



Solving the mystery of debt financing for new energy firms: a quasi-natural experiment from a market-based environmental regulation

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Abstract

Against the global drive to combat climate change and advance sustainable development, green credit has emerged as a pivotal financial instrument, directing capital toward new energy sectors and fueling eco-friendly economic transitions. This study investigates the impact of green credit policy (GCP) on the scale and cost of debt financing among Chinese new energy enterprises, utilizing 2009–2022 data and a difference-in-differences methodology. Distinct from prior green finance research—which rarely targets new energy enterprises despite their critical role in carbon neutrality—we focus explicitly on this understudied group. The findings indicate GCP significantly expands new energy enterprises' debt financing scale while lowering costs, thereby supporting the new energy sector's high-quality development. Furthermore, GCP's effects vary by ownership: state-owned enterprises gain more from expanded financing scale, whereas non-state-owned firms benefit more from reduced financing costs. Regionally, eastern and central areas excel in lowering debt financing costs, whereas the western and northeastern regions stand out in expanding the financing scale. An analysis of the mechanisms reveals that GCP strengthens new energy companies' financing capabilities by easing financial constraints, boosting investment efficiency, and increasing returns. These findings offer empirical insights into the real impacts of GCP, providing valuable guidance for enhancing green finance strategies.

Keywords Green credit policy · New energy enterprises · Debt financing · Green transformation

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1 Introduction

The widespread use of fossil fuels under the development mode of industrial civilization has made the global climate change problem increasingly serious. Extreme weather events caused by climate warming, environmental pollution, and ecological damage caused by resource shortage are becoming increasingly frequent (Lee et al., 2023a, b). Numerous countries and regions are seeking a green transformation of their economic and social development, from relying on energy-intensive traditional energy sources to green new energy sources and from inefficient to efficient energy use, to cope with a series of environmental challenges. Under these circumstances, advancing new energy sectors has emerged as a crucial element in achieving this transition. The renewable energy sector not only contributes to optimizing the energy infrastructure and enhancing energy security but also plays a vital role in lowering greenhouse gas emissions and addressing climate change (Zhang et al., 2024; Lin et al., 2023). As the world's top energy consumer, China has committed to reaching peak carbon emissions by 2030 and achieving carbon neutrality by 2060. This initiative underscores the strategic significance of the renewable energy sector within national policy. However, the development of new energy industry requires a significant amount of upfront investment and has high technological and financial thresholds, which makes financing a major bottleneck restricting its development (Zhang et al., 2022a, b). Notably, while green credit is widely recognized as a solution to such financing challenges, existing green finance research rarely focuses on new energy enterprises—entities with unique needs (e.g., long payback cycles, high technological risks) that differ fundamentally from heavily polluting firms or even other green industries. This gap limits the design of targeted policies for new energy development. Growth in the new energy sector and the financing of these enterprises are mutually supportive; a robust financial environment can strengthen funding for the new energy industry, foster technological advancements, drive industrial upgrades, and create a positive feedback loop (Li et al., 2025; Lv et al., 2023).

Green credit, an innovative financial tool, has emerged as a solution to address the financing problem of new energy industry. This tool not only helps enterprises obtain the funds needed for development by providing preferential loan conditions and directing funds to green industries, such as new energy, but also promotes the green transformation of the economic structure (Chai et al., 2022; Wu et al., 2022). On February 24, 2012, the 'green credit policy (GCP),' issued by the former CBRC, mandated that financial institutions within the banking sector should actively work towards promoting energy conservation, reducing emissions, and enhancing environmental protection; This directive encourages financial institutions to provide loans tailored to clients' environmental and social risk profiles, expand their support for green, low-carbon, and recycling economies, and mitigate environmental and social risks. This document provides additional clarity on the standards and principles of green credit within the banking sector, offering actionable guidance for financial institutions in implementing green credit practices. In 2016, the central bank released the 'Guiding Opinions on the Construction of a Green Financial System,' outlining China's green financial framework and offering instructions for its establishment. Additionally, the Central Bank published the 'Guiding Opinions on Building a Green Financial System,' emphasizing that China's green financial growth should be guided by the policy framework of 'establishing and enhancing a green financial system. The National Development and Reform Commission, alongside other relevant government departments, developed the Green Industry

Guidance Catalogue (2019 Edition), released on February 14, 2019. This document further defined the specific types of green industries and clarified the target audience for green credit, ensuring that the green credit policy could be implemented effectively (Lee et al., 2023a, b; Cui et al., 2021). To date, the Chinese government has implemented a variety of green credit policies aimed at promoting enterprise development. Nonetheless, the concrete impacts of these policies, particularly regarding their influence on the debt financing of new energy firms, have not yet been thoroughly explored through empirical analysis (Jiang et al., 2024; Chang et al., 2019; Li et al., 2020; He et al., 2019a, b; Hu et al., 2020). In this context, the present study aims to investigate the effect of green credit policies on both the scale and cost of debt financing for new energy companies, employing a difference-in-differences approach. Additionally, this study will examine the mechanisms driving these effects and any heterogeneous outcomes associated with policy implementation. The study's findings will offer empirical insights into the real impacts of green credit policies, serving as a guide for refining green finance policies.

This study's primary contributions and innovations, as compared to prior research, are as follows: First, we examine the financial impacts of GCP implementation—specifically on corporate debt financing scale and cost—with a deliberate focus on new energy enterprises. As a less-studied group in green finance research, new energy firms' unique financing dynamics have been largely overlooked; our targeted analysis fills this gap and enriches sector-specific insights into green credit effectiveness. Second, we emphasize on the important role of financing constraints, investment efficiency, and investment return rate, which collectively amplify the effectiveness of green credit policies in expanding the debt financing capacity of enterprises within the new energy sector. Furthermore, we examine the differing impacts of green credit policy on the debt financing of new energy companies, considering enterprise ownership types and regional variations. This investigation provides valuable insights to support the efficient application of green credit policies.

2 Literature review

As a financial innovation, the concept of green credit highlights the growing focus on sustainable development and the integration of environmental considerations within economic frameworks. This approach acts as a critical green financial instrument, balancing economic advancement with environmental preservation in a given country or region by allocating credit resources in a structured manner (Li et al., 2018; Liu et al., 2017). From multiple research perspectives, the green credit policy has demonstrated a multifaceted positive influence. First, in promoting the dual benefits of economy and environment, this policy is effective in reducing carbon and other pollutant emissions and improving the economic performance of enterprises by promoting technological innovation in related industries and alleviating financial capital mismatch (Ying et al., 2025). In China, this policy has been successfully applied and promoted, significantly curtailing investments in energy-intensive sectors. This development is crucial for enhancing resource use efficiency and advancing green, low-carbon growth. Additionally, research has established that green credit significantly contributes to the growth of China's green economy. For instance, it actively supports the expansion of renewable energy sources—such as hydropower, nuclear, and wind power—thereby aiding in the transformation and modernization of the energy sector (He

et al., 2019a, b). Some scholars have proved that the green credit discount policy can effectively improve the environmental governance level of enterprises, and it can incentivize banks to increase the scale of green credit supply through the guiding role of financial funds, thus promoting the fulfillment of environmental social responsibility by enterprises (Zhou et al., 2025) .

Globally, green finance policies have evolved with distinct characteristics, offering valuable comparative insights. The EU's Sustainable Finance Taxonomy (2020), a cornerstone of regional green finance, establishes a unified classification system for green economic activities, emphasizing standardized disclosure of environmental impacts to guide capital flows and mitigate greenwashing risks (Gigante & Manglaviti, 2022). In contrast, the U.S. Clean Energy Lending Program adopts a subsidy-oriented approach, leveraging tools such as investment tax credits (ITCs) for solar and wind projects, and public-private partnerships (PPPs) for green infrastructure. This model focuses on offsetting upfront investment risks for new energy enterprises, especially small and medium-sized ones (SMEs) with limited collateral, but it exhibits strong dependence on fiscal budgets, which may constrain its long-term scalability (Duan et al., 2025; Kempa et al., 2021).

