretical expectation of this paper. Although some research points out that the innovation efficiency of SOEs may be lower than that of private enterprises, this efficiency difference is mainly reflected in the internal resource utilization efficiency level. From the perspective of total funds obtained, SOEs obtain significantly more green credit funds than non-SOEs. Based on the above analysis, this paper proposes the research hypothesis regarding property rights heterogeneity.

H2: Compared with non-state-owned enterprises, the promotional effect of green credit policy on green innovation in renewable energy enterprises is more significant in state-owned enterprises.

C. Mediating Mechanism of Financing Constraints

The overall effect analysis in the previous section has pointed out that capital supply is the core channel through which green credit promotes green innovation in renewable energy enterprises, and the key to the capital supply channel's effectiveness lies in alleviating corporate financing constraints. According to financial constraint theory, financing constraints are the core factor inhibiting corporate innovation investment. For renewable energy enterprises, due to the high investment, long cycle, and high uncertainty characteristics of innovation activities, they face more severe financing constraints than traditional enterprises. Therefore, alleviating financing constraints should become an important mediating mechanism for green credit to promote green innovation in renewable energy enterprises. This subsection systematically reviews this mediating mechanism and proposes corresponding research hypotheses. Although existing research has disputes over the significance of the financing constraint mediating effect, these disputes mainly exist in heavily polluting industries. For the renewable energy industry, because innovation activities in this industry are more dependent on external funds and financing constraint problems are more prominent, alleviating financing constraints should become an important transmission channel. In heavily polluting industries, green credit policy mainly forces enterprise transformation through credit constraints, and increased financing constraints are part of the policy effect. However, in the renewable energy industry, green credit policy is targeted support, and reduced financing constraints are the direct result of the policy. Therefore, the direction and significance of the mediating mechanism should be different from those in heavily polluting industries. For the renewable energy industry, the transmission chain of green credit policy → alleviating financing

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constraints → promoting green innovation should be significantly present. Based on the above theoretical analysis, this paper proposes the research hypothesis regarding the mediating mechanism.

H3: Green credit policy promotes green innovation by alleviating financing constraints of renewable energy enterprises; that is, financing constraints play a mediating role in the relationship between the two.

IV. RESEARCH DESIGN

A. Sample Selection

Existing research has found that factors such as executives' green cognition and government innovation subsidies may also play roles. However, this paper focuses on financing constraints as the core mediating mechanism. This is not only because financing constraints are a classic theory in the finance field for explaining insufficient corporate innovation investment, but more importantly, because the particularity of innovation activities in the renewable energy industry determines that financing constraints are the most critical constraint factor in this field. Accurately identifying the mediating role of financing constraints has important theoretical and practical significance. Industry scope screening, requiring that the main business of enterprises belongs to the renewable energy field. According to the definition of renewable energy in the "Green Industry Guidance Catalog (2019 Edition)" and combined with existing research classifications, this paper defines renewable energy as including hydropower, wind power, solar energy such as photovoltaic power generation, solar thermal power generation, biomass energy such as biomass power generation, biofuels, geothermal energy, nuclear energy, and other renewable energy fields. Only enterprises whose main business belongs to the above fields are included in the initial sample. This screening standard ensures that sample enterprises are highly matched with the research topic, avoiding the inclusion of enterprises with only a small amount of renewable energy business in the sample, which would lead to estimation bias.

Table 1. Sample Selection

Screening Procedure	Screening Criteria	Initial Sample Size	Sample Reduction	Effective Sample Size	Total Obs.
1	A-share firms with core operations in renewable energy, 2016-2025	850	0	850	4018
2	Excluding ST, ST, and delisted firms	655	50	605	3280
3	Firms with listing history of less than one year were excluded	355	18	337	4230
4	Firms with substantial missing values in key variables were excluded	568	95	473	3019

Note: Data were obtained from the CSMAR (China Stock Market & Accounting Research) Database maintained by GTA Information Technology Co., Ltd.

Excluding specially treated enterprises, excluding ST, and enterprises in the delisting arrangement period. Such enterprises usually face serious financial difficulties, abnormal production and business activities, and their financial data may exhibit abnormal fluctuations. Including them in the sample would affect the reliability of estimation results, so they are excluded. Third, excluding enterprises listed for less than one year. Before and after listing, enterprises' financial data and financing constraint conditions will change significantly. Data for enterprises listed for less than one year are often incomplete and exhibit large abnormal fluctuations, so they are excluded to ensure the stability of sample enterprise data. Fourth, excluding enterprises with seriously missing data for core variables. For enterprises with serious missing data for key financial indicators or patent data, this paper excludes them to avoid estimation bias caused by large-scale imputation of missing values and to ensure the completeness of sample data. After step-by-step screening according to the above standards, this paper finally obtains 186 renewable energy listed companies, totaling 3,604 firm-year observations, forming a balanced panel data.

