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Can green finance policy reduce energy consumption: quasi-natural experimental evidence from green finance reform and innovations pilot zone

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Introduction: The Green Finance Pilot Policy is a crucial initiative in China's green finance reform, playing a significant role in reducing energy consumption and achieving carbon neutrality goals. This study examines whether the establishment of green finance reform and innovation pilot zones effectively reduces energy consumption and explores the underlying mechanisms of its impact.

Methods: Using panel data from 30 provincial-level administrative regions in China from 2013 to 2021, this study employs the staggered Difference-in-Differences (DID) model as a quasi-natural experiment. The analysis evaluates the effect of green finance reform policy on energy consumption and investigates the mediating effects of industrial structure optimization and green innovation.

Results: The results indicate that the green finance reform and innovation pilot zones significantly reduce energy consumption levels, and this conclusion remains robust after a series of robustness tests. Mechanism analysis reveals that the policy primarily reduces energy consumption by optimizing industrial structure and promoting green innovation.

Discussion: These findings provide new evidence for understanding the impact of green finance reform pilot zones on energy consumption and offer insights for further unlocking the energy-saving potential of green finance policy. The study suggests deepening institutional frameworks, establishing long-term support mechanisms, and optimizing policy implementation strategies to enhance the effectiveness of green finance policy in energy conservation and emissions reduction.

KEYWORDS

energy consumption, different-in-different model, green finance policy, industrial structural upgrading, mediation effect

1 Introduction

China's energy requirements have significantly increased due to years of fast economic development. China is currently the biggest energy consumer, coal manufacturer and consumer, and the biggest carbon dioxide generator in the entire globe. A majority of the energy consumed in China is used by the manufacturing industry (Guo and Hu, 2024). Furthermore, as the world's largest developing nation, China faces significant gaps in

environmental governance compared to developed countries and some emerging economies. Therefore, a pressing imperative for achieving green and low-carbon development in China is to enhance energy efficiency and establish a development model characterized by low energy consumption, minimal pollution, and reduced emissions, thereby contributing to pollution and carbon reduction (Wang et al., 2024a).

As the impacts of climate change intensify, urban green innovation has emerged as a critical technological approach for reducing carbon emissions and addressing climate-related risks (Hou and Shi, 2024). Building a green financial system is a key initiative for transforming the mode of economic development, promoting the construction of a resource-saving and environment-friendly society, and an inevitable choice for the advanced stage of economic development (Krastev and Hristova, 2024). As a financial tool that can realize economic and environmentally coordinated development, green finance has been extensively applied in environmental pollution control and promoting green development (Lee and Lee, 2022; Zhang et al., 2021). The Chinese Government has pointed out that “promoting the greening and decarbonization of economic and social development is a key link in achieving high-quality development.” This is a major judgement and strategic plan based on the essential requirements of Chinese modernization and the acceleration of the green transformation of development. On one hand, China has adhered to the new development concept, shaped new dynamics and new advantages in economic development led by the innovation drive, accelerated the construction of a green, low-carbon and recycling economic system, and pushed for a steady improvement in economic development. On the other hand, China’s green development is synchronized with its economic transformation, and the demand for energy resources will remain rigidly growing in the coming period, with the industrial structure and energy structure having obvious high-carbon features. According to the *Statistical Communiqué of the People’s Republic of China on the 2023 National Economic and Social Development*, China’s total energy consumption in 2023 amounted to 5.72 billion tons of standard coal equivalent, up by 5.7 percent over that of 2022, the highest rate since 2012. The degradation of the natural environment undermines residential quality and presents a substantial risk to the long-term viability of urban development (Guo et al., 2025). How to effectively reduce energy consumption and optimize the energy structure has become one of the major issues for China to achieve the “dual carbon” goals as soon as possible.

Promoting green and low-carbon development is the trend and the general trend. With the support of a series of policies, China’s green finance is developing rapidly. *The China Regional Financial Operation Report (2023)* shows that the balance of green loans nationwide was RMB 22.0 trillion in 2022, up 38.5 per cent year-on-year. In August 2016, seven ministries and commissions, including the People’s Bank of China, jointly issued the *Guidelines for Establishing the Green Financial System*, announcing that localities should focus on solving outstanding ecological and environmental problems and promote the construction of a green financial system in the light of the actual situation. It’s the world’s first green financial policy framework formulated by a central government department. In June 2017, the

State Council approved parts of Xinjiang Uygur autonomous region and Zhejiang, Jiangxi, Guangdong, Guizhou provinces as the first pilot zones for green finance reform and innovations. In December 2019 and August 2022, Gansu province and Chongqing municipality were approved to join the pilot, and the pilot zones for green finance reform and innovations was expanded again. China’s green finance entered a new development stage that combines “top-down” design and “bottom-up” regional exploration (Jia et al., 2023). In contrast to other green finance, the pilot policy clearly defines the target audience for policy implementation, which minimises the risk of biased estimates arising from misidentification of the target audience for green finance policy.