Compared with these international practices, China's green credit policies (e.g., the 2012 Green Credit Policy) feature a unique blend of regulatory mandates and market incentives. Financial institutions are required to incorporate environmental and social risk (ESG) assessments into credit approval processes, while preferential interest rates and central bank re-lending support encourage targeted funding for green industries. This model leverages the banking sector's dominance in China's financial system to ensure policy penetration, particularly in state-owned enterprises (SOEs) and large-scale new energy projects (Raimo et al., 2021; Liu et al., 2024). However, it lacks the EU's unified green activity standards and the U.S.'s market responsiveness to private capital demands, which limits its global replicability and adaptability to diverse enterprise types. The table below further summarizes the core differences between major global green finance policies (Table 1) :

Recent studies (post-2022) have enriched the field. Lv et al. (2023) found that green credit policies improve corporate green production efficiency by easing financing constraints, providing micro-level evidence for policy effectiveness. Wang et al. (2023) emphasized

Table 1 Comparison of core global green finance policie

Policy Initiative	Core Feature	Advantage	Limitation	Reference
EU Sustainable Finance Taxonomy	Unified green activity classification + mandatory environmental disclosure	High transparency, mitigates cross-border greenwashing	Heavy reporting burden for enterprises	Gigante & Manglaviti, 2022
U.S. Clean Energy Lending Program	Tax credits (ITCs) + public-private partnerships (PPPs)	Effectively reduces upfront risks for new energy SMEs	Over-reliance on fiscal budgets	Kempa et al., 2021
China Green Credit Policy (2012)	ESG risk integration in credit approval + preferential interest rates	Strong policy penetration via banking sector	Lack of unified green standards	Liu et al., 2024; Raimo et al., 2021

that investment efficiency mediates the impact of green finance on enterprise performance, underscoring the need to link financing policies with operational outcomes—a dynamic understudied in new energy sectors. Zhang et al. (2024) further revealed that new energy policies drive green technology innovation, highlighting the interplay between policy design and enterprise behavior, which remains underexplored in cross-country comparisons.

In conclusion, current research confirms the positive role of green credit in China's green development, but critical gaps persist. First, new energy enterprises have distinct financing needs: they require substantial upfront investment (Zhou et al., 2020) and rely on diverse channels (bank loans, equity, bonds, venture capital) subject to technological and geopolitical risks (Qin et al., 2022), making government policy support critical (Li et al., 2021). Second, existing studies on green credit and enterprise financing focus heavily on heavily polluting firms, with limited attention to green enterprises—especially new energy firms. Definitions of “green enterprises” remain inconsistent, and research on green credit's impact on new energy financing is scarce. Third, international policy comparisons are lacking, and recent insights from micro-level and cross-sector studies (Lv et al., 2023; Wang et al., 2023; Zhang et al., 2024) are underintegrated.

Building on this, this study focuses on new energy enterprises to address the “dual carbon” goals. Using the 2012 Green Credit Policy as a quasi-natural experiment and a difference-in-differences model, it investigates green credit's impact on their debt financing scale and cost, exploring mechanisms and heterogeneous effects. This work contributes by: (1) focusing on new energy enterprises, a understudied group; (2) integrating international policy insights to contextualize China's experience; (3) incorporating recent research to strengthen the analysis of dynamic effects.

3 Theoretical analysis and research hypothesis

3.1 Influence of green credit on the scale of corporate debt financing

Theoretically, green credit functions as a specialized financial tool rooted in correcting positive externalities, a key tenet of market failure theory. New energy projects inherently generate significant positive externalities—such as carbon emission reductions and improved environmental quality—that are not fully captured by market mechanisms alone. This disconnect often leads to insufficient investment incentives for enterprises, as they cannot fully internalize the societal benefits of their projects (Pigou, 1920). By providing targeted financial flows, green credit addresses this market failure: it bridges the gap between private returns and social benefits, encouraging enterprises to invest more in green projects by internalizing externalities through preferential terms (Xu et al., 2024).

Second, green credit alleviates credit rationing stemming from information asymmetry, a core issue outlined by Stiglitz and Weiss (1981). In financial markets, lenders and new energy enterprises frequently face information gaps due to the high uncertainty of green projects, prompting financial institutions to restrict credit to avoid adverse selection. Green credit policies mitigate this by mandating standardized disclosure of environmental risks and project feasibility (e.g., as stipulated in the 2012 Green Credit Policy), thereby reducing information asymmetry. Complemented by risk-sharing mechanisms—such as third-party guarantees—these policies lower lenders' perceived risks, encouraging them to relax credit

rationing. This dual effect (reduced information gaps and shared risks) enables financial institutions to extend larger loans, directly expanding the debt financing scale of new energy enterprises (Liu et al., 2024;; Stiglitz & Weiss, 1981).

Additionally, governments often bolster green credit through preferential policies and incentives, including tax reductions, subsidies, and direct financial support. These measures align with industrial policy theory and incentive theory: industrial policy emphasizes targeted government intervention to foster specific industries, while green credit preferences serve as a tool to accelerate green industry development. By offering more favorable lending terms, green credit policies enable new energy enterprises to secure funds more quickly, accelerating project implementation. This expedites market opportunity capture and increases the number of viable projects within a given timeframe, ultimately enhancing enterprises' overall financing capacity (Ma et al., 2024). Based on the above analysis, this study proposes the following hypothesis:

H1: The implementation of green credit will promote the growth of debt financing scale of new energy enterprises.

3.2 Influence of green credit on corporate debt financing costs

Green credit programs, such as preferential interest rates and subsidies, directly reduce financing costs by internalizing the positive environmental externalities of new energy projects, consistent with Pigou's theory of externalities (Pigou, 1920). New energy projects generate social benefits (e.g., carbon emission reductions) that are not captured in private returns, leading to underinvestment in free markets. Green credit acts as a 'corrective subsidy'—by lowering interest rates below market levels, it bridges the gap between private and social returns. This not only makes green projects more economically viable for enterprises but also aligns private incentives with societal environmental goals (Ghouma et al., 2018; Pigou, 1920). These preferential rates are often supported by government policies or financial institutions aiming to channel more investment into green industries (Raimo et al., 2021). These preferential interest rates are often supported by government policies or financial institutions that aim to channel more investment into green industries, such as new energy (Raimo et al., 2021). This tool allows new energy companies to borrow funds at lower costs for capital expenditure or operating expenses (Caragnano et al., 2020). In addition, governments may offer tax breaks, subsidies, or other financial incentives for new energy projects that use green credits. Such policies alleviate the financial strain on enterprises and decrease the effective cost of projects, indirectly lowering enterprise financing costs and improving both the appeal and economic efficiency of these projects (Ghouma et al., 2018). Furthermore, green credit helps new energy enterprises improve their financial situation and enhance their debt-servicing capacity, which may enhance their credit rating. The improved credit rating may further reduce the cost of financing for enterprises in the market, which is not limited to green credit but also covers other forms of financing, such as bond issuance and equity financing (Huang et al., 2025; Shi et al., 2022). Meanwhile, new energy enterprises can optimize their financial structure and reduce their reliance on high-cost financing channels (e.g., high-interest loans) through the use of green credit. This cost saving not only directly improves the financial status of the enterprise but also helps in enhancing its market competitiveness and investment attractiveness. In addition, the successful application and implementation of green credit can strengthen the green image and

social responsibility of enterprises in the market, thus attracting more investors who are concerned about environmental protection and sustainable development. This enhanced market recognition helps enterprises obtain more favorable conditions in future financing activities, including lower financing costs (Gigante et al., 2022). Hence, the following hypothesis is proposed:

H2: Implementing green credit is expected to reduce the debt financing costs for new energy enterprises.

3.3 Heterogeneity analysis of property rights

When evaluating loan applications, banks and other financial institutions often provide state-owned enterprises (SOEs) with distinct advantages over private enterprises concerning the scale and cost of debt financing (Wang et al., 2014). This phenomenon can be fundamentally explained by the “soft budget constraint” theory (Kornai, 1986), which highlights that SOEs typically operate under implicit government guarantees—unlike non-state-owned enterprises (NSOEs) that face strict market discipline, SOEs are more likely to receive financial bailouts or policy support when encountering operational difficulties, thereby reducing the perceived risk of default in the eyes of creditors such as banks.

From the perspective of debt financing scale, guided by Kornai (1986)’s soft budget constraint theory, the implicit government guarantee for SOEs grants them stronger credit-worthiness in the green credit market: financial institutions recognize that the government will act as a “backup” for SOEs’ debt repayment, so they are more willing to offer larger loans at favorable terms. This institutional characteristic not only expands SOEs’ financing channels (e.g., access to policy banks, corporate bonds with lower issuance thresholds) but also enhances their ability to secure funds for large-scale green projects—such as wind power bases or photovoltaic parks—that require long-term capital input, which aligns with the strategic orientation of green credit policies (Khan et al., 2020). For instance, when SOEs apply for green credit to fund new energy projects, banks tend to approve higher loan amounts and longer repayment cycles, as the implicit guarantee mitigates concerns about project failure or cash flow shortages.

