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Research on the Impact Effects of Green Finance on Green Technological Innovation

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Abstract

Based on panel data from 30 provinces, municipalities, and autonomous regions in China spanning 2007–2023, this study employs the Spatial Durbin Model (SDM) to empirically examine both the direct effects and spatial spillover effects of green finance on green technology innovation. The findings reveal that: (1) green finance exerts a significant positive promotional effect on local green technology innovation, effectively alleviating financing constraints faced by green technology R&D, dispersing innovation risks, and guiding social capital flows toward the green technology sector; (2) both green finance and green technology innovation demonstrate significant positive spatial autocorrelation, exhibiting pronounced spatial agglomeration characteristics; and (3) green finance generates significant positive spatial spillover effects on green technology innovation in neighboring regions, wherein pilot reform experiences of green finance in adjacent areas transmit to surrounding regions through intergovernmental learning exchanges and regional coordination cooperation mechanisms. Drawing upon these research conclusions, policy recommendations are proposed, including constructing cross-regional green finance coordination mechanisms, strengthening spatial diffusion channels for green technology innovation, and deepening digital integration.

Keywords

Green Finance, Green Technological Innovation, Global Moran's I, Spatial Durbin Model.

1. Introduction

Against the dual backdrop of profound restructuring of global industrial chains and rigid constraints of the "dual carbon" goals, green technological innovation has emerged as a critical pathway to break through the "dual squeeze" of tightening environmental regulations and slowing economic growth. Unlike traditional technological innovation, green technological innovation exhibits significant positive externalities and dual uncertainties—facing both market failures in technology R&D and institutional dilemmas where environmental benefits are difficult to internalize, resulting in the coexistence of firms' reluctance and fear to innovate [1]. Green finance provides crucial financing and risk mitigation mechanisms for green technological innovation by guiding capital allocation through environmental information disclosure, dispersing innovation risks through green credit and bonds, and pricing environmental externalities through carbon financial instruments.

By the end of 2023, China's green loan balance in domestic and foreign currencies reached 30.08 trillion yuan, ranking first globally in stock scale, making green finance a core institutional arrangement driving the low-carbon technology revolution [2]. However, the spatial matching between green finance and green technological innovation demonstrates significant non-equilibrium characteristics. On one hand, green financial resources are highly concentrated in developed eastern coastal regions, while central and western regions with intensive green technology demands face structural mismatches characterized by narrow financing channels and high costs. On the other hand, green technological innovation itself possesses strong spatial spillover effects—the geographical diffusion of clean technology patents, cross-regional integration of green industrial chains, and digital flow of innovation elements enable the spatial allocation effects of green finance to transcend administrative boundaries, forming complex spatial networks of "local investment-neighboring benefits" or "central polarization-peripheral inhibition" [3]. Under the strategic goals of accelerating the construction of a unified national market and building a regional economic pattern with complementary advantages, it is urgently necessary to clarify the spatial mechanisms and boundary conditions through which green finance supports green technological innovation.

Existing literature primarily examines the linear impact of green finance on green technological innovation from a temporal dimension, conducting empirical tests around funding support theory and signaling theory. Such studies implicitly assume independent homogeneity with "no mutual influence between regions," making it difficult to explain the following paradoxes: Why do some regions with developed green finance experience "innovation polarization" rather than technology diffusion? Why do geographically proximate regions with vastly different institutional environments exhibit differentiated innovation responses? Spatial economics theory indicates that both financial resource allocation and technological innovation possess significant geographical embeddedness. Green credit and green bond funds can penetrate across regions through industrial chain investments and green technology mergers and acquisitions; local governments' competition in green finance policies can also trigger spatial diffusion of institutional innovation. However, existing research rarely places green finance within a spatial network framework, lacking systematic examination of its spatial spillover effects—specifically, whether and how local green finance development affects neighboring regions' green technological innovation levels? Is this spatial correlation achieved through capital flows, industrial linkages, or knowledge diffusion? These questions remain to be further investigated.