The pilot zones for green finance reform and innovations policy are not only conducive to reducing the level of energy consumption by promoting the development of green finance, but also conducive to exploring a win-win sustainable development model for both the environment and the economy, and promoting China’s green financial reform and innovation to a deeper level. It has certain theoretical value and practical significance for further exerting the effectiveness of green financial policy and promoting the low-carbon emission reduction effect in the pilot areas. Then, as a green finance policy aimed at promoting new attempts at green finance and facilitating the green transformation of the economy, what is the impact of the establishment of the pilot zones for green finance reform and innovations in reducing total energy consumption and optimising the structure of energy consumption? Is it possible to improve the overall green development status and energy consumption level of the region by leveraging the policy demonstration effect of the pilot zones? The study of these issues will help to give full play to the role of green financial policy in promoting energy conservation and emission reduction in cities, promoting low-carbon and efficient use of energy, and contributing to the achievement of the ‘dual carbon’ goal.

Therefore, this paper’s marginal contributions are mainly in the following aspects.

First, while the green finance reform and innovation pilot zone policy has been examined in previous studies, cities that joined the policy at later stages were often excluded due to the relatively short period of time in which the policy was implemented. The study incorporates these later-joining cities, and constructs staggered DID models for different start-up times of the green finance pilot zone policy, thereby exploring the impact of the pilot zone policy on energy consumption more comprehensively. Additionally, the use of staggered DID modelling avoids the variable measurement errors that arise from measuring green finance through quantitative indicators. It also addresses the endogeneity problem caused by reverse causality during the process of causal identification. The causal relationship between green finance policy and urban energy saving and emission reduction was identified more accurately.

Second, the study extends the existing literature by exploring the mechanisms in which green finance policy affect energy consumption. Specifically, it investigates the mediating role of industrial structure optimisation and increase of green innovation, thus offering deeper insights into the effective application of staggered DID models in dynamic policy evaluation contexts. In addition, the analysis considers the heterogeneity of pilot zones in terms of economic development,

industrial spatial distribution, and degree of openness to external markets, contributing to the literature on regional policy differentiation. It also provides actionable recommendations for balancing economic development with sustainable development goals.

2 Literature review

Green finance refers to financial activities that promote environmental improvement, combat climate change and effectively conserve resources, and is of great significance in promoting environmental improvement, economic development and the development of financial institutions (Scholtens and Dam, 2006). Among the existing studies, the research content on green financial reform policy mainly focuses on the development effect of green finance, the pollution and carbon reduction effect of green finance, the relationship between green finance and sustainable development of energy, and the impact of green credit policy from different perspectives.

Green credit is an important part of China's green financial policy (Zhao et al., 2023). In terms of the development effectiveness of green finance, green credit through a series of incentive mechanisms, has significantly increased the amount of green credit allocated and enhanced the financing vigour of green listed enterprises. And all of this presents low negative shocks in terms of total output, total employment and environmental quality, demonstrating its win-win potential for both the economy and the environment (Haiying et al., 2023). In the area of environmental improvement and carbon reduction, green finance has had a more significant impact in non-industrialised cities and in the eastern region (Chen et al., 2025). The implementation of green financial policy promotes green technological innovation and industrial structure upgrading, and effectively promotes the process of industrial pollution control (Ke et al., 2023). Pilot regions have demonstrated lower rates of carbon emission growth than non-pilot regions, further confirming the positive contribution of green finance in reducing emissions (Bai et al., 2022). In terms of the relationship between green finance and the sustainable development of energy, as the green finance development index continues to climb, carbon intensity shows a significant downward trend, signalling the important role of green finance in promoting the transition to a low-carbon economy (Ren et al., 2020). In addition, policy measures such as green investment, green bonds and government subsidies can gradually optimise the structure of energy consumption in the long term and provide a strong impetus for sustainable development in the energy sector (Moran et al., 2021). Green credit policy as one of the main measures of green financial reform, have been seen by some scholars as having an impact that favours green economic growth and reduces carbon emissions (Krstev and Hristova, 2024). There are also some scholars who argue that green credit policy reflects the principles of sustainable development, aiming to fundamentally restrict the financing of enterprises that prioritize economic growth at the expense of environmental performance. By strengthening the restrictions and constraints on heavily polluting, high-energy-consuming,

and high-emission industries, this policy effectively curbs excessive investment in these sectors, limits pollution sources, and rectifies urban environmental pollution (Wang et al., 2024b). Green credit has taken a range of efficient and appropriate incentives such as subsidised interest rate policies, targeted reductions in reserve requirement ratios and refinancing of loans. These measures can play a positive role in promoting the green transformation of the economy and optimising the overall economic structure (Hu et al., 2020). At the same time, the implementation of these policies does not have a significant negative impact on the level of total social output and employment, contributing to the achievement of the dual objectives of economic development and environmental protection (Md et al., 2022). Overall, although current research has comprehensively analysed the multiple effects of green finance in environmental governance and energy saving and emission reduction, it is still important to point out that there is a lack of sufficient academic attention and validation of the actual effects of pilot zones for green finance reform and innovations policy, and there is an urgent need to carry out further validation in order to assess the effectiveness of the governance of the green financial policy more comprehensively and deeply.