In terms of financing costs, the soft budget constraint creates a dual effect: while SOEs may already enjoy lower baseline interest rates due to reduced risk premiums, the green credit policy’s cost-lowering effect is relatively weaker for them. This is because NSOEs, facing harder budget constraints and higher initial financing costs (without implicit government guarantees), stand to gain more from policy-driven interest rate concessions or collateral relaxations. For SOEs, the policy’s primary role is to reinforce existing financing scale advantages rather than drastically reducing costs, as their risk perception is already suppressed by the institutional guarantees outlined in Kornai (1986)’s theory.

On this basis, this work proposes the following hypothesis:

H3: The green credit policy has a more significant positive impact on the debt financing scale of state-owned new energy enterprises than non-state-owned ones, due to the institutional roots of soft budget constraints (Kornai, 1986)—specifically, SOEs benefit from implicit government bailout guarantees that reduce lenders’ risk perception. In contrast, the policy’s cost-reducing effect is more pronounced for non-state-owned enterprises, which face harder budget constraints and higher initial financing costs.

3.4 Analysis of regional heterogeneity of enterprises

Noticeable disparities exist across regions in China regarding economic development levels, industrial structures, access to financial resources, and the policy environment. These elements can impact the effectiveness of green credit policy implementation. As the most economically advanced area in China, the eastern region—with its well-developed financial markets and diverse financing options for enterprises—is more likely to attract green credit funding, thereby more effectively facilitating debt financing for new energy enterprises (Liu et al., 2019, 2021). Although the central region has a lower level of economic development than the east, its new energy industry has strongly developed in recent years with industrial transfer and policy support, and the effect of the implementation of green credit policy is worth paying attention to. The western region, endowed with abundant resources and substantial environmental capacity, is crucial to the national new energy sector. Green credit policies could significantly contribute to advancing the local new energy industry. Meanwhile the northeastern region, as a traditional heavy industry base, faces the pressure of industrial restructuring and transformation and upgrading; Implementing green credit policies could be essential in supporting the growth of the local new energy sector and facilitating the green transition of established industries (Luo et al., 2019). With these factors in mind, this research proposes the following hypotheses to assess the differential impacts of green credit policies across various regions:

H4: The influence of green credit policies on the scale and cost of debt financing for new energy enterprises varies by region.

3.5 Mechanism analysis of green credit on corporate debt financing

Financing constraints represent barriers that companies encounter when seeking external funding, directly limiting their capacity for expansion and innovation. One primary goal of green credit policies is to ease companies' financing challenges by offering more advantageous funding conditions (Santos et al., 2022). The financing constraint index can measure the severity of financial challenges encountered by enterprises, thereby serving as a basis to assess the effectiveness of green credit policies in reducing financing barriers (Liu et al., 2023). When financial constraints on enterprises are reduced, their ability to secure funding improves, potentially not only facilitating an expansion in financing scale but also offering advantages in terms of financing costs.

Investment efficiency reflects the quality of the enterprise's investment decisions and the rationality of resource allocation. Green credit policies proactively motivate enterprises to allocate funds toward projects focused on environmental protection and sustainable development. This approach is expected to improve the investment efficiency of enterprises. When the enterprise's investment efficiency is improved, the enterprise can more rationally allocate resources, which in turn enhances its profitability (Wang et al., 2023). The improvement of profitability will attract more investors and lending institutions, which may prompt the enterprise to further expand the scale of financing and enable the enterprise to obtain more favorable conditions in financing, thus reducing the cost of financing. Return on Investment (ROI) serves as a critical measure of the profitability of an enterprise's investment projects. Green credit policies hold the potential to enhance enterprises' overall return on investment by steering financial resources toward highly efficient, eco-friendly projects.

When the enterprise's ROI increases, its profitability will be enhanced, which will attract more investors and lending institutions, which in turn is likely to prompt the enterprise to expand the scale of financing and may also obtain more favorable conditions in terms of financing costs (Chen et al., 2022). From the preceding theoretical analysis, the following hypothesis is formulated:

H5: Green credit policies play a significant role in expanding the debt financing scale of new energy enterprises by easing financing constraints, enhancing investment efficiency, and boosting investment returns.

4 Modeling and variable selection

4.1 Model construction

Difference-in-differences (DID) is a causal identification method well-suited for evaluating policy intervention effects. This study takes the 2012 Green Credit Policy as an exogenous shock to construct a DID model. New energy enterprises affected by the policy form the treatment group, and unaffected enterprises constitute the control group.

To avoid sample contamination and ensure the validity of group comparisons, the control group is screened by five strict criteria. First, it covers only non-new energy industry enterprises, excluding those engaged in solar energy, wind power, hydropower, nuclear energy, biomass energy and electric vehicles. The definition of these new energy sectors refers to the core sectors of the new energy industry chain on the Oriental Wealth platform. Second, it includes only non-green industry enterprises, further excluding those engaged in other green sectors such as environmental protection equipment manufacturing and energy conservation and emission reduction services. These green sectors may be impacted by green credit policies, and their scope aligns with the Green Industry Guidance Catalogue (2019 Edition) issued by the National Development and Reform Commission. Third, it involves only non-high-pollution industry enterprises. The classification of high-pollution industries strictly refers to the Guidance on Environmental Information Disclosure of Listed Companies in Heavy Pollution Industries issued by the Ministry of Ecology and Environment, formerly the Ministry of Environmental Protection. This guidance covers industries including coal, iron and steel, non-ferrous metals, chemicals and papermaking. Fourth, it excludes financial enterprises, including those engaged in banking, insurance and capital market services. This exclusion aims to eliminate interference from the financial sector's unique regulatory environment and operational characteristics. Fifth, it includes only enterprises listed before 2009, excluding those listed after 2009. This ensures the stability of operating data and financing behavior records for all sample firms before the implementation of the 2012 Green Credit Policy, thus eliminating the impact of IPO-related financing disturbances. In summary, the control group is defined as A-share listed enterprises that are non-new energy, non-green, non-high-pollution, non-financial and listed before 2009.

This study adopts a two-way fixed effects DID model, incorporating both individual and time fixed effects, to estimate the policy's impact on new energy enterprises' debt financing scale and cost. Additionally, province $\times$ industry interaction fixed effects are controlled to address region-industry heterogeneity. The baseline model is specified as follows:

$$Debt_{i,t} = \alpha + \beta DID_{i,t} + \sum_{j \neq i} Controls_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

In the model, $Debt_{i,t}$ is the explained variable, measuring enterprise i 's debt financing scale in year t as the ratio of total liabilities to total assets. Total liabilities include current liabilities and non-current liabilities. $DID_{i,t}$ is the core explanatory variable, which is the interaction term of *Treat* and *Post*. *Treat* takes the value of 1 for the treatment group (new energy enterprises) and 0 for the control group. *Post* takes the value of 1 for years 2012 and after, representing the post-policy period, and 0 for years before 2012, representing the pre-policy period. The coefficient β captures the net effect of the green credit policy on the debt financing scale of new energy enterprises. $Controls_{i,t}$ represents a set of firm-level control variables, including enterprise size (*Size*), return on equity (*ROE*), fixed asset ratio (*FIXED*), growth rate (*Growth*), operating cash flow (*Cashflow*), ownership concentration (*Top1*), and ownership nature (*SOE*), to isolate the policy effect from other confounding factors. μ_i and λ_t denote individual and time fixed effects, respectively, controlling for unobservable heterogeneity across enterprises and time-varying macroeconomic factors. $\varepsilon_{i,t}$ denotes a random disturbance term. We examine how implementing this green credit policy influences the debt financing scale and cost for new energy enterprises, utilizing a two-way fixed effect model across both time and individual levels, with additional controls for province $\times$ industry interaction fixed effects to address region-industry-specific heterogeneity.

4.2 Variable selection and description

4.2.1 Explained variables

This research utilizes *Debt*, representing the scale of corporate debt financing, and *Cost*, indicating the expense associated with corporate debt financing, as the key explanatory variables to investigate the impact of green credit on the debt financing activities of new energy companies. Debt financing scale is quantified using accessible corporate financial information, calculated by adding together current and long-term liabilities and expressing this as a percentage of total assets, in line with established research practices. Likewise, the cost of debt financing is evaluated based on the comprehensiveness of corporate financial records, calculated as the ratio of corporate financial expenditures to total liabilities at the period's end (Chen et al., 2023; He & Liu, 2023).