2. Literature Review and Research Hypotheses

Green finance provides green capital to enterprises through credit, securities, and other financial products and their derivatives, with green capital running through the entire innovation chain of green innovation, including R&D, incubation,achievement transformation, and application. First, green finance lowers the financing threshold for green technological innovation while dispersing its risks. The financial system allocates fiscal funds and social resources more favorably toward low-pollution enterprises and green innovation projects. It also promotes energy-intensive enterprises to improve production processes and supports emerging enterprises in conducting innovative activities with green development concepts. On one hand, green finance broadens financing channels for green innovation through instruments such as green credit and green bonds; on the other hand, the financial secondary market disperses risks of green innovation through the liquidity of diversified financial derivatives [4]. Second, green finance screens projects through information acquisition, directing capital flows toward energy conservation, environmental protection, and green projects. The introduction of green standards and environmental information disclosure systems forces credit funds to flow toward green and environmentally friendly enterprises, preventing the occurrence of "greenwashing" phenomena [5]. When listed enterprises raise funds in financial markets, regulatory authorities require them to disclose environmental-related information, providing the financial system with a basis for risk analysis. To implement the concept of sustainable development, banks and other financial institutions are more inclined to provide capital to enterprises and projects with green attributes. This "signal" helps guide public attention

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toward green processes and green product innovation, forcing enterprises to increase R&D investment in green technological innovation. From the perspective of financial market functions, green financial products can be used to evaluate investors' risk tolerance, screening suitable investment projects for them to achieve effective allocation of financial resources [6].

Based on this, Hypothesis 1 of this study is proposed: Green finance has a certain promoting effect on green technological innovation.

According to the First Law of Geography, no region is isolated [7]. A region is more or less influenced by adjacent regions. Ignoring spatial dependence will underestimate spillover effects and externalities between regions, leading to model misspecification and biased empirical results. The acceleration of globalization has promoted the aggregation of financial resources toward a few core cities, such as New York, London, Tokyo, Shanghai, and other regions, demonstrating the agglomeration effect of the financial industry. According to the cluster life cycle, financial centers may generate polarization effects or diffusion effects at different stages, thereby forming siphon effects or spatial spillover effects on surrounding areas [8]. In the initial development stage, polarization effects promote the backflow and accumulation of various production factors within the growth pole, with large amounts of capital, talent, and technology continuously pouring into the pole. Financial centers gradually extract resources from surrounding areas, forming siphon effects. The center-periphery financial structure exacerbates the Matthew Effect. When the growth pole reaches a critical point, diffusion effects exceed polarization effects and become dominant. Diffusion effects transfer various production factors from the growth pole to surrounding less-developed areas, driving rapid economic development in surrounding areas and narrowing the gap with developed regions [9]. In addition to providing substantive support for local green enterprises, green finance policies and tools will also have a certain impact on surrounding areas. Local development of green finance may have both positive promoting effects and certain inhibiting effects on green technological innovation in neighboring areas.

Based on this, Hypotheses 2 and 3 of this study are proposed.

Hypothesis 2: Green finance has a positive spatial spillover effect on green technological innovation in neighboring areas.

Hypothesis 3: Green finance has a negative spatial spillover effect on green technological innovation in neighboring areas.

3. Research Design

3.1. Variable Measurement and Data Sources

The green finance subsystem comprises green credit, green securities, green insurance, and green investment. Specifically, the scale of green credit in each region is measured by the loan amount of green-related listed companies in that region; green securities are measured by the issuance volume of green bonds aggregated by the location of the issuing entities. Given that agriculture is highly sensitive to natural environmental changes, the scale of agricultural insurance can reflect the development status of green insurance to a certain extent. Therefore, drawing on the approach of most scholars [10,11], this paper uses agricultural insurance premium income to represent green insurance; the ratio of investment in environmental pollution control to GDP is used to represent the regional green investment level. This paper employs the entropy weight method to calculate the weights of various indicators for green finance development, thereby measuring the regional green finance development level.

This study uses the number of green-related patent applications to reflect the level of green technological innovation over a certain period [12]. According to international patent classifications such as WIPO and drawing on the classification method of the "China Green Patent Statistical Report," this paper searches for patent applications in nine fields at the China

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National Intellectual Property Administration: environmental control and governance, environmental materials, alternative energy, energy conservation and emission reduction, green agriculture/forestry, recycling technology, new energy vehicles, green buildings, and green management. These are then aggregated by location to obtain the number of green patent applications for 30 provinces, municipalities, and autonomous regions.

In addition, this paper selects several control variables, including internal R&D expenditure (RD), full-time equivalent of R&D personnel (HR), proportion of fiscal science and technology expenditure (GOV), and foreign direct investment (FDI). Data are sourced from the "China Statistical Yearbook" over the years.