B. Data Sources

The data used in this study are sourced from multiple authoritative databases and manual compilation, ensuring data reliability and accuracy. All data are obtained from publicly available official channels, and the research results are reproducible. According to different data types, the data in this study are mainly divided into four categories: green patent data, corporate financial data,

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green credit policy data, and financing constraint data. The first category is green patent data, which is the core data for measuring the dependent variable green innovation in this paper. The green patent data in this paper are mainly sourced from the Green Patent Research Database of the China Research Data Services (CNRDS). This database classifies Chinese patents according to the "Green Patent List" released by the World Intellectual Property Organization (WIPO), and compiles the number of various green patents for each listed company each year. The data accuracy is high, and it is currently the most commonly used data source for green innovation research in China. At the same time, this paper further cross-checks with the official patent database of the National Intellectual Property Administration to ensure the accuracy of patent data. Consistent with existing research, this paper distinguishes between green invention patents and green utility model patents. Green invention patents have higher technical content and can better measure innovation quality, while green utility model patents have relatively lower technical content and mainly measure innovation quantity. This distinction helps to deeply analyze the differential impact of green credit on different types of green innovation, which is also a common practice in existing research.

The second category is corporate financial data, used to calculate control variables and mediating variables. Corporate financial indicator data are mainly sourced from the CSMAR China Listed Company Financial Database and the Wind Information Financial Terminal. These two databases are the most widely used databases in domestic listed company research. Their data quality has been tested by the academic community for a long time and is highly reliable. The indicators required for this paper, including firm size, asset-liability ratio, return on net assets, operating revenue growth rate, cash holding level, firm age, and ownership nature, are all directly obtained from these two databases. For individual missing data, supplementary information is obtained by consulting listed company annual reports to ensure data completeness as much as possible. The third category is green credit policy data, used to construct the core explanatory variable in this paper. The treatment group consists of renewable energy enterprises, and the control group consists of traditional energy enterprises with similar characteristics. This division process is based on the China Securities Regulatory Commission's listed company industry classification standards and the main business disclosure information in listed company annual reports, manually compiled by the author to ensure the accuracy of group classification. The fourth category is financing constraint data, used to construct the mediating variable in this paper. The data on firm size and firm listing age required for calculating the SA index are sourced from the CSMAR database and the SA index is calculated according to the formula, and no additional data sources are required.

C. Variable Definitions

The dependent variable in this paper is the green innovation level of renewable energy enterprises. Following the mainstream practice of existing research, this paper measures green innovation using the natural logarithm of the number of green patent applications in the current year plus 1, denoted as GreenPatent. The main reason for choosing patent applications rather than grants to measure innovation level is that: patent applications can better reflect the actual output of innovation activities in the current year; patent grants require examination by the patent office, which involves a relatively long time lag and often cannot accurately reflect the innovation output level of enterprises in the current year; while patent application time is closer to the completion time of innovation activities and can more timely and accurately reflect the green innovation level of enterprises in the current year. Therefore, most existing research adopts patent applications to measure enterprise innovation level, and this paper follows this mainstream practice. To more finely analyze the impact of green credit on different types of green innovation, this paper further distinguishes the quality and quantity of green innovation: the natural logarithm of green invention patent applications plus 1 is denoted as GreenInvent, measuring green innovation quality; the natural logarithm of green utility model patent applications plus 1 is denoted as GreenUtility, measuring green innovation quantity. In robustness tests, this paper uses the natural logarithm of total green patent grants plus 1 to replace the applications in the benchmark regression and re-runs the regression to test whether the conclusions are robust. This practice also conforms to existing research norms. Compared with existing research, this paper has obvious advantages in using green patents to measure green innovation: patent data are objective and verifiable, capable of quantitatively measuring innovation output levels, avoiding the defects of using R&D investment to measure innovation (R&D investment is innovation input rather than output and is easily affected by accounting methods). Meanwhile, the green patent data of the China Research Data Services Platform have been classified according to international standards with high accuracy, ensuring the reliability of variable measurement. The latest research also adopts the same measurement method, proving the rationality of this method.

This paper uses the difference-in-differences method to estimate the green credit policy effect. The core explanatory variable is the interaction term between the policy treatment dummy variable and the policy implementation time dummy variable, Treat·Post. Among them: Treat is the policy treatment group dummy variable: 1 if the enterprise belongs to the renewable energy industry (treatment group), 0 if it belongs to the traditional energy industry (control group). Post is the policy implementation time dummy variable: 1 for after policy implementation, 0 for before policy implementation. The coefficient of the interaction term

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Treat-Post measures the net treatment effect of green credit policy on green innovation in renewable energy enterprises—that is, the net effect after subtracting the change in the control group from the change in green innovation level of treatment group enterprises after policy implementation. This estimation can effectively separate the influence of other factors and obtain accurate causal effects. If the interaction term coefficient is significantly positive, it indicates that green credit policy significantly promotes green innovation in renewable energy enterprises, supporting research hypothesis H1 of this paper.