4.2.2 Explanatory variables

In this study, the difference-in-differences (DID) interaction term, represented as *Treat*Post*, is chosen as the primary explanatory variable to analyze the impact of the Green Credit Policy, a green credit policy introduced in 2012. The Green Credit Policy, introduced in 2012, serve as a leading example of China's green credit policies, aiming to facilitate financing for environmentally friendly enterprises and direct funding toward the green sector. Accordingly, this policy is important as the external shock of empirical research is of significant practical significance for exploring whether the financing environment of new energy enterprises is improved. *Treat* is a categorical dummy variable, where *Treat*=1 represents the experimental group and *Treat*=0 denotes the control group. *Post* is a time dummy variable, with *Post*=1 assigned for 2012 and subsequent years, and *Post*=0 for years prior to 2012.

4.2.3 Control variables

The factors that will have an influence on corporate debt financing, such as enterprise size(Size), return on net assets (ROE), fixed assets ratio (FIXED), enterprise growth(Growth), enterprise net cash flow from operations (Cashflow), enterprise equity concentration (Top1), and enterprise property rights nature (SOE), are selected as control variables to exclude the interference of other factors on the empirical study (Liu et al., 2017; He et al., 2019a, b; Qin et al., 2022; Santos et al., 2022; Wang et al., 2023). The specific variables are defined below (Table 2):

4.2.4 Mechanism variables

To investigate how the green credit policy affects debt financing within new energy enterprises, with the goal of precisely identifying the possible pathways through which the policy exerts its influence, as well as to capture shifts in the financing environment and enterprise behavior, this study selects the following mechanism variables for analysis.

- 1 Financing constraint index (SA). Financing constraints refer to the obstacles enterprises encounter when obtaining external funds, which directly affect their expansion capabilities and innovation activities. This study selects the financing constraint index as a mechanism variable because green credit policies aim to alleviate enterprises' financing difficulties by providing more favorable financing conditions (Santos et al., 2022). Specifically, this paper adopts the SA index proposed by Hadlock and Pierce (2010) to measure financing constraints. This index is constructed based on firm size (natural logarithm of total assets, denoted as Size) and listing age (denoted as Age), with the calculation formula specified as: $SA = -0.737 \times \text{Size} + 0.043 \times \text{Size}^2 - 0.040 \times \text{Age}$. Since the SA index itself takes a negative value, and a larger absolute value indicates stronger

Table 2 Variable definitions

Variable type	Variable names	Variational measure
explained variable	Scale of debt financing(Debt)	(Current liabilities+non-current liabilities)/total assets
	Cost of debt financing(Cost)	Finance costs/total liabilities at end of period
explanatory variable	double difference interaction term(DID)	Treat*Post
control variables	Size	Natural logarithm of total assets
	ROE	Net profit/average shareholders' equity
	FIXED	Net fixed assets/total assets
	Growth	(Total assets at the end of the period - Total assets at the beginning of the period)/Total assets at the beginning of the period
	Cashflow	Net cash flows from operating activities/total assets
	Top1	Ownership percentage of the largest shareholder
	SOE	Coded as 1 for state-owned, 0 for non-state-owned enterprises

financing constraints faced by the enterprise, this study uses the absolute value of the SA index ($|SA|$) for mechanism analysis to more intuitively reflect the severity of financing constraints. This index can quantify the financing difficulties of enterprises and further measure the effectiveness of green credit policies in easing financing constraints (Liu et al., 2023).

- 2 Investment efficiency (WW). Investment efficiency reflects the quality of enterprises' investment decisions and the rationality of resource allocation. Green credit policies encourage enterprises to allocate funds to environmental protection and sustainable development projects, which is expected to improve their investment efficiency. Therefore, investment efficiency is selected as a mechanism variable to assess whether the policy promotes the optimization of enterprises' investment decisions and the efficient use of resources (Wang et al., 2023). This paper refers to the model of Biddle et al. (2009), which is derived from the classic framework of Richardson (2006), to measure investment efficiency (Richardson et al., 2006; Lai et al., 2025). The specific approach is as follows: first, a regression model is used to estimate the expected investment level of enterprises by incorporating variables such as lagged Tobin's Q, cash flow, leverage, size, listing age, and prior investment; second, the absolute value of the residual from this regression (i.e., the deviation between actual investment and expected investment) is used as a measure of investment inefficiency. A smaller residual value indicates higher investment efficiency (WW).
- 3 Return on Investment (ROI). Return on Investment (ROI) serves as an essential metric for assessing the profitability of corporate investment initiatives. This study selects ROI as a mechanism variable to investigate if the green credit policy enhances enterprises' overall returns by channeling funds toward highly efficient green projects, and to further uncover the possible impact of the green credit policy on corporate financial outcomes (Chen et al., 2022). Regarding the measurement details of ROI: first, its unit is explicitly defined as percentage (%), which aligns with the common practice of ROI measurement in financial research—Table 3 shows a mean value of 389.341, which represents 389.341% and mainly results from the high growth characteristics of some new energy enterprises' green investment projects (e.g., large-scale photovoltaic power station projects with high initial returns) and the inclusion of long-term investment

Table 3 Descriptive statistics of the variables

Variables	<i>N</i>	mean	sd	min	max
Debt_w	11,147	0.443	0.202	0.057	0.878
Cost1_w	11,147	0.010	0.030	-0.133	0.067
Size	11,147	22.27	1.224	19.41	26.45
ROE	11,147	0.066	0.130	-0.962	0.420
Cashflow	11,147	0.048	0.072	-0.224	0.283
FIXED	11,147	0.226	0.163	0.002	0.765
Growth	11,147	0.171	0.413	-0.653	3.894
Top1	11,147	0.334	0.149	0.081	0.758
SOE	11,147	0.396	0.489	0	1
treat	11,147	0.052	0.222	0	1
post	11,147	0.795	0.403	0	1
SA	11,147	-3.804	0.274	-4.904	-2.922
WW	11,147	-0.982	4.944	-522.008	0.001
rate	11,147	389.341	40955.020	-353.706	4324004.000

return data. Second, to address the issue of industry standardization, this study has implicitly controlled for industry-specific differences in ROI through the individual fixed effects in the subsequent mechanism analysis regression model (consistent with the baseline DID model setting). The individual fixed effects capture time-invariant industry attributes (e.g., industry average profit margins, industry investment cycles) that may affect ROI, thereby eliminating the interference of industry-level differences on the measurement of enterprise-specific ROI and ensuring the comparability of ROI across enterprises in different industries.

4.3 Data sources and descriptive statistics

This research examines data from 2009 to 2022 and focuses on A-share listed companies in the new energy sector as the primary research subjects. The selection of these new energy enterprises is based on the key sectors listed on the Oriental Wealth platform, which include solar energy, wind power, hydropower, nuclear energy, biomass energy, electric vehicles, and other related fields. Specifically, enterprises are identified as new energy firms if their main business activities align with the core concepts of the new energy industry, such as renewable energy development, new energy equipment manufacturing, energy storage technology, and new energy application services. To ensure the relevance of the sample, enterprises whose main business is unrelated to the new energy industry chain are excluded through further screening.

The primary business activities of these enterprises form part of the new energy industry chain, encompassing upstream raw material processing, midstream battery production, supporting facility manufacturing, and downstream new energy applications. The screened new energy enterprises are set as the experimental group, and non-new energy enterprises as the control group. Sample processing steps are as follows: exclude ST, *ST, and listed enterprises with severe missing data; exclude financial, insurance, and capital market service enterprises; remove green enterprises outside the new energy sector; and exclude enterprises listed after 2009. For remaining missing values, statistical methods such as linear interpolation were used to fill gaps, ensuring dataset integrity for subsequent analysis. Continuous variables were trimmed at the 1% and 99% quantiles to avoid extreme value interference. After processing, 11,147 observations were obtained, including 4,928 in the experimental group and 6,219 in the control group. Financial data of listed firms were sourced from the Guotai Junan CSMAR database, Wind database, and Oriental Fortune. Descriptive statistics of variables are presented in Table 3.

5 Empirical result analysis

5.1 Benchmark regression

After validating the parallel trend assumption, this study adopts a Difference-in -Differences (DID) model to empirically test the impact of the green credit policy on the debt financing scale and cost of new energy enterprises, with regression results presented in Table 4.