The implementation of pilot zones for green finance reform and innovations policy is conducive to promoting the green transformation and sustainable development of China's financial sector and further exploring green financial reform and innovation models and improving the commercial sustainability of green finance. Current research focuses on the impact of the pilot zone policy on a number of dimensions, such as optimisation of industrial structure, growth of green enterprises and financing costs of enterprises. The study shows that these policies not only enhance the fair distribution and efficient allocation of credit resources, but also effectively promote the ecologization of regional industrial structure (Ma et al., 2024; Xu et al., 2024). At the same time, the pilot zone policy promotes green innovation in enterprises by reducing financing constraints and providing credit incentives, significantly reducing the energy consumption of polluting enterprises (Shuangshuang et al., 2022; Xu, 2024). In particular, for heavily polluting enterprises, the pilot zone policy not only promotes innovative compensatory effects and reduces the cost of debt financing for enterprises (Shi et al., 2022), but also encourages them to pay more attention to and fulfil their environmental and social responsibilities through measures such as enhanced financing constraints, green innovation and corporate governance mechanisms (Xie, 2024). For micro and small enterprises, the establishment of the pilot zones is expected to significantly increase the market value of green enterprises in the long run, and help green enterprises add value in terms of capital market effects and practical effects (Jun et al., 2021). Existing studies have amply demonstrated the positive effects of pilot zone policy on industrial upgrading and the development of green enterprises. However, it is worth noting that there is still a lack of in-depth exploration of whether this reform policy can reduce energy consumption. Relevant empirical studies need to be further expanded and enriched in order to more comprehensively assess the green contribution of the pilot zone policy.

3 Research hypotheses

The pilot zones for green finance reform and innovations policy combines the dual characteristics of market incentives and administrative directives, reflecting both the flexibility of market-based environmental regulation and the authority of command-based environmental regulation. From the theoretical level, this pilot policy is implemented through the construction of a green financial system environment, the innovation of green financial products and service systems, and the strengthening of green financial reform and innovation safeguards. These measures have reshaped the allocation of credit resources to enterprises in the region, guided capital flows towards green investments and stimulated green technological innovation, which in turn has had a profound impact on energy consumption patterns.

First, from the perspective of building institutional environment, the pilot policy can effectively play a guiding role in the institutional system and act as a catalyst for the task of reducing energy consumption and promoting the green transition. It also effectively promotes corporate environmental responsibility and awareness of sustainable development strategies through the signalling mechanism. Compared with developed countries, China's green development is still in the primary stage, corporate environmental social responsibility awareness is generally weak, and the environmental information disclosure system has yet to be perfected. In this regard, the pilot policy focuses on building a standardised and unified system of green financial standards and promoting a mechanism for cross-regional, cross-sectoral and cross-institutional synergies and cooperation. The policy also creates a positive green financial ecosystem through the introduction of special documents to optimise the assessment system for local green enterprises and projects. It aims to promote the economy's development towards green development, sending a strong signal that the Government supports green enterprises and adheres to the green transformation of the economy. On one hand, policies incentivise enterprises to actively embrace the concept of green development, formulate and implement green production strategies, and adjust the structure of factor inputs to achieve the green transformation of production factors. On the other hand, through green certification and other 'labelling' means, it creates external pressure to force enterprises to improve production technology to enhance energy efficiency and reduce energy consumption per unit of output, thereby fundamentally easing the rise in the level of energy consumption.

Second, from the perspective of green financial market system, the pilot policy has built a diversified green financial market system. This system is able to accurately respond to the external problems of environmental projects by virtue of its differentiated treatment mechanisms, effectively curbing the growth of total energy consumption. The policy clearly defines the focus of green financial support, promotes banks and other financial institutions to build a system of green identification standards, and refines the target groups of green financial services. It can also provide more abundant credit support for enterprises and projects in the fields of new energy, new materials, green building and other energy-saving protection areas. For high-energy-consuming and high-emission enterprises and non-green projects, the pilot policy implements more stringent punitive lending rates as external pressure to prompt

their transformation and upgrading, forcing them to take the initiative to carry out rectification. At the same time, in order to ensure the environmental friendliness and energy consumption issues of enterprises' investment, construction and production activities in the pilot region, the relevant authorities also require enterprises receiving green credit support to disclose more environmental information. This series of measures mitigates the contradiction between financial resource allocation and environmental externalities, and incentivises existing enterprises to improve energy efficiency through the resource allocation effect (Liu et al., 2019; Malin et al., 2021). In addition, through the identification criteria under the green credit system, they have played the 'information effect' to guide the flow of funds to green enterprises, realising the function of optimising the allocation of financial resources by information, and thus promoting the achievement of the goal of reducing energy consumption.

Third, from the perspective of safeguard initiatives, the financial incentives and supervisory mechanisms brought about by the pilot policy can greatly mobilise market players to devote themselves to green finance. It effectively reduces energy consumption per unit of output through significant structural effects and a complete governance cycle. The limitations of the traditional financial model in identifying, assessing and monitoring the environmental level of enterprises and the flow of funds have resulted in green enterprises and projects not being favoured in the credit market. But the pilot policy has innovatively constructed platforms such as an information project library and incorporated the participation of multiple subjects, including third-party certification organisations, to break down the obstacles of information barriers and significantly enhance the efficiency of green investment and financing. Strengthened external governance, as well as measures to ease financial constraints and reduce risk-taking, have created a strong driving force for highly polluting companies to actively engage in green innovation and take on environmental responsibility (Hongyun et al., 2023). In addition, the policy's financial incentives, such as interest subsidies and tax incentives, further motivate enterprises to enhance their green innovation capabilities and optimise their energy-use structure, thereby making a significant contribution to the goal of reducing energy consumption. In conclusion, this paper proposes:

Hypothesis 1: The implementation of the pilot policy resulted in a significant reduction in the total number of energy consumption in the region.