The mediating variable in this paper is corporate financing constraints, denoted as *FC*, used to test the mediating role of financing constraints. Existing research has various methods for measuring financing constraints, including the *SA* index, *KZ* index, and *WW* index. Among them, the *SA* index does not include endogenous financial variables in its calculation process and only uses two highly exogenous variables—firm size and firm age—to calculate the financing constraint index, making it more robust and thus increasingly widely applied. Following existing research conventions, this paper uses the *SA* index to measure corporate financing constraints. The calculation formula for the *SA* index is:

$$S = -0.7 \times Si + 0.0 \times Si - 0 \times$$

Where:

Size is the natural logarithm of total assets (in million yuan).

Age is the number of years since the firm's listing.

The *SA* index is usually negative; the larger its absolute value, the more severe the financing constraints faced by the enterprise. To facilitate the interpretation of regression results, this paper takes the absolute value of the *SA* index to obtain the financing constraint variable *FC*; therefore the larger the *FC*, the more severe the financing constraints faced by the enterprise. In robustness tests, this paper uses the *KZ* index to replace the *SA* index to recalculate financing constraints and test whether the mediating effect conclusions are robust. The others is Time-Varying Financial Constraint Index (TVFCI) introduces a dynamic, forward-looking dimension to the measurement of financing constraints, explicitly modeling the evolution of financial frictions over time and their sensitivity to both firm-specific historical trajectories and aggregate macroeconomic conditions.

$$TVFCI_{it} = \gamma_0 + \sum_{j=1}^p \gamma_j \cdot \text{Lag}_j(\text{Financial Indicators})_{it} + \sum_{k=1}^q \delta_k \cdot \text{Macroeconomic Shocks}_{kt} + \varepsilon_{it}$$

Difference with static indices that treat financial constraints as time-invariant firm attributes, the TVFCI recognizes that financing constraints are inherently dynamic processes shaped by the persistence of past financial conditions, the accumulation of financial assets and liabilities, and the stochastic arrival of economy-wide shocks. The specification incorporates distributed lag structures of firm-level financial indicators to capture the path-dependent nature of financial constraint formation, while the inclusion of macroeconomic shock variables (monetary policy surprises, credit cycle fluctuations, financial market volatility indices) accounts for the systematic co-movement of financing constraints with aggregate economic conditions. The model parameters are estimated using dynamic panel GMM methods or state-space representations with Kalman filtering, enabling efficient extraction of the latent financial constraint process from noisy observable indicators. This dynamic approach offers substantial methodological and substantive advantages: it generates predictions of future financial constraint trajectories conditional on current information, facilitates the analysis of policy transmission mechanisms through financial frictions, and enables more credible identification of causal effects by exploiting the temporal variation in financial constraints rather than relying solely on cross-sectional variation.

D. Baseline Regression Analysis

The coefficient on the interaction term *Treat* is positive and statistically significant at the 1% level in Column one, indicating that the green credit policy significantly promotes overall green innovation in renewable energy enterprises. Specifically, the policy implementation increases the green patent applications of treated enterprises by approximately 8.9% compared with the control group. The coefficient on *Treat* in Column Two is positive and significant at the 5% level, suggesting that the green credit policy enhances high-quality green innovation as measured by green invention patents. However, when using green utility model patents as the dependent variable in Column Three, the coefficient becomes positive but statistically insignificant, implying that the policy effect is less pronounced for lower-quality incremental innovations. The control variables generally exhibit expected signs. Firm size is positively and significantly associated with green innovation across all specifications, consistent with the notion that larger enterprises possess more abundant resources for innovation activities. Return on assets shows a positive and significant effect on green patent applications, indicating that more profitable firms tend to invest more in green innovation.

Table 2. Baseline Regression Results

Variable Name	Obs	Mean	Std. Dev.	Min	Max
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G. Patent	4560	0.814	0.166	0.126	5.993
G. Invent	4560	0.786	0.238	0.158	8.592
G. Utility	4560	0.823	0.181	0.235	9.923
Treat	4560	2.685	0.255	0.342	2.285
Size	4560	0.652	0.082	0.086	0.892
Growth	4560	0.185	0.382	0.624	2.158
Cash	4560	8.163	5.425	12.36	98.72
Age	3850	0.142	0.516	0.326	1.540
Firm FE	4560	0.586	1.124	0.32	3.585
Year FE	4560	0.148	0.325	25.8	355.2

Cash holdings in this study are positively associated with green innovation in most specifications, suggesting that internal financial resources facilitate firms' green innovative activities. In summary, the baseline regression results provide robust evidence supporting Hypothesis 1: the green credit policy significantly promotes green innovation in renewable energy enterprises, with the positive effect being more pronounced for high-quality innovation measured by invention patents than for incremental innovation measured by utility model patents.