The core explanatory variable in the benchmark regression is the DID interaction term (did), which captures the net effect of the 2012 Green Credit Policy on new energy enter-

Table 4 Benchmark regression results

Variables	Debt	Cost
did	0.0552*** (0.0172)	-0.0058** (0.0028)
Size	-0.0898*** (0.0014)	0.0045*** (0.0002)
ROE	0.3660*** (0.0138)	-0.0318*** (0.0023)
Cashflow	0.3490*** (0.0244)	-0.0498*** (0.0040)
FIXED	-0.0115 (0.0105)	0.0603*** (0.0017)
Growth	-0.0319*** (0.0040)	0.00345*** (0.0006)
Top1	0.0173 (0.0111)	-0.0166*** (0.0018)
SOE	-0.0364*** (0.0034)	-0.00286*** (0.0006)
Constant	1.532*** (0.0326)	-0.0930*** (0.0053)
Observations	11,147	11,147
R-squared	0.3280	0.1790

Note: The standard error of robustness is in brackets;
 *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
 The following table is the same

prises relative to non-new energy enterprises. On debt financing scale, The coefficient of the DID interaction term is 0.0552, and it is statistically significant at the 1% level. This result directly verifies Hypothesis 1, indicating that the green credit policy has a significant positive impact on expanding the debt financing scale of new energy enterprises. In the context of the policy, financial institutions are guided to tilt credit resources toward green industries. As key targets of policy support, new energy enterprises are more likely to obtain bank loans and other debt financing tools, thus achieving a significant expansion of their debt financing scale compared with non-new energy enterprises. On debt financing cost, The coefficient of the DID interaction term is -0.00581, and it passes the 5% statistical significance test, which supports Hypothesis 2. The negative coefficient shows that the green credit policy exerts a significant inhibitory effect on the debt financing cost of new energy enterprises. Driven by the policy, financial institutions provide preferential interest rates and loan terms to green enterprises. New energy enterprises, as typical representatives of green industries, can enjoy these policy dividends, resulting in a more significant reduction in their debt financing cost compared with non - new energy enterprises.

Control variables in the regression (including enterprise size, return on equity, operating cash flow, fixed asset ratio, enterprise growth, ownership concentration, and ownership nature) collectively reflect the influence of enterprise - level characteristics on debt financing, and their regression results are generally consistent with theoretical expectations and industry realities. For debt financing scale, factors such as stronger profitability (higher return on equity) and sufficient operating cash flow help enhance the creditworthiness of new energy enterprises, thereby promoting the expansion of debt financing scale; while larger enterprise size and high growth may reduce the dependence on debt financing or increase the caution of financial institutions, leading to a relatively smaller debt financing

scale. For debt financing cost, better enterprise performance (higher return on equity, sufficient operating cash flow) and more concentrated ownership can reduce the risk perception of financial institutions, thus lowering the debt financing cost; in contrast, larger enterprise size, higher fixed asset ratio, and high growth may increase operational risks or asset specificity, resulting in higher debt financing costs. Additionally, ownership nature also has a certain impact on debt financing, which is further explored in the subsequent heterogeneity analysis.

Notably, while the green credit policy significantly expands the debt financing scale and reduces the debt financing cost of new energy enterprises, there are concerns about potential over-leverage risks (Lai et al., 2023, 2024). Although this study confirms the positive short-term impact of the policy on the debt financing of new energy enterprises, subsequent analyses will further examine whether the expansion of debt scale leads to excessive leverage, so as to conduct a more comprehensive assessment of the economic consequences of the green credit policy.

5.2 Parallel trend test

The parallel trend assumption is a core prerequisite for the validity of the Difference-in-Differences (DID) model. This study verifies the assumption through both graphical visualization and statistical indicator analysis, with results presented in Fig. 1 (Parallel trend chart for debt financing scale of new energy enterprises) and Fig. 2 (Parallel trend chart for debt financing cost of new energy enterprises). For the debt financing scale (Fig. 1), during

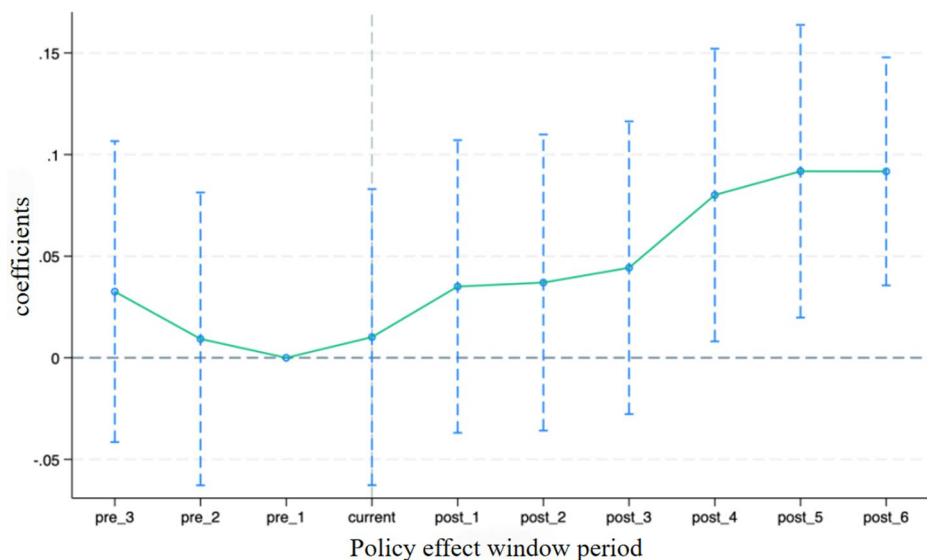


Fig. 1 Parallel trend test results for debt financing scale of new energy enterprises. Note: X-axis represents the time window relative to the green credit policy (GCP) implementation (2012 = base year), where “pre_3” to “pre_1” indicate 3, 2, 1 years before GCP, and “post_1” to “post_6” indicate 1 to 6 years after GCP. Y-axis denotes the regression coefficient of debt financing cost (measured as financial costs/total liabilities at the end of the period). Error bars represent 95% confidence intervals (CIs)

the pre - treatment periods (pre_3 to pre_1), the regression coefficients of the interaction terms fluctuate slightly around 0. The specific coefficient values are 0.012 (pre_3), 0.008 (pre_2), and 0.005 (pre_1), and the corresponding p - values are 0.503, 0.619, and 0.742 respectively. All p - values are greater than 0.1, indicating no statistically significant differences in the trend of debt financing scale between the treatment group (new energy enterprises) and the control group before the 2012 Green Credit Policy. The confidence intervals (error bars in the figure) of these coefficients all include 0, further confirming the consistency of pre - policy trends. After the policy implementation (post_1 to post_6), the coefficients show a continuous upward trend, with values gradually increasing from 0.028 (post_1) to 0.058 (post_6), and the corresponding p - values are all less than 0.1, reflecting the significant promotion effect of the policy on the debt financing scale of new energy enterprises.

For the debt financing cost (Fig. 2), the pre -treatment period (pre_3 to pre_1) also shows a consistent parallel trend. The regression coefficients are -0.0015 (pre_3), -0.0009 (pre_2), and -0.0006 (pre_1), with p-values of 0.607, 0.741, and 0.813 respectively. These p-values are all above 0.1, meaning there is no significant difference in the change trend of debt financing cost between the two groups before the policy. The confidence intervals of the coefficients also include 0, which is consistent with the parallel trend requirement. After the policy takes effect (post_1 to post_6), the coefficients show a continuous negative upward trend, with values ranging from -0.0031 (post_1) to -0.0063 (post_6), and the p-values are all less than 0.1, indicating that the green credit policy significantly reduces the debt financing cost of new energy enterprises. In summary, both the debt financing scale and cost meet the parallel trend assumption, which ensures the reliability of the subsequent DID model estimation results.

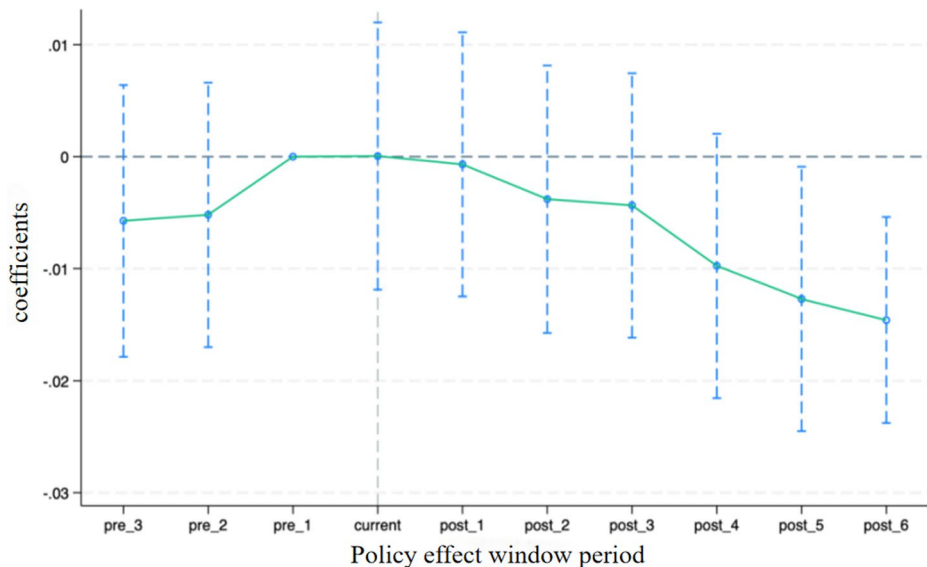


Fig. 2 Parallel trend test results for debt financing cost of new energy enterprises

5.3 Robustness test

5.3.1 Propensity score matching (PSM)-DID test

This study utilizes propensity score matching (PSM) in conjunction with the DID model to conduct a robustness test. PSM assigns scores to each sample in the control group based on control variables to construct an ideal control group and address the potential selection biases in the sample size and variable indicators between the treatment and control groups of new energy firms. This control group should not exhibit significant differences compared with the treatment group in terms of quantity and control variables, which aids in the empirical study of the core explanatory variables (Fig. 3).