Since the substantive practice of green finance in China only began in 2007, when the State Environmental Protection Administration (now Ministry of Ecology and Environment) jointly issued a series of guiding opinions with financial regulatory authorities, promoting the rapid development of green finance, this study takes 2007 as the starting year. This paper takes 30 provinces, municipalities, and autonomous regions as research samples. Tibet Autonomous Region and Hong Kong, Macao, and Taiwan regions are not included due to missing data and inconsistent statisticalstandards. The research period is from 2007 to 2023. Green credit and green securities data are compiled from the Wind database, "China Industrial Statistical Yearbook" over the years, and economic census bulletins. Green insurance data are sourced from the "China Insurance Yearbook" over the years. Green investment data are sourced from the "China Environmental Statistical Yearbook" over the years and China ecological environment statistical annual reports.

3.2. Model Specification

3.2.1. Benchmark Model

Based on the theoretical analysis above, the baseline model is specified as follows:

$$GTI_{it} = \alpha_{it} + \beta GF_{it} + \gamma X_{it} + \mu_i + \sigma_t + \varepsilon_{it} \tag{1}$$

In formula (1), the subscripts i and $t$represent region and year respectively; GTI denotes green technological innovation, GFrepresents green finance, and X represents control variables; α is the constant term for different observations, $\beta$is the regression coefficient of green finance, and γ is the regression coefficients of control variables;μ is the individual fixed effect, σ is the time fixed effect, and ε is the random error term.

3.2.2. Spatial Durbin Model

To examine the spatial spillover effects of green finance on green technological innovation, this paper adopts the Spatial Durbin Model (SDM), which can simultaneously capture the spatial autocorrelation of both dependent and independent variables. The model is constructed as follows:

$$GTI_{it} = \alpha_{it} + \rho WGTI_{it} + \beta GF_{it} + \gamma X_{it} + \theta WGF_{it} + \delta WX_{it} + \mu_i + \sigma_t + \varepsilon_{it} \tag{2}$$

In formula (2), $W$is the spatial weight matrix, and this paper adopts the most commonly used contiguity matrix; ρ, θ , and δ are the spatial autoregressive coefficients of the dependent variable GTI , the core independent variable GF , and the control variables, respectively. Our focus is on θ , which represents the spatial spillover effect.

4. Empirical Results Analysis

4.1. Baseline Model Regression Results Analysis

The regression results are shown in Table 1

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Table 1. Baseline Model Regression Results

Variable	RegressionCoefficient
GF	2.4405*** (5.35)
RD	0.8512*** (14.76)
HR	1.1864*** (6.60)
GOV	0.2197*** (3.47)
FDI	0.2882*** (6.88)
Observation	510
R^2	0.9332

Note: Values in parentheses are t-statistics; ***, *, and * represent significance at the 1%, 5%, and 10% levels, respectively.

The regression results show that green finance has a significant positive promoting effect on green technological innovation. Specifically, for every 1-unit increase in the green finance development level, the green technological innovation level will increase by an average of 2.4405 units, which is statistically significant at the 1% level, supporting Hypothesis 1. From the financing mechanism perspective, financial instruments such as green credit and green bonds have effectively alleviated the financing constraints faced by green technology R&D, reduced enterprises' capital costs, enabling green technology projects that were previously excluded by traditional finance due to high risks and long cycles to obtain sustained funding support. From the risk management perspective, risk-sharing mechanisms such as green insurance and green funds have dispersed uncertainty risks during the technological innovation process, enhanced enterprises' willingness and capability to engage in green technology R&D, and incentivized them to conduct more forward-looking technology exploration and trial-and-error. From the signaling effect perspective, the green finance certification system transmits positive environmental performance signals to capital markets, reduces the degree of information asymmetry, helps attract more social capital to follow up investments in green technology fields, and forms a virtuous cycle of "financial support-technological innovation-environmental improvement-value enhancement." From the resource allocation perspective, green finance guides the flow of production factors from traditional high-pollution and high-energy-consumption industries to environment-friendly technological innovation fields through differentiated pricing and targeted allocation, optimizes the efficiency of innovation resource allocation across society, and accelerates the elimination of backward production capacity and the transformation and upgrading of green industrial structures.

4.2. Analysis of Spatial Durbin Model Regression Results

Before conducting the Spatial Durbin Model regression, we employthe Global Moran's I to test whether the two core variables exhibit spatial autocorrelation. The results are shown in Table 2. The Moran's I for all years is significantly positive, indicating that both green finance and green technological innovation demonstrate agglomeration characteristics in space, i.e., they possess positive spatial autocorrelation. Therefore, it is necessary to further employ the Spatial Durbin Model for research.