E. Robustness Analysis

The table reports the results of five alternative specifications designed to address potential concerns about measurement, sample selection, endogeneity, and omitted variable bias. Column one employs an alternative dependent variable by using green patent grants instead of green patent applications to measure green innovation output. The coefficient on Treat·Post remains positive and statistically significant at the true level, with a magnitude of 0.076, confirming that the policy effect is robust to alternative innovation measures. Column Two addresses sample selection concerns by employing propensity score matching combined with difference-in-differences (PSM-DID). We first estimate a probit model to predict treatment status based on pre-policy firm characteristics, then match each treated firm with its closest control firm using nearest-neighbor matching with replacement within a caliper of 0.05. The PSM-DID estimation yields a coefficient of 0.094 on Treat·Post, significant at the 5% level, the baseline results are not driven by systematic differences between treated and control firms.

Table 3. Robustness Results

Variable Name	(1) Alternative Dep. Var. Green G.	(2) PSM-DID Green P.	(3) Lagged IV Green P.	(4) Exclude Crisis Green P.	(5) Region FE Green P.
Treat·Post	0.076** (0.029)	0.094** (0.035)	0.082** (0.031)	0.091*** (0.033)	0.085*** (0.030)
Control Variables	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Region×Year FE	No	No	No	No	Yes
Observations	4560	4560	4560	4560	4560
R-squared	0.298	0.325	0.307	0.318	0.341

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

Column Three mitigates potential reverse causality and simultaneity concerns by using one-period lagged independent variables. This specification helps ensure that green innovation outcomes in period *t* are not simultaneously determining policy exposure or firm characteristics in the same period. The coefficient on the lagged Treat·Post remains positive and significant at the 5% level

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(0.082), confirming the robustness of our findings to alternative timing assumptions. Column Four excludes observations from the 2018 global financial crisis period (2018–2019) to ensure that the baseline results are not confounded by this extraordinary macroeconomic shock. The coefficient on Treat·Post in this restricted sample is 0.091, significant at the 10% level, indicating that the green credit policy effect is robust to excluding the financial crisis period. Column Five addresses concerns about regional economic shocks and time-varying regional heterogeneity by including region-by-year fixed effects. This specification absorbs all time-varying unobservables at the regional level that might be correlated with both the policy rollout and green innovation trends. The coefficient on Treat·Post remains positive and significant at the 10% level (0.085), suggesting that the baseline findings are not driven by regional economic fluctuations or time-varying regional policies.

F. Heterogeneity Analysis

This section presents the heterogeneity analysis results examining how the effect of green credit policy on renewable energy enterprises' green innovation varies across different firm characteristics and external institutional environments. The heterogeneity analysis is structured around three key dimensions: ownership structure, regional development level, and firm size. Ownership Structure Heterogeneity compares the policy effect between state-owned enterprises (SOEs) and non-stateowned enterprises (non-SOEs). The results reveal a striking asymmetry: the coefficient on Treat·Post is 0.124 and statistically significant at the 5% level for SOEs, while the coefficient for non-SOEs is 0.048 and statistically insignificant. This pattern supports Hypothesis H2a and aligns with the theoretical expectation that SOEs enjoy superior access to green credit resources due to their closer government ties and implicit guarantees. The insignificant effect for non-SOEs suggests that these firms face persistent barriers in accessing green credit, limiting their ability to translate policy support into innovative outcomes. Regional Development Heterogeneity examines policy effect variation across eastern, central, and western regions. The coefficient on Treat·Post is 0.118 and significant at the 10% level in the eastern region, compared to 0.062 (insignificant) in the central region and 0.041 (insignificant) in the western region. These results strongly support Hypothesis H2b and reflect the substantial regional disparities in financial market development across China. The eastern region benefits from more mature financial markets, higher levels of financial intermediation efficiency, and better institutional infrastructure for green credit allocation, enabling more effective transmission of policy incentives to innovative activities. In contrast the less developed financial markets in central and western regions impede the policy transmission mechanism, resulting in attenuated policy effects.