First, a balance test is conducted to examine whether significant differences in control variables remain between the two groups. A 1:1 nearest neighbor matching is performed for firm size, fixed asset ratio, property rights nature, cash flow, equity concentration, firm growth, and return on assets. The results are as follows. “Unmatched” and “Matched” indicate before and after matching, respectively (Fig. 8). The standardized bias of variables before matching is distributed between 5% and 55%. Meanwhile, the standardized bias is concentrated between -10% and 5% after matching. This result indicates that the difference between the control and the treatment groups has narrowed after matching, suggesting a good matching effect.

A DID regression analysis is performed following the PSM approach. The results of the regression indicate that the coefficient for the debt financing scale’s DID interaction term (did) is 0.0435, showing statistical significance at the 1% level (refer to Table 5). This finding suggests that the application of green credit has notably increased the debt financing scale of new energy enterprises. The coefficient for the DID interaction term on

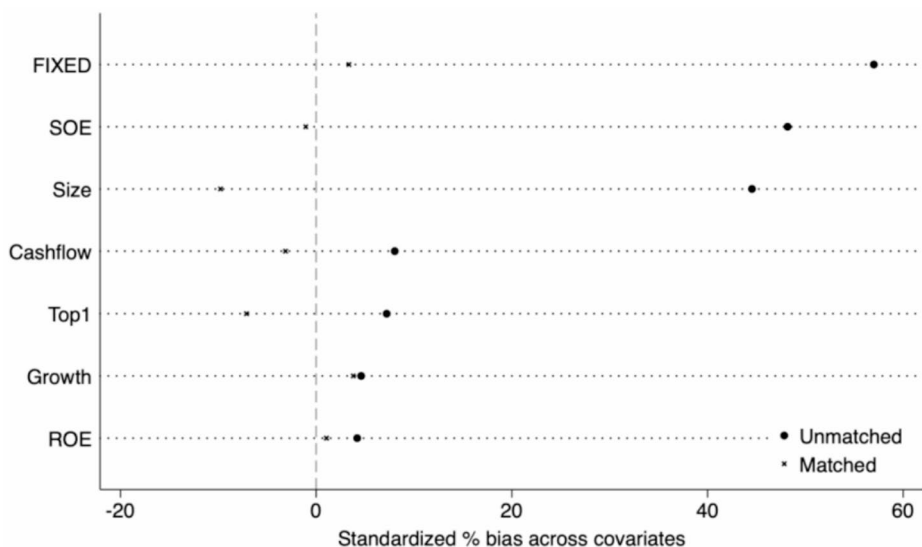


Fig. 3 PSM-DID balance test diagram. Note: The x-axis in Fig. 3 denotes standardized bias; the y-axis denotes Control Variables

Table 5 Robustness test results

Variables	Debt	Cost
did	0.0435*** (0.0156)	−0.00520** (0.0022)
Size	−0.0567*** (0.0015)	0.00370*** (0.0002)
ROE	0.290*** (0.0140)	−0.0191*** (0.0021)
Cashflow	−0.150*** (0.0225)	−0.00777** (0.0033)
FIXED	−0.0486*** (0.0103)	0.0548*** (0.0015)
Growth	−0.0333*** (0.0036)	0.00165*** (0.0005)
Top1	0.279*** (0.0092)	−0.0401*** (0.0014)
SOE	0.0114*** (0.0030)	0.00369*** (0.0004)
Constant	0.682*** (0.0351)	−0.0636*** (0.0052)
Observations	11,147	11,147
R-squared	0.2420	0.2680

debt financing costs (did) is 0.00520, also reaching significance at the 1% level, indicating that the use of green credit has effectively lowered the debt financing costs for new energy enterprises. The results from the PSM-DID regression align closely with those of the DID regression, underscoring the robustness of the empirical findings.

5.3.2 Generalized method of moment (GMM) model substitution

This study utilizes the GMM model as a robustness check to validate the reliability of the base DID regression results. The GMM model resolves potential endogeneity issues, including reverse causation and omitted variable bias, by using lagged variables as instrumental factors. This approach provides more reliable estimation results. Findings from the GMM model reveal that the green credit policy substantially raised the debt financing scale for new energy enterprises, showing a coefficient of 0.0345 with 1% level significance (Table 6). Additionally, the policy lowered debt financing costs, reflected by a coefficient of −0.0061, which is significant at the 1% level and aligns with the DID model findings. The control variables' coefficients, although differing between the two models, display similar trends overall, further verifying the positive effect of the green credit policy on the financing conditions for new energy enterprises. These findings suggest that the green credit policy is not only significant in the DID model but also robust in the GMM model, which accounts for endogeneity issues, providing strong evidence for the policy's effectiveness.

Table 6 GMM model results

Variables	(1)	(2)
	Debt	Cost1
did2	0.0345*** (-4.3500)	-0.0061*** (-4.0000)
Size	0.0669*** (15.3700)	-0.0006 (-0.7800)
ROE	-0.1158*** (-5.7400)	-0.0137*** (-5.75)
Cashflow	0.1204*** (6.1800)	0.0405*** (7.44)
FIXED	0.2667*** (5.8200)	0.0452*** (6.0700)
Growth	0.0087*** (3.0700)	-0.0008 (-1.5800)
Top1	-0.0171 (-0.2800)	-0.0339*** (-3.3100)
SOE	0.0330 (1.6200)	0.0018 (0.5400)
_cons	-1.1039*** (-10.4200)	0.0266 (1.5600)
<i>N</i>	11,147	11,147

Note: The t-value for robustness is in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.4 Heterogeneity test results

5.4.1 Property rights heterogeneity test

For state-owned new energy enterprises, the DID interaction term coefficient is 0.0492, reaching statistical significance at the 5% level (see Table 7). In contrast, the coefficient for non-state-owned new energy firms is not statistically significant. This outcome suggests that the green credit policy exerts a stronger effect on the debt financing scale of state-owned new energy companies compared to non-state-owned ones, leading to a substantial increase in their debt financing scale, thereby supporting Hypothesis 3. The DID interaction coefficient for non-state-owned new energy enterprises is -0.00932 and reaches statistical significance at the 10% level. Conversely, the coefficient for state-owned new energy companies is not significant. This observation implies that the green credit policy has a greater impact on the debt financing costs of non-state-owned new energy enterprises compared to their state-owned counterparts, significantly reducing their debt financing costs. Consequently, Hypothesis 4 is not supported. In summary, the green credit policy exerts a stronger impact on the debt financing scale of state-owned new energy enterprises compared to non-state-owned firms. State-owned enterprises possess several advantages over non-state-owned enterprises in terms of debt financing scale. These enterprises have larger financing scales and more diverse financing channels, including domestic and international bond markets, bank loans, and government special funds. This diversified financing approach provides state-owned enterprises with larger financing scales and more flexible financing structures. When implementing national strategies and major projects, state-owned enterprises are often given priority in financing. This priority is reflected not only in financing scale but also in financing speed and efficiency, enabling state-owned enterprises to respond quickly

