HOW DOES GREEN FINANCE DRIVE THE ENHANCEMENT OF ECOLOGICAL RESILIENCE? — MECHANISMS, EXPLORATION AND EFFECT VERIFICATION FROM CHINA

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Abstract. In the context of escalating global climate change and environmental pollution, enhancing ecological resilience has become a critical task for achieving sustainable development. Although green finance, as a key instrument for promoting environmental protection and economic transformation, has garnered widespread attention, existing research rarely delves into the specific mechanisms through which green finance affects ecological resilience and its spatial spillover effects. Using panel data from 30 provinces in China from 2013 to 2023, this study constructs a panel regression model, a threshold effect model, a mediation effect model, and the Spatial Durbin Model (SDM) to systematically analyze how green finance enhances ecological resilience through pathways such as technological innovation and economic restructuring. The findings reveal that the development of green finance significantly improves ecological resilience, with notable heterogeneity based on geographical location and resource endowments. Moreover, the impact of green finance exhibits a threshold effect and significant spatial spillover effects. These conclusions provide key insights for policymakers, suggesting that strengthening policy guidance, optimizing resource allocation, and enhancing regional cooperation can further harness the positive role of green finance in promoting ecological resilience.
Keywords: *green finance, ecological resilience, sustainable development, technological innovation, economic restructuring*

Introduction

Against the backdrop of