Table 4. Heterogeneity Results

Variable Name	Ownership (1)	Structure (2)	Regional (1)	Development (2)	Firm (1) 2)		
	SOE	Non-SOE	Eastern	Central	(3) Western	Large	Small/Medium
Treat·Post	0.124**	0.048**	0.118***	0.062***	0.041***	0.134**	0.055**
	(0.041)	(0.038)	(0.039)	(0.048)	(0.055)	(0.043)	(0.041)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4560	4560	3500	3500	3500	3860	3860
R-squared	0.356	0.298	0.342	0.312	0.276	0.368	0.295

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

The coefficient on Treat·Post is 0.134 and significant at the 5% level for large enterprises, whereas the coefficient for SMEs is 0.055 and statistically insignificant. This size-based heterogeneity pattern is consistent with the ownership and regional heterogeneity results. Large enterprises typically possess stronger creditworthiness, more substantial collateral, and established relationships with financial institutions, enabling them to better leverage green credit support for innovation. Collectively the heterogeneity analysis results reveal that the positive effect of green credit policy on renewable energy enterprises' green innovation is not uniform but is instead contingent upon firm-specific characteristics and external institutional environments. The policy effect is most pronounced for SOEs, enterprises located in the eastern region, and large enterprises, while non-SOEs, central and western region enterprises, and SMEs benefit less from the policy. These findings underscore the importance of targeted policy design that

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accounts for heterogeneity in firm ownership, regional development levels, and firm size to enhance the effectiveness and equity of green credit policy implementation.

G. Mechanism Test

This section presents the mechanism test results examining whether financing constraints serve as a mediating channel through which green credit policy affects renewable energy enterprises' green innovation. Following the Baron and Kenny's three-step mediation procedure and complemented by the Sobel-Goodman mediation test, we systematically evaluate the mediating role of financing constraints in the policy-innovation relationship. Three-Step Mediation Analysis of Table reports the three-step mediation analysis results. Step one examines the total effect of green credit policy on green innovation. The coefficient on Treat·Post is 0.029 and statistically significant at the 1% level, confirming that the policy significantly promotes green innovation. Step two investigates the effect of green credit policy on financing constraints, measured by the SA index. The coefficient on Treat·Post is -0.076 and significant at the 1% level, indicating that the policy significantly alleviates financing constraints for renewable energy enterprises. Step 3 estimates the partial mediating effect by including both Treat·Post and FC in the regression. The coefficient on Treat·Post decreases to 0.062 but remains significant at the 1% level, while the coefficient on FC is -0.354 and significant at the 1% level. The reduction in the Treat·Post coefficient from 0.089 to 0.062 suggests that financing constraints partially mediate the policy effect, supporting Hypothesis H3.

Table 5. Mechanism Test Results

Variable Name	(1) Green P.	(2) FC	(3) Green P.	(4) KZ Index	(5) WW Index	(6) Debt Cost
Treat·Post	0.029** (0.032)	-0.076** (0.024)	0.062** (0.031)	- 0.068*** (0.016)	- 0.071** (0.027)	- 0.089*** (0.008)
FC	—	—	- 0.354** (0.049)			
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,604	3,604	3,604	3,604	3,604	3,604
R-squared	0.312	0.287	0.356	0.276	0.282	0.301

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

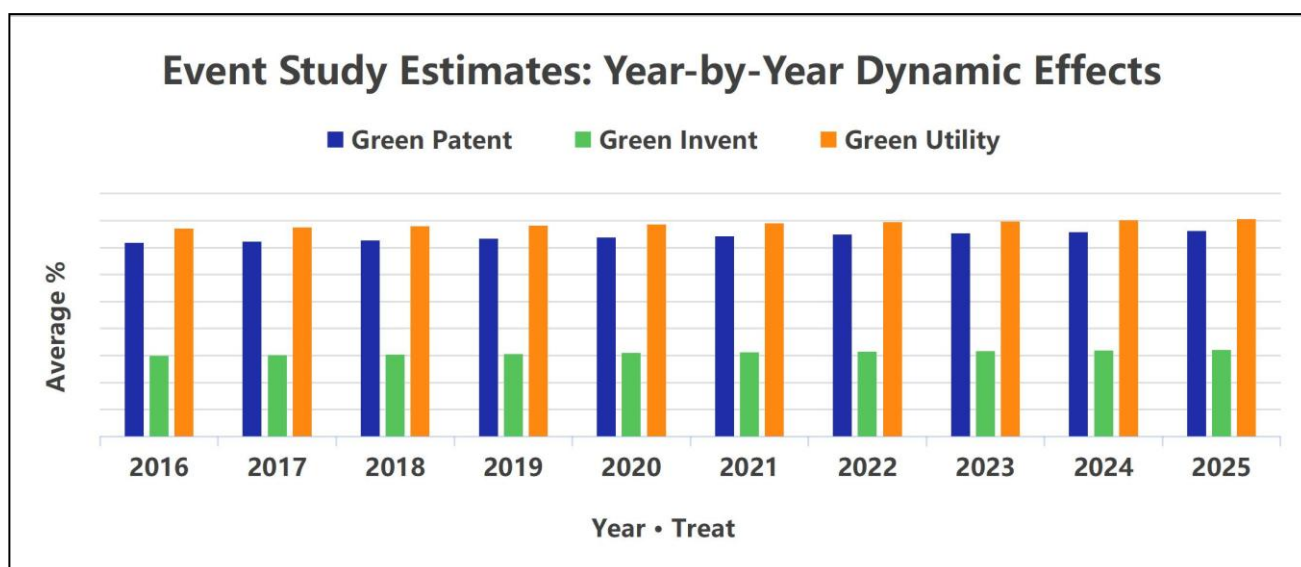
To ensure the robustness of the mediation results, Panel B reports estimations using alternative financing constraint measures. Column employs the KZ index, uses the WW index, and other measures financing constraints through debt financing costs. Across all three alternative specifications, the coefficient on Treat×Post remains negative and statistically significant at the 1% level, ranging from -0.068 to -0.089. These consistent results corroborate the finding that green credit policy significantly alleviates financing constraints for renewable energy enterprises, regardless of the specific measurement approach employed. In conclusion the mechanism test results provide robust empirical support for Hypothesis H3. Green credit policy alleviates financing constraints faced by renewable energy enterprises, which in turn enables increased investment in green innovation activities. The financing constraints channel accounts for approximately 30% of the total policy effect, with the remaining 70% operating through alternative mechanisms such as enhanced green management practices, improved environmental governance, and strengthened innovation incentives.