In terms of mechanisms for optimising the industrial structure, industry plays a crucial role as the core of the economic system, and its structure directly affects the energy consumption patterns of the economy. At the micro level, the implementation of the pilot policy has led to structural adjustments in the flow of credit funds by significantly optimising the allocation of resources, which in turn has had an impact on the direction of industrial structure development. In particular, driven by the concept of green finance, banks and other financial institutions, in response to environmental regulatory requirements and the need to achieve their own profitability, are taking measures such as capital controls on companies and projects that violate industrial policy or environmental regulations. These behaviours have effectively curbed the blind expansion of highly polluting and energy-

intensive enterprises (Liu et al., 2017). At the same time, enterprises and projects that meet green finance standards are offered more favourable financing terms, such as low-interest loan support. These conditions greatly incentivise companies to engage in green innovation, accelerate the iterative upgrading of existing technologies and actively participate in the construction of green projects, thus gradually promoting the transformation of energy consumption patterns towards a more environmentally friendly, ecological and green direction (Hu et al., 2020). At the macro level, the pilot policy breaks the systemic shackles that bind green development, broadens the scope of financial services, and promotes the free flow and coordinated and efficient allocation of key factors such as knowledge, technology, talent and capital. By building a new mechanism of ‘government-guide, market-led’, the policy not only accelerates the optimisation and adjustment of the industrial structure, but also promotes the transformation of industrial production methods in a cleaner and more efficient direction. In conclusion, this paper proposes:

Hypothesis 2: The establishment of the pilot policy will reduce the total regional energy consumption by optimising the industrial structure.

In terms of environmental governance mechanisms, innovation is an important force in leading the green transformation of the economy and improving the structure of energy consumption. It is also a source of power to enhance energy efficiency and achieve energy conservation and emission reduction goals. As market failures are widespread in the research and development market, it is difficult to develop optimal levels of clean technology research and development by relying on market-based incentives alone (Popp, 2002). Therefore, government incentives play a very crucial role. For the establishment of the pilot policy, firstly, it strengthens the market’s expectation of green development. Through signalling, it directs more resources to green enterprises and green projects, and incentivises enterprises to carry out more green innovation activities to enhance their competitive advantage in order to offset the costs of environmental regulations. Secondly, it solves the contradiction between the goal of corporate profit maximisation and the assumption of environmental social responsibility under the traditional financial system. Pilot policy through the construction of scarce environmental products market, to achieve the reconfiguration of financial resources, to provide enterprises with more market information for technological improvement (Goulder and Parry, 2008). Thirdly, the pilot policy establishes special funds and financial subsidies for energy conservation and emission reduction. It will incentivise producers to undertake green technology research and development and adaptation through matching funds and direct incentives. When breakthrough green innovation occurs and the positive externalities of the green industry begin to materialise, a positive feedback mechanism will be formed within the pilot policy where economic and environmental benefits coexist, and energy intensity will be reduced. In conclusion, this paper proposes:

Hypothesis 3: The establishment of the pilot policy will reduce regional energy intensity by promoting green innovation.

4 Model setting and indicator description

4.1 Econometric modelling

The total effect of the change in total energy consumption after the implementation of the pilot zones for green finance reform and innovations policy consists of two components: The first part is the “time effect”, which refers to the variation in energy consumption levels caused by inherent “inertia” factors such as one’s own development characteristics or economic situations. The second part is the “policy treatment effect”, which refers to the variation in energy consumption levels resulting from the green finance pilot policy. Therefore, the key to assessing green finance pilot policy is how to reasonably distinguish between time-induced changes in total energy consumption and the “policy treatment effect” of green finance pilots. Staggered difference-in-difference method (staggered DID) is a causal effect parameter identification strategy, and in this paper, it treats green finance pilot policy as “quasi-natural experiments”. By comparing the differences between the two types of subjects before and after policy implementation, it can effectively separate the “time effect” and the “policy treatment effect”, and eliminate the influence of unobserved confounding factors. As a result, this paper chooses a staggered DID model to examine the impact of green finance pilot policy on total energy consumption.