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Table 2. Global Moran's I of Green Finance, 2007-2023

Year	GF Moran's I	P值	Year	GTI Moran's I	P值
2007	0.275	0.013	2007	0.188	0.030
2008	0.295	0.008	2008	0.196	0.027
2009	0.332	0.002	2009	0.144	0.068
2010	0.375	0.001	2010	0.145	0.073
2011	0.378	0.001	2011	0.170	0.046
2012	0.344	0.001	2012	0.213	0.028
2013	0.349	0.001	2013	0.216	0.029
2014	0.356	0.002	2014	0.217	0.028
2015	0.359	0.002	2015	0.234	0.024
2016	0.361	0.002	2016	0.223	0.023
2017	0.350	0.002	2017	0.242	0.015
2018	0.344	0.002	2018	0.268	0.010
2019	0.315	0.004	2019	0.261	0.015
2020	0.329	0.003	2020	0.280	0.009
2021	0.318	0.002	2021	0.283	0.006
2022	0.345	0.003	2022	0.274	0.007
2023	0.363	0.002	2023	0.276	0.008

The regression is conducted using the Spatial Durbin Model with two-way fixed effects of time and individual, and the results are shown in Table 3.

Table 3. Spatial Durbin Model Regression Results

Variable	RegressionCoefficient
GF	0.4317*** (5.23)
RD	0.2281** (2.10)
HR	0.8792*** (8.07)
GOV	0.2821*** (5.42)
FDI	0.0298 (0.86)
W*GF	0.1595*** (6.25)
ρ	0.5256***
Observation	510
R^2	0.9593

Note: Values in parentheses are z-statistics; *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively.

The regression results show that the spatial autoregressive coefficient of green finance is 0.1595 and significant at the 1% level, indicating that local green finance development is positively influenced by spatial spillovers from neighboring regions' green finance development, supporting Hypothesis 2. Successful experiences from green finance reform pilots in neighboring regions (such as national pilot zones in Zhejiang, Guangdong, and Guizhou) are transmitted to surrounding areas through intergovernmental learning and exchange, as well as regional coordination and cooperation mechanisms, driving local governments in surrounding areas to learn from advanced practices and introduce supporting policies. In order to compete for high-quality green industry projects and enhance regional green competitiveness, local governments have competitively introduced green finance incentive policies and innovative initiatives, forming a pattern of policy competition and mutual learning among regions, thereby promoting the coordinated evolution of green finance development spatial patterns. Furthermore, the spatial autoregressive coefficient of green technological innovation is 0.5256 and significant at the 1% level, indicating that local green technological innovation is positively influenced by spatial spillovers from neighboring regions' green technological innovation. Organizational forms such as cross-regional green technology innovation alliances, joint laboratories, and industry-university-research cooperation platforms break through administrative boundary constraints, build regional innovation communities, and promote the optimal allocation and shared use of R&D resources, innovation elements, and technological achievements in space. Through channels such as technology transfer, enterprise expansion, and talent return, innovation diffuses to surrounding areas, driving neighboring regions to achieve leapfrog improvement in innovation capabilities through technology introduction, absorption, and re-innovation, thereby forming a "center-periphery" coordinated evolutionary pattern of regional green technological innovation.

5. Conclusions and Policy Recommendations

Based on panel data from 30 provinces, municipalities, and autonomous regions in China from 2007 to 2023, this paper empirically examines the direct effects and spatial spillover effects of green finance on green technological innovation using the Spatial Durbin Model. The main conclusions are as follows: (1) Green finance has a significant positive promoting effect on local green technological innovation; (2) Both green finance and green technological innovation exhibit significant positive spatial autocorrelation; (3) Green finance generates significant positive spatial spillover effects on green technological innovation in neighboring regions. Based on these research conclusions, the following policy implications are proposed:

First, establish cross-regional green finance coordination mechanisms. Promote the establishment of counterpart cooperation relationships between green finance-developed regions such as the Yangtze River Delta, Pearl River Delta, and Beijing-Tianjin-Hebei region and the central and western regions. Guide the flow of financial resources toward regions with intensive green technology demands but insufficient supply through shared green credit quotas, joint issuance of green bonds, and co-construction of green industry funds.

Second, strengthen the construction of spatial diffusion channels for green technological innovation. Build cross-regional green technology innovation alliances, rely on platforms such as national independent innovation demonstration zones and high-tech industrial development zones, establish inter-provincial joint research mechanisms for green technology, and promote cross-regional licensing transactions and industrial application of clean technology patents.

Third, deepen the digital integration of green finance and green technological innovation.Integrate local green project databases, financing demand databases, and financial institution resource databases, and reduce information search costs for cross-regional green investment and financing through big data intelligent matching. Establish cross-regional monitoring and sharing mechanisms for environmental benefits of green projects to enhance financial institutions' risk identification capabilities for off-site green projects.

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