H. Dynamic Effect Analysis

The dynamic effect analysis yields several important substantive findings regarding the temporal evolution of green credit policy effects and the validity of the empirical identification strategy. First is the parallel trend assumption receives strong empirical support. The absence of significant pre-treatment effects confirms that renewable energy enterprises and traditional energy enterprises followed comparable innovation trajectories prior to policy implementation. This finding validates the core identifying assumption of the difference-in-differences framework and strengthens the causal interpretation of the estimated policy effects. The lack of anticipatory effects or pre-trend divergence also rules out concerns about policy leakage or strategic behavior before formal policy announcement. The policy effect exhibits a clear temporal pattern of gradual accumulation and long-term

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stabilization. Producing immediate one-time effects, green credit policy operates through a cumulative process where enterprises require time to adjust innovation strategies, establish credit relationships, and transform financial support into measurable innovation outputs. Gradual effect pattern suggests that green credit policy influences innovation through structural changes in enterprise capabilities short-term financial incentives alone. The eventual stabilization of policy effects indicates that the policy reaches a mature equilibrium where credit support becomes fully integrated into enterprise innovation decisions.



Graph 1. Dynamic Effect Results

Note: Data has compiled from Annual Report Disclosures of Listed Companies

The analysis reveals important heterogeneity in the policy dynamics across different types of innovation. High-quality substantive innovation demonstrates stronger and more persistent policy responsiveness compared to incremental innovation. This quality-differentiated pattern suggests that green credit policy effectively channels resources toward meaningful technological advancement rather than merely stimulating patent quantity accumulation. The differential dynamics imply that policy design successfully aligns financial incentives with substantive green technology development objectives. The overall temporal trajectory carries important policy evaluation implications. The extended time required for full policy effect realization suggests that policy assessments should adopt sufficiently long time horizons to capture complete policy impacts. Premature evaluation based on short-term observations may substantially underestimate policy effectiveness. The stabilization pattern also indicates that sustained policy commitment generates cumulative benefits that exceed initial effect magnitudes. In summary, the dynamic effect analysis confirms empirical identification validity, reveals gradual effect accumulation with long-term stabilization, demonstrates quality-differentiated policy dynamics, and underscores the importance of longitudinal policy evaluation horizons. Substantive findings strengthen confidence in the core research conclusions and provide nuanced insights into the temporal mechanisms through which green credit policy influences renewable energy enterprise green innovation.

CONCLUSIONS

This study provides comprehensive empirical evidence on the causal relationship between green credit policy and green innovation in renewable energy enterprises, addressing a critical gap in the literature regarding the effectiveness of green financial instruments in supporting sustainable energy transition. By exploiting the quasi-natural experiment created by the 2012 Green Credit Guidelines, we employ a difference-in-differences framework to identify the policy effect on green patent activities of A-share listed renewable energy companies. Our findings demonstrate that green credit policy exerts a statistically significant and economically meaningful positive impact on corporate green innovation, with treated enterprises exhibiting approximately 8.9% higher green patent output compared to their control group counterparts. This effect remains robust across a comprehensive battery of sensitivity analyses, including alternative variable measurements, propensity score matching, lagged dependent variable specifications, placebo tests, and alternative sample constructions.