Assuming the same time-effect trend in energy consumption levels in pilot and non-pilot provinces and districts before policy implementation. The econometric model is constructed with green finance pilot provinces and regions as the treatment group and non-pilot provinces and regions as the control group. Drawing on the research method of Guo et al. (Guo et al., 2024a), by introducing time dummy variables (*Time*) and city dummy variables (*Treat*), a Difference-in-Differences model is constructed as follows:

$$ener_{it} = \alpha + \beta \times DID_{it} + \gamma Controls_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where *ener* is total energy consumption, which is calculated as the sum of the four energy sources converted to coal: the natural gas supply, the petroleum gas supply, the city’s electricity consumption (Duan, 2024). *DID_{it}* is the dummy variable of pilot policy, taking the value of 1 for the experimental group implementing the pilot zones for green finance reform and innovations policy and 0 for the control group. *Controls_{it}* is a series of related control variables, including economic development, urbanisation rate, *FDI*, etc. γ_t and μ_i represent the time-fixed effects and region-fixed effects, respectively. And ε_{it} represents the random error term. β represents core regression coefficients.

4.2 Variables’ selection

4.2.1 Explained variable

Ener is the logarithm of total energy consumption in a region, which is obtained by summing up the actual consumption of fossil fuels such as coal, oil and natural gas in the region after converting them into a comparable standard coal equivalent, and the data are derived from *China Statistical Yearbook*.

4.2.2 Explanatory variable

DID is the explanatory variable and is the interaction term between the regional dummy variable and the time dummy variable. The regional dummy variable identifies the treatment and control groups based on the criterion of whether the city was selected as a model city for the green credit policy, with 1 for the treatment group and 0 for the other cities. The time dummy variable is based on when the policy was implemented, where 1 indicates the year of implementation and the year after, and 0 indicates the year before.

4.2.3 Control variables

From the perspective of their respective development situations, the five pilot provinces are clearly differentiated, and have certain typicality and representativeness in terms of the level of economic development, the size of the population and the degree of openness to the outside world. Considering that the above factors may influence the identification of pilot provinces and have an impact on the level of energy consumption, the control variables in this paper include the following (Guo et al., 2024b; Li et al., 2024; Shubin et al., 2021; Zarco-Soto et al., 2021): (1) level of economic development (*PGDP*), expressed as *GDP per capita*; (2) scale of the population (*POP*), substituted by the number of permanent resident population; (3) level of openness to the outside world (*FDI*), replaced by the actual utilization of foreign direct investment. In addition, numerous studies confirm that the urban-rural structure of the population (Shubin et al., 2021) and the economic influence of the government (Haitao et al., 2021) are important factors influencing the level of energy consumption, which is controlled. (4) The urban-rural structure of the population (*UR*) is replaced by the urbanisation rate; (5) the economic influence of the government (*ECO*) is expressed as local public financial expenditures on energy conservation and environmental protection. To avoid biases such as heteroskedasticity due to excessive numerical difference, the control variables in this paper are treated logarithmically.

4.2.4 Mediator variable

Green finance policy may contribute to the reduction of energy consumption levels through the optimisation of industrial structures and the increase of green innovation. Therefore, these two variables are the mediator variable in this paper. (1) The optimisation of industrial structures (*Indstru*) (Guo et al., 2024c), measured as the logarithm of the ratio of regional tertiary sector output to regional secondary sector output; (2) Green Innovation (*Ingrva*), measured by the number of green patent applications filed annually in each province.

4.3 Source of data

The data were selected taking into account the following two aspects:

First, controlling for interference from other policy factors. Average energy consumption showed large fluctuations due to the impact of environmental policies such as PM2.5 monitoring from 2012 onwards. Therefore, 2013 was chosen as the beginning of the study interval.

Second, the pilot policy and the actual operational situation. In April 2016, PBOC Vice Governor Chen Yulu indicated that the first

batch of green finance pilots would soon be launched, including Zhejiang, Guangdong, Guizhou, Jiangxi provinces and Xinjiang Uygur autonomous region. In December 2019 and August 2022, Gansu province and Chongqing municipality were approved to join the pilot. These regions have actively carried out preparatory work and introduced various policies related to the development and implementation of green finance, thus laying the foundation for the smooth implementation of green finance pilot work. Chongqing Municipality was not studied as an experimental group due to the relatively short implementation period of the pilot policy and the lack of obvious policy effects. In view of this, this paper conducts study based on a panel data of 30 provincial administrative regions in China (excluding Hong Kong, Macao, Taiwan and Tibet) from 2013–2021. The dates are sourced from *China Statistical Yearbook*. Descriptive statistics for the key variables are presented in Table 1.

5 Empirical analysis

First, based on the parallel trend test, control variables are added sequentially to estimate the impact of green finance pilots on total energy consumption using a staggered DID model. Second, the model was tested for robustness using methods such as changing the control group and counterfactual tests to ensure the reliability of the results of empirical analysis. Third, the mediating effect of the role of green finance policy is further examined based on the pathway of green finance affecting total energy consumption (Figure 1).

5.1 Parallel trend test

Staggered DID model requires the sample to satisfy the parallel trend assumption, thus ensuring unbiased estimates. Specifically, in the baseline regression model, the parallel trend assumption means that total energy consumption in pilot and non-pilot cities should be roughly the same in terms of time trend before the establishment of the pilot zones. After the establishment of the pilot areas, the parallel trend between the experimental and control groups should be broken, with a significant change in trend of energy consumption in the pilot cities relative to the non-pilot cities.