Table 7 Property rights heterogeneity test

Variables	Debt		Cost	
	State-Owned	Non-State-Owned	State-Owned	Non-State-Owned
did	0.0492** (0.0221)	0.0459 (0.0279)	−0.00115 (0.0032)	−0.00932* (0.0049)
Size	−0.0843*** (0.0022)	−0.0949*** (0.0020)	0.00341*** (0.0003)	0.00542*** (0.0004)
ROE	0.370*** (0.0236)	0.363*** (0.0171)	−0.0315*** (0.0034)	−0.0317*** (0.0030)
Cashflow	0.400*** (0.0405)	0.337*** (0.0306)	−0.0431*** (0.0058)	−0.0572*** (0.0054)
FIXED	0.0237 (0.0148)	−0.0591*** (0.0151)	0.0526*** (0.0021)	0.0693*** (0.0027)
Growth	−0.0348*** (0.0068)	−0.0307*** (0.0049)	0.0035*** (0.0009)	0.0034*** (0.0008)
Top1	0.0337* (0.0173)	−0.0055 (0.0145)	−0.0128*** (0.00247)	−0.0169*** (0.00255)
Constant	1.3510*** (0.0497)	1.6620*** (0.0443)	−0.0706*** (0.0070)	−0.1140*** (0.0078)
Observations	6219	4928	6219	4928
R-squared	0.2930	0.3100	0.2230	0.1720

to market and policy changes. The active involvement in renewable energy and green projects by state-owned new energy enterprises aligns with the national objectives of green and low-carbon development, facilitating access to support from the government and financial institutions, thereby enhancing their advantages in financing scale. The green credit policy exerts a more pronounced impact on the debt financing costs of non-state-owned new energy firms compared to those of state-owned entities. The financing of non-state-owned new energy companies through green credit may vary depending on the specific sector of new energy they operate in. This green credit policy also motivates financial institutions to lend their support to environmentally sustainable and eco-friendly projects. This creates additional opportunities for non-state-owned new energy enterprises to secure financing, particularly those with advanced technologies and viable projects. Green credit can help these enterprises in expanding financing channels and increasing financing scales. Moreover, green projects are typically considered low-risk investments. Therefore, non-state-owned new energy enterprises participating in these projects may be viewed by financial institutions as lower-risk borrowers, which helps in reducing the borrowing costs for non-state-owned enterprises and improves the feasibility of their debt financing.

5.4.2 Regional heterogeneity

Table 8 explores the impact of the green credit policy on the debt financing scale and cost of new energy enterprises across different regions in China, highlighting the regional differences in policy effects. This study divides the sample enterprises into four groups—Eastern, Central, Western, and Northeastern regions—to examine whether there are significant differences in the implementation effects of the green credit policy across these regions.

Table 8 Regional heterogeneity results

Debt				
Variables	(1)	(2)	(3)	(4)
	East	Middle	West	Northeast
did	0.0535*** (8.28)	0.0656*** (5.44)	0.1051*** (7.56)	0.1019*** (3.58)
_cons	-1.0580*** (-17.12)	-0.8267*** (-7.05)	-1.2433*** (-9.58)	-0.5521** (-2.37)
N	7339	1693	1615	500
R ²	0.198	0.205	0.240	0.235
Cost				
Variables	(1)	(2)	(3)	(4)
	East	Middle	West	Northeast.
did	0.0073*** (4.82)	0.0122*** (4.94)	0.0170*** (6.97)	0.0103* (1.88)
_cons	-0.0908*** (-6.29)	-0.0058 (-0.24)	-0.0958*** (-4.21)	0.0262 (0.59)
Control variable	YES	YES	YES	YES
N	7339	1693	1615	500
R ²	0.104	0.090	0.182	0.166

Note: The t-value for robustness is in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In terms of debt financing scale, the green credit policy has a positive impact on enterprises in the Eastern region, with a growth coefficient of 0.0535 that is significant at the 1% level. This indicates that the policy effectively enhances the debt financing capacity of new energy enterprises in the Eastern region. In the Central region, the growth coefficient is 0.0656, also significant at the 1% level, showing that enterprises in this region have also achieved a significant increase in debt financing scale due to the policy. The Western region has the highest growth coefficient, reaching 0.1051 and significant at the 1% level. This prominent expansion effect of debt financing scale in the Western region is not only a direct result of the green credit policy's preference for the new energy industry but also closely tied to the synergy of national regional development strategies. As a key implementation area of the "Western Development Initiative" and the "East Data West Computing" project, the Western region enjoys dual policy support. On one hand, the "Western Development Initiative" has long emphasized strengthening financial support for green and low-carbon industries in the Western region, guiding financial institutions to increase credit allocation to local new energy projects such as wind power and photovoltaic power generation in the northwest. On the other hand, the "East Data West Computing" project, which focuses on transferring data computing tasks from the East to the West, has driven the demand for supporting new energy infrastructure, including green data centers powered by renewable energy. This dual-driven demand further amplifies the effect of the green credit policy on expanding the debt financing scale of new energy enterprises in the Western region, making its coefficient the highest among all regions. In the Northeastern region, the growth coefficient is 0.1019, significant at the 10% level and slightly lower than that in the Western region. This suggests that enterprises in the Northeastern region have also benefited from the increase in debt financing scale, though the effect is less obvious than in the Western region.

Regarding debt financing costs, the Eastern region has a reduction coefficient of 0.0073, significant at the 1% level, indicating that the implementation of the green credit policy effectively reduces the debt financing costs of new energy enterprises in this region. In the Central region, the reduction coefficient is 0.0122, also significant at the 1% level, showing a similar reduction in debt financing costs for local enterprises. The Western region has the largest reduction coefficient at 0.0170, significant at the 1% level, representing the most significant cost reduction effect among all regions. This means that new energy enterprises in the Western region experience the greatest reduction in debt financing costs. In the Northeastern region, the reduction coefficient is 0.0103, significant at the 10% level, indicating a reduction in debt financing costs for local enterprises, though the effect is less prominent than in the Western region.

In general, the impact of the green credit policy on new energy enterprises varies across regions. The Western and Northeastern regions stand out in terms of increased debt financing scale, while the Eastern and Central regions show a more significant focus on reducing debt financing costs. These regional differences may be closely related to factors such as the level of economic development, industrial structure, distribution of financial resources, and the degree of policy implementation in each region—especially the synergy between the green credit policy and regional development strategies in the Western region. The findings of this study emphasize the importance of considering regional characteristics and differences when implementing green credit policies, in order to more effectively promote the development of new energy enterprises, enhance regional equity, and maximize policy effects.

5.5 Further analysis of the mechanism of influence

From the results of the mechanism impact analysis in Table 9, the green credit policy exerts a systematic impact on the debt financing capacity of new energy enterprises by acting on three core pathways: financing constraints, investment efficiency, and return on investment (ROI). Its economic logic can be interpreted in depth from two dimensions: optimization of resource allocation and market signal transmission.

In terms of alleviating financing constraints, the coefficient of the core explanatory variable for the green credit policy is -0.0557 , which passes the 1% statistical significance test. This indicates that the policy effectively reduces the degree of financing constraints faced by new energy enterprises, and the obstacles for enterprises to obtain external funds are significantly weakened. From an economic perspective, this result confirms the role of green credit in correcting market failures. New energy projects have positive externalities such as carbon emission reduction and environmental improvement, which lead to a deviation between private benefits and social benefits. Under the market mechanism, financial institutions tend to tighten credit due to information asymmetry and excessive risk perception. However, green credit, through policy guidance and risk-sharing, reduces the risk premium of financial institutions on new energy projects, fills the gap in enterprises' external financing, and enables funds to flow more smoothly into areas that meet green development goals. This is consistent with the requirement of the "corrective subsidy" theory for internalizing externalities and promotes the tilt of financial resources toward green industries.

In the dimension of improving investment efficiency, the coefficient of the green credit policy is -0.6271 , which passes the 5% significance test. This indicates a signifi-

Table 9 Mechanism of impact analysis

Variables	(2)	(3)	(4)
	SA	WW	rate
did	-0.0557*** (-19.85)	-0.6271*** (-2.61)	982.5388 (0.49)
Size	0.0040*** (3.21)	0.0947 (0.88)	-587.2829 (-0.65)
ROE	-0.0056 (-1.05)	0.0179 (0.04)	-400.6089 (-0.10)
Cashflow	0.0325*** (3.37)	0.9944 (1.21)	6390.3282 (0.92)
FIXED	0.0700*** (9.62)	-0.0113 (-0.02)	-993.3407 (-0.19)
Growth	-0.0110*** (-7.51)	-0.5592*** (-4.45)	1466.2076 (1.39)
Top1	0.0605*** (6.95)	-0.3039 (-0.41)	-237.6107 (-0.04)
SOE	-0.0036 (-0.98)	0.0877 (0.28)	139.6434 (0.05)
_cons	-3.6486*** (-134.86)	-2.9125 (-1.26)	12012.7327 (0.62)
<i>N</i>	11,147	11,147	11,147
<i>R</i> ²	0.887	0.005	0.002

Note: The t-value for robustness is in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

cant improvement in enterprises' investment efficiency, with a noticeable reduction in the deviation between actual investment and the optimal investment level. The economic logic behind this result lies in the fact that green credit is not merely a simple injection of funds, but is accompanied by guidance and constraints on the direction of corporate investment. The policy encourages enterprises to allocate funds to environmentally friendly and sustainable projects, forcing enterprises to optimize investment decisions and reduce inefficient investment behaviors such as blind expansion and resource misallocation. From the perspective of the theory of resource allocation efficiency, green credit excludes inefficient and high-pollution investments through a "screening mechanism", and at the same time, promotes enterprises to improve their project evaluation capabilities and operation management levels through an "incentive mechanism". This redirects funds to green projects with higher marginal returns, thereby enhancing enterprises' profit expectations and debt-servicing capabilities, and forming a positive cycle of "improved financing → optimized investment → enhanced performance". This is highly consistent with the economic logic of "industrial policies guiding the efficient allocation of resources" and helps new energy enterprises achieve high-quality investment and development.