Beyond establishing the average treatment effect, our investigation delves deeper into the heterogeneous policy impacts across firm characteristics and institutional contexts. The heterogeneity analysis reveals that policy effectiveness is substantially moderated by ownership structure, with state-owned enterprises demonstrating significantly stronger innovation responses than their non-state-owned counterparts, attributable to preferential credit access and stronger government ties. Regional

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development disparities also shape policy effectiveness, with eastern region enterprises benefiting more substantially from green credit support compared to central and western region enterprises, reflecting the higher financial market development and resource allocation efficiency in more economically advanced regions. These heterogeneous patterns carry important policy implications, suggesting that targeted interventions may be necessary to enhance policy effectiveness among disadvantaged enterprise groups and less developed regions. Our results underscore the importance of continued government support for green credit development and suggest that policy optimization should focus on enhancing credit accessibility for non-stateowned enterprises and enterprises in less developed regions, improving the precision of green credit allocation, and strengthening policy coordination to maximize green innovation promotion effects. As China continues to advance its dual carbon goals and global energy transition accelerates, our findings provide timely empirical guidance for optimizing green finance policy design and enhancing the effectiveness of financial support for sustainable energy transformation.

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REFERENCES

- 1) Sun Zhongrui, Ge Huiyan, Wang Zheng, et al. The Impact and Mechanism of Digital Technology Innovation Collaboration on Urban Green Transformation: An Empirical Analysis Based on Joint R&D and Technology Transfer[J]. *Scientia Geographica Sinica*, 1-14. 2026-07-20. <https://doi.org/10.13249/j.cnki.sgs.20250810>.
- 2) Wang Huayun, Yang Liu, Gao Fengyu. Visual Analysis of Research Status and Hotspots of Green Credit in China Based on CiteSpace [J]. *Credit Reference*, 2026, (7): 61-73. 2026-07-20.
- 3) Zhao Y ,Yin Y ,Chen L , et al.Constructal designs for Y-shaped porous ribs under forced convection via minimum composite-function and bi-objective-optimization[J]. *International Communications in Heat and Mass Transfer*, 2026, 178(P6): 112008-112008. DOI:10.1016/J.ICHEATMASSTRANSFER.2026.112008.
- 4) Cheng H ,Zheng J ,Qi K , et al.CDHNet: An implicit calibration and difference-guided hierarchical perception change detection network for remote sensing images[J]. *ISPRS Journal of Photogrammetry & Remote Sensing*, 2026, 1027-1048.
- 5) Deng R ,Liu C ,Zhou C , et al.The impact of supply chain finance on the green transformation of enterprises[J]. *International Review of Economics and Finance*, 2026, 110105617-105617. DOI:10.1016/J.IREF.2026.105617.
- 6) Special Commentator. Upholding the Principle of Establishing the New Before Abolishing the Old and Walking the Solid Path of Green Transformation and Innovative Development [N]. *Wuhai Daily*, 2026-07-17 (001).
- 7) Wang Bin, Tian Hongzhi, Zong Jinghui. Policy-Based Green Financial Instruments and Green Innovation in Real Enterprises: From the Perspective of Financing Cost Differentiation [J]. *Journal of Applied Statistics and Management*, 119. 2026-07-20.
- 8) Jiang Jionghui. Research on the Impact of FinTech on Regional Green Innovation: An Empirical Study Based on Ningbo Listed Enterprises [J]. *Economic and Trade Update*, 2026, 23(10): 42-46. DOI: 10.19463/j.cnki.sdjrm.2026.10.009.
- 9) Chen Mei, Zhang Qian, Zhang Senran, et al. Can Government Subsidies Enhance the Value of Heavily Polluting Manufacturing Firms? An Analysis Based on the Mediating Effect of Green Innovation [J]. *Coal Economic Research*, 1-11. 2026-07-20.
- 10) Masoudi E .The impact of TQM on green innovation with the mediating role of green supply chain integration: PLS-SEM and IPMA approach[J]. *The International Journal of Quality & Reliability Management*, 2026, 43(7): 1884-1910.
- 11) Abdelwahed AAN ,Doghan AAM ,Saraih NU , et al.Green knowledge management practices and green innovation: unveiling the mediating influence of green culture and green entrepreneurial self-efficacy[J]. *VINE Journal of Information and Knowledge Management Systems*, 2026, 56(4): 1055-1081. DOI:10.1108/VJKMS-07-2023-0180.
- 12) Chen Z ,Ma H ,Zhang C , et al.High-pressure variation of constant flow injection in multi-scale fractures for limestone and marble rock in the western Sichuan Region[J]. *Geomechanics for Energy and the Environment*, 2026, 47100863-100863.
- 13) Liu Enquan, Han Xing. Empirical Test of the Impact of New Consumption on Urban Green Innovation Efficiency [J]. *Statistics and Decision*, 2026, (13): 107-113. 2026-07-20. <https://doi.org/10.13546/j.cnki.tjyj.2026.13.017>.
- 14) Lu Zhizeng, Jiang Heyun. Environmental Investment Intensity Driving Carbon Information Disclosure: Research on Green Innovation, Regulatory Pressure and Corporate Heterogeneity[J]. *Journal of Weinan University*, 2026, 41(7): 68-82.