From Figure 2, the estimated coefficients for each year before the implementation of the pilot policy are not significant. This indicates that before the establishment of the pilot area, there was no significant difference in the trend of total energy consumption between the pilot and non-pilot cities, verifying the parallel trend hypothesis. And after the implementation of the pilot policy, the total energy consumption of the pilot cities was significantly reduced. The above analysis shows that the parallel trend assumption of the baseline regression model used in this study is valid and further analysis can be carried out.

According to Figure 2, there is a certain lag in the policy effect of green financial reform policy to reduce energy consumption. This phenomenon may be caused by a number of factors. The impact of the green finance pilot zone policy on energy consumption involves structural adjustment and increase in green innovation, and these changes will take time to take effect. In addition, the implementation of the policy requires a great deal of co-operation between multiple stakeholders such as local governments, financial institutions and

TABLE 1 Descriptive statistics.

Type	Variables	Obs	Mean	SD	Min	Max
Explained variables	<i>ener</i>	220	0.137	0.0784	0.001	0.264
Core explained variables	<i>DID</i>	225	0.124	0.331	0	1
Control variables	<i>lnPGDP</i>	225	10.91	0.422	10.04	12.12
	<i>lnECO</i>	225	4.932	0.616	3.143	6.617
	<i>lnPOP</i>	225	8.266	0.693	6.483	9.448
	<i>lnFDI</i>	225	12.74	1.809	6.483	15.98
	<i>Indstru</i>	225	0.233	0.152	0.031	0.435
	<i>Ingrva</i>	225	7.431	1.237	4.454	10.09
	<i>UR</i>	225	12.43	7.665	0.100	25.40

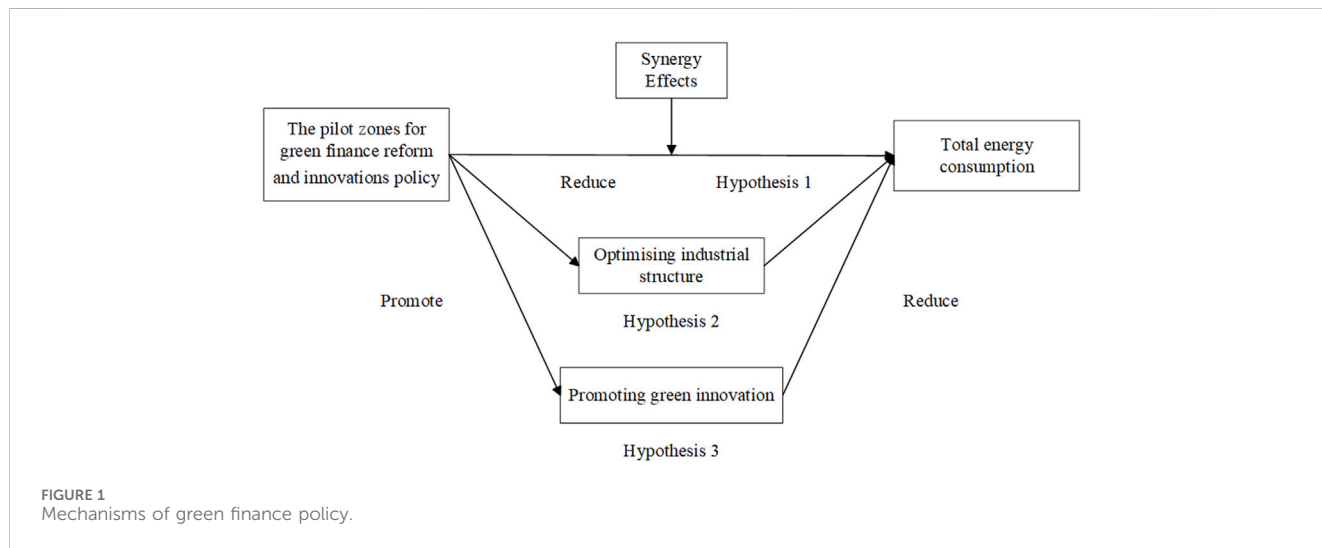


FIGURE 1 Mechanisms of green finance policy.

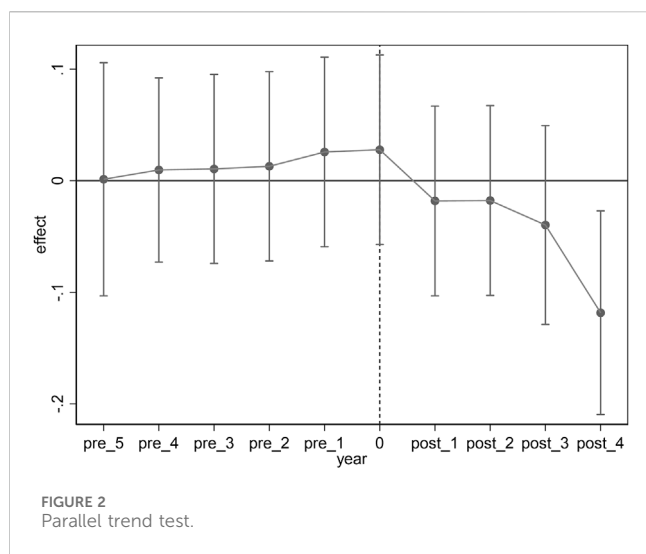


FIGURE 2 Parallel trend test.

businesses. Market participants, such as enterprises and financial institutions, also need time to adapt and respond to the new policy framework, gradually adjusting their behaviour as they gain a better understanding of policy. These harmonizations and adaptations will lead to delays in the manifestation of the effects of the policy once they are fully implemented.