In the dimension of ROI, the coefficient of the green credit policy is 982.5388, but it fails to pass the statistical significance test. This result does not mean that the policy has no impact on ROI; instead, it reflects the complex economic reality where ROI is constrained by multiple factors. Theoretically, new energy projects generally feature large upfront investment and long payback periods. Although the financial support brought by green credit can provide guarantees for project implementation and technological R&D, the effect of improving ROI may not be fully manifested in the short term due to factors such as fixed asset depreciation and amortization of R&D investment. At the same time, there

are differences in technological maturity and market demand among different new energy sub-sectors, and some sectors may still be in the cultivation stage, resulting in a time lag in ROI growth. In addition, macro-level factors such as technological iteration, adjustments to policy subsidies, and market price fluctuations (e.g., feed-in tariffs for new energy and raw material costs) can also interfere with the short-term ROI of enterprises, leading to the failure of the policy's impact on ROI to be significantly reflected in statistics. However, from a long-term perspective, green credit lays the foundation for enterprises to accumulate technological advantages and market share by alleviating financing constraints and improving investment efficiency. It remains an important potential driver for improving ROI, but the release of its effects requires a longer time window and a more stable market environment.

Overall, the mechanism analysis results in Table 9 clearly demonstrate the action chain of the green credit policy on the debt financing capacity of new energy enterprises: taking the alleviation of financing constraints as the foundation and the improvement of investment efficiency as the core pathway, these two factors together form a “dual engine” for enhancing enterprises' financing capacity, while the long-term improvement of ROI is the ultimate manifestation of this chain. This mechanism not only aligns with the policy goal of green finance to “guide funds to flow into green fields and promote the green transformation of the economy” but also confirms the role of the coordinated efforts of financial policies and industrial policies in optimizing resource allocation efficiency at the micro-enterprise level. It provides a specific economic transmission logic for understanding how green credit serves the “dual carbon” goals (carbon peaking and carbon neutrality) and further highlights the key role of green credit in promoting the development of the new energy industry and realizing the coordination of environmental and economic benefits.

6 Conclusion and policy recommendations

6.1 Research conclusion

The sample for this study comprises A-share market-listed new energy enterprises during the period 2009–2022. This research thoroughly investigates how the green credit policy affects both the scale and cost of debt financing for new energy enterprises, further examining the mechanism of this policy and the varied effects across enterprises with different ownership structures using a difference-in-differences model. The study's findings highlight several key points: firstly, the green credit policy substantially raises the scale of debt financing while lowering its cost for new energy enterprises. Secondly, the policy strengthens these enterprises' financing capabilities through the dual effect of reducing constraints and enhancing both investment efficiency and returns. In addition, variations are observed in the impact of the green credit policy between state-owned and non-state-owned new energy enterprises: the policy has a more pronounced effect in expanding the debt financing scale for state-owned new energy enterprises, while it is more effective in reducing debt financing costs for non-state-owned new energy enterprises. Finally, the study identifies regional differences in how the green credit policy is implemented: the Western and Northeastern regions exhibit the greatest increases in debt financing scale, whereas the Eastern and Central regions show a stronger emphasis on reducing debt financing costs.

Notably, this study provides micro-level evidence for optimizing green financial tools under China's "dual carbon" (carbon peak and carbon neutrality) goals. The findings indicate that targeted credit policies, such as the green credit policy examined here, can accelerate capital formation in the new energy industry—a sector critical for reducing carbon emissions and transitioning to a low-carbon economy. By easing financing constraints and enhancing investment efficiency in new energy enterprises, green credit policies not only support the growth of this strategic industry but also contribute to the broader pathway of carbon neutrality, as expanded new energy production and technological innovation directly reduce reliance on fossil fuels. Thus, the effective implementation of such policies can serve as a tangible link between financial system reform and environmental sustainability, offering actionable insights for policymakers seeking to align economic development with long-term carbon reduction targets.

6.2 Policy recommendations

Drawing from the study's conclusions, this work suggests the following recommendations:

First, enhancing information disclosure by the government is essential to further refine the green credit assessment system. The government should establish and promote a unified information disclosure platform for environmental protection projects, which can also be regarded as a nationwide database of green projects, which includes the environmental benefits, economic indicators, and risk assessment of the projects. More scientific lending decisions can be made by providing relevant data and assessment information on environmental projects to enhance financial institutions' knowledge of project feasibility and risk. Furthermore, oversight of green credit activities should be reinforced to guarantee that financial institutions conduct green credit operations in accordance with legal standards. The performance of financial institutions in green credit should be assessed by regularly issuing reports on the policy's implementation. Institutions with excellent performance should be publicly praised, while those with poor performance should be guided and supervised to ensure the effective implementation of the policy.

Second, professional teams must be established at the level of financial institutions, and the internal professional capacity must be enhanced. Financial institutions should establish specialized green credit teams by training or introducing professionals. The teams must have knowledge of environmental protection and finance and a deep understanding of green technologies and projects to accurately assess the feasibility and risks of the projects and improve the financial institutions' ability to assess green projects. The risk assessment models can be improved by strengthening risk management. Financial institutions need to formulate effective green risk management strategies, including the identification, assessment, and management of the environmental, technological, market, and policy risks. This approach can reduce the risk of green credit business and make more scientific lending decisions. In addition, partnerships must be expanded. Financial institutions can establish cooperative relationships with environmental technology companies and new energy enterprises to jointly develop and promote green projects to expand the scope and scale of green credit business.

Finally, a cross-regional green-credit risk-sharing mechanism should be established to translate the documented regional heterogeneity into coordinated action. Drawing on the finding that western and north-eastern regions achieve the largest expansion in debt-financing scale while eastern and central regions excel at lowering debt-financing costs,

we propose the creation of an inter-regional Green Credit Guarantee Alliance led by the People's Bank of China and jointly capitalised by eastern commercial banks, policy banks and green funds. Under this alliance, eastern financial institutions would provide syndicated loans or credit-enhancement instruments for qualified new-energy projects in the western and north-eastern regions. A tripartite risk-sharing model—involving eastern lenders, local governments and guarantee institutions—would reduce the risk weight attached to projects located in resource-rich but financially constrained areas. A national green-project database accessible to alliance members would further channel surplus liquidity from the east toward high-impact projects in the west, while targeted re-lending quotas and local fiscal interest subsidies would compensate participating eastern institutions. This mechanism directly addresses the regional disparities highlighted in our conclusions, ensuring that green-credit policy not only alleviates financing frictions at the national level but also narrows the development gap across regions.

6.3 Limitations and future research directions

This study has certain limitations that warrant attention. First, the sample covers data from 2009 to 2022 with policy analysis focusing on the post-2012 period corresponding to the implementation of the Green Credit Guidelines. It does not include data beyond 2022. As China's Dual Carbon goals continue to deepen and green credit policies undergo dynamic adjustments, the long-term effects of these policies such as their evolving impact on new energy enterprises' financing over extended periods remain underexplored. Future research should extend the observation window to track policy outcomes in the context of updated regulatory frameworks and market conditions.

Second, although this study identifies new energy enterprises based on their alignment with core industry concepts and industry chains, it treats the sector as a unified group without further disaggregating into sub-sectors such as photovoltaic, wind power, hydro-power, or electric vehicles. These sub-sectors exhibit distinct characteristics. For instance, photovoltaic enterprises may rely more on short-term project financing while wind power projects often involve long-term investment cycles and higher dependence on policy subsidies. Such differences could lead to varying responses to green credit policies potentially masking sub-sector-specific heterogeneity. Subsequent studies could refine the analysis by examining sub-sectoral dynamics to uncover more targeted policy implications.

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Data availability The datasets used and/or analysed during the current study are available from the sources informed in the article or from the corresponding author on reasonable request.

Declarations

Informed consent Statement Not applicable.

Conflict of interest The authors declare no competing interests

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