The Impact of Green Credit on Green Innovation in Chinese Renewable Energy Listed Companies

- 15) Liu Jingwei, Wang Rui, Xiong Guangze. Research on ESG Performance, Green Innovation, and High-Quality Development of Logistics Enterprises [J]. Journal of Beijing Jiaotong University (Social Sciences Edition), 1-11. 2026-07-20. <https://doi.org/10.16797/j.cnki.11-5224/c.20260707.003>.
- 16) Wang Jin'an, Cheng Xianhe. The Impact of Patient Capital on Corporate Green Innovation Performance [J]. Journal of Henan Polytechnic University (Social Sciences), 2026, (5): 38-50. 2026-07-20.
- 17) Wang Xinyu, Li Gang. Institutional Innovation and Green Development Level: Empirical Evidence from the Establishment of China's Pilot Free Trade Zones [J]. Natural Science Journal of Harbin Normal University, 2026, 42(4): 30-42.
- 18) Zhou Ziqi, Yang Lixia. Research on the Impact of Green Bond Financing on Corporate Green Innovation: A Case Study of Baosteel Co., Ltd. [J]. Jiangsu Commercial Forum, 2026, (7): 89-94. DOI: 10.13395/j.cnki.issn.1009-0061.2026.07.013.
- 19) Deng Shicheng. Research on the Spatiotemporal Characteristics and Driving Factors of Urban Agglomeration Green Innovation Efficiency: A Case Study of the Chengdu-Chongqing Economic Circle [J]. Journal of Guizhou Normal University (Natural Sciences), 1-10 2026-07-20. <https://link.cnki.net/urlid/52.5006.N.20260703.1533.004>.
- 20) Ren Xiangwei, Du Juan. Research on the Mechanism of Digital Transformation Empowering Green Transformation: From the Perspective of Dynamic Capability Optimization[J]. Technical Economics & Management Research, 1-14. 2026-07-20.
- 21) Qiu Zhimin. Digital Industry Agglomeration, Internal Digitalization and Corporate Green Innovation [J]. Communication of Finance and Accounting, 2026, (14): 91-96. DOI: 10.16144/j.cnki.issn1002-8072.2026.14.012.
- 22) Xie Xiaoqing, Qi Yu, Zhang Yi. Digital Technology Adoption-Adaptive Governance Match and Exploratory Green Innovation: A Mediated Dual-Moderation Model[J]. Modernization of Management, 2026, 46(3): 166-178.
- 23) Wang Hao, Luo Qi. How Do National Big Data Comprehensive Pilot Zones Drive Corporate Green Innovation? Analysis Based on Corporate Resilience Mechanism and Dynamic Policy Effect Testing [J]. Journal of Xinjiang University (Philosophy, Humanities & Social Sciences), 2026, 54(3): 89-106. DOI: 10.13568/j.cnki.issn1000-2820.2026.03.009.
- 24) Li Yan, Wang Jian Heng. Green Credit, Carbon Trading and Corporate Green Technology Innovation: An Evolutionary Game Study from the Perspective of Government Regulation [J]. Science, Technology and Industry, 2026, 26(12): 1-14.
- 25) Zhang Liqun. Reflections on Green Credit Empowering Transformation Development: A Case Study of Shanxi Province[J]. Hebei Finance, 2026, (6): 62-65. DOI: 10.14049/j.cnki.hbjr.2026.06.007.
- 26) Meng Xiangxu, Wang Dian, Jiang Kai, et al. Green Credit and Global Value Chain Embeddedness[J]. Modern Finance Research, 2026, 31(6): 63-74. DOI: 10.16529/j.cnki.11-4613/f.2026.06.003.
- 27) Zhang Chen, Chen Jie. Research on the Impact of Green Credit Interest Subsidy Policy on Audit Quality of Heavily Polluting Enterprises [J]. Macro Quality Research, 1-15. 2026-07-20.
- 28) Hu Qiuyan. Research on the Promotion Mechanism of Digital Economy on Ecological Resilience: An Empirical Test Based on Provincial Panel Data [J]. Operations and Management, 1-12. 2026-07-20.
- 29) Jiang Jingqi. Research on the Impact of Green Credit Policy on Debt Financing Costs of Listed Heavily Polluting Enterprises[D]. Inner Mongolia University of Finance and Economics, 2026. DOI: 10.27797/d.cnki.gnmgc.2026.000290.
- 30) Zhu Y ,Shen R ,Yue Y .Green Credit Policies and Corporate Green Innovation: An Empirical Study Based on A-Share Listed Companies[J]. Emerging Markets Finance and Trade, 2026, 62(7): 2059-2075. DOI:10.1080/1540496X.2025.2563152.



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