5.2 Result of DID

From Table 2, the coefficients of the green finance pilot policy are all significantly negative, indicating that the green finance pilot policy have effectively reduced energy consumption per unit of GDP, and the policy effect is very significant. Column (1) controls only for province and year and not considering the effect of other factors, the interaction coefficient is -0.030 , which passes the 5% significance test. Columns (2) to (7) sequentially add

TABLE 2 Regression results of green policy on energy consumption.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	<i>ener</i>	<i>ener</i>	<i>ener</i>	<i>ener</i>	<i>ener</i>	<i>ener</i>
<i>DID</i>	-0.030** (-2.52)	-0.030** (-2.55)	-0.028** (-2.34)	-0.028** (-2.36)	-0.030** (-2.43)	-0.032** (-2.54)
<i>Constant</i>	0.044*** (3.08)	0.049*** (3.02)	0.316 (1.11)	0.335 (1.17)	-0.047 (-0.07)	-0.035 (-0.05)
<i>Observations</i>	265	265	265	265	265	265
<i>R-squared</i>	0.786	0.786	0.787	0.788	0.788	0.789
<i>Id FE</i>	YES	YES	YES	YES	YES	YES
<i>Year FE</i>	YES	YES	YES	YES	YES	YES

Note: T-statistics in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.

TABLE 3 Robustness tests.

Variables	Different control group	Counterfactual tests
	(1)	(2)
<i>DID</i>	-0.027* (-1.90)	-0.078 (-1.27)
<i>Constant</i>	0.032 (0.04)	1.983 (1.61)
<i>Observations</i>	220	265
<i>R²</i>	0.766	0.729
<i>Id FE</i>	YES	YES
<i>Year FE</i>	YES	YES

Note: T-statistics in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.

control variables to column (1), and after controlling for other influencing factors, the estimated coefficients of core explanatory variable (*DID*), are all significantly negative, suggesting that total energy consumption is significantly declined in pilot cities compared to non-pilot cities. Equation 1 reflects the fact that the pilot policy can effectively reduce the level of energy consumption and has a significant energy-saving effect. Hypothesis 1 is verified.

5.3 Robustness tests

5.3.1 Different control group

The DID model requires stability in the treatment and control groups, and the same province cannot travel between the treatment and control groups. According to the database of SynTao Green Finance, in the first half of 2017, in addition to the five pilot provinces, five other provinces enacted green finance policy, including Fujian, Jiangsu, Qinghai, Shanxi provinces and Inner Mongolia Autonomous Region. In order

TABLE 4 Analysis of the mechanisms.

Variables	<i>Indstru</i> (1)	<i>ener</i> (2)	<i>Ingrva</i> (3)	<i>ener</i> (4)
<i>DID</i>	0.044** (2.07)	-0.026** (-2.23)	0.219*** (3.34)	-0.036*** (-3.03)
<i>Indstru</i>		-0.070* (-1.93)		
<i>Ingrva</i>				0.029** (2.47)
<i>Controls</i>	Yes	Yes	Yes	Yes
<i>Id FE</i>	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes

Note: T-statistics in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.

to reduce estimation error and improve the accuracy of the results, these five provinces were excluded from the control group to form control group (Wang et al., 2024a). New control and treatment groups still meet parallel trend assumptions. The column (1) of Table 3 shows that the coefficients remain significant when using different control groups, suggesting that green finance pilot policy are effective in reducing total energy consumption and improving energy efficiency, and this finding is robust. The significant impact of green finance reform policy on reducing energy consumption is not disturbed by other similar policies.

5.3.2 Counterfactual tests

To rule out the influence from placebo effects and randomness in the results, a counterfactual test was conducted, drawing on Yanfang Zhang and Siyuan Guo's approach of changing the timing of policy implementation (Yanfang et al., 2021). In line with common practice, policy implementation is estimated 4 years in advance. If the estimated coefficient of the counterfactual test is significantly negative, it

suggests that the decline in total energy consumption may have come from other policy or stochastic factors. Conversely, if the estimated coefficient is not significant, it suggests that the reduction in the level of energy consumption stems from the implementation of the pilot policy. The column (2) of Table 3 shows that the coefficient rises sharply and is statistically insignificant when the policy is implemented 4 years earlier. This suggests that the decline in the level of energy consumption stems mainly from the green finance pilot policy, rather than placebo effects or randomness. The results of the study are reliable.

6 Analysis of the mechanisms

In order to reveal the intrinsic relationship between the pilot policy and total energy consumption, a mediation effect model is constructed to empirically test the potential transmission mechanism.

6.1 Mechanism analysis for industrial structure optimisation

Table 4 shows that columns (1) and (2) report on the impact mechanisms and transmission paths of the establishment of the pilot zones that affect regional energy consumption levels through industrial structure optimisation, using cities that are not pilot zones as a control group. It can be found that optimisation of the industrial structure is an important way for the pilot policy to achieve energy savings. Changes in the industrial structure largely determine the intensity of energy consumption and the type of pollutant emissions during the operation of the regional economy. The pilot policy has changed the flow of credit resources, forcing polluting industries to upgrade by limiting their access to credit resources. This promotes the development of the industrial structure of the entire region in the direction of green cleanliness and ecological environmental protection, which is conducive to the reduction of the total energy consumption level. Hypothesis 2 is verified.

6.2 Mechanism analysis for green innovation

Similarly, columns (3) and (4) are the estimation results with green innovation as the mediating variable. It can be found that the regression coefficient of the implementation of the pilot policy on green innovation in column (3) is significantly positive. This suggests that the implementation of the pilot policy will lead to an increase in the overall level of green innovation in the region. At the same time, the estimated coefficient of green innovation on energy intensity in column (4) is significantly positive. This suggests that green innovation by firms may indeed be beneficial in reducing energy intensity in the pilot area. However, a large number of green innovations have yet to be implemented as they are still in the research and development phase at this stage. Increased investment in innovation can lead to some rise in energy consumption in the short term.

7 Conclusion and discussion

Since the reform and opening up, China has experienced rapid economic growth for nearly 40 years, significantly contributing to global economic prosperity. However, this growth does not without cost. Green finance is an effective means to improve environmental quality (Zhang et al., 2024). Regional green finance pilot policy, represented by the pilot zones for green finance reform and innovations policy, provide a new way of thinking to address energy consumption and environmental pollution. Using the pilot zones for green finance reform and innovations set up in China as a quasi-natural experiment, the study is conducted using a staggered DID method based on panel data from 30 provincial-level administrative regions in China for the period of 2013–2021, and examines the transmission paths of the pilot policy established to promote energy conservation. The results show that the pilot policy significantly reduced the level of energy consumption and promoted energy conservation in China by optimising the industrial structure and promoting green innovation.

The findings of the study have important policy implications for China to continue to improve and give full play to the energy-saving effects of green finance. (1) Enhancing the positive contribution of pilot zones for green finance reform and innovations to energy conservation requires deepening the institutional framework and establishing a long-term mechanism to support the sustainable development of the green economy. Government guidance and financial market fundamentals are the two core drivers of the pilot zone policy to demonstrate the effectiveness of energy saving and emission reduction. In the face of the growing trend of China's green financial market, further strengthening the guarantee system for the implementation of the green financial system and clarifying the division of responsibilities between the government and the market in the process of policy implementation are key steps to unleash the energy-saving potential of green finance. At the same time, accelerating the transformation of the government's environmental policy from the traditional directive type to the market incentive type, and laying a more solid market-based cornerstone for the efficient operation of the green financial system are also important measures for unleashing the full impact of green financial policy. (2) Differentiate the promotion of pilot green finance policy, take full account of the differences in the institutional framework and resource conditions of various regions, and, on the basis of summing up the successful experience of the existing pilot policies, flexibly adjust the strategy to accelerate the promotion of pilot green finance throughout the country (Xiaojin and Ziyi, 2024). While drawing on the successful cases of the pilot, local governments should also customise the appropriate policy toolkit in close conjunction with the characteristics of the local industrial structure, the degree of marketisation and other actual circumstances. In addition, the government can also adopt a progressive reform path from a number of dimensions, such as the construction of supporting infrastructure, the development of intermediary organisations and services, as well as the cultivation of professional, technical and managerial personnel, so as to avoid blindly copying the pilot models of other regions and ensure the effective implementation of green financial policy. (3) It's necessary to stimulate the vitality of green innovation in enterprises and to establish diversified financing channels to attract more market

participants to join the green financial system aimed at improving energy efficiency, optimising energy structure and promoting green innovation. It is also important to further enhance the energy-saving effect of pilot zones for green finance reform and innovations and to incentivise enterprises to take the initiative to engage in green innovations. On the one hand, the government should introduce green incentive policies to promote the innovation of green financial products, and optimise the financing mechanism to alleviate the problem of green investment constraints caused by the financing constraints of enterprises. On the other hand, it is imperative to strengthen cross-sectoral and cross-regional synergy mechanisms, foster closer cooperation and exchanges with green financial intermediary service institutions, and refine accountability and supervision frameworks for ecological environmental protection. Through these measures, a favourable external environment can be created to expand the regional energy-saving impact of green finance.

Although we have examined thoroughly the effect of the green finance policy on city's energy consumption, there are still some limitations that deserve a further study. Due to the lack of valid data sources, the data in the text is only collected until 2021. With the continued promotion of China's green financial reform and innovation policy, Chongqing Municipality has also become a pilot city for green financial reform and innovation policy in 2022. Because of the short implementation period, this city is not taken into account in this paper. This may have some impact on the empirical results. Therefore, there is still room for further expansion and improvement of the above studies in the future. In addition, more accurate analyses are not possible in this paper due to data availability constraints. Future research should explore synthetic control methods to better control unobserved confounders and consider the impact of potential shocks on total energy consumption. At the same time, further consideration of interregional heterogeneity in policy implementation is needed for a more comprehensive study.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2025.1511837/full#supplementary-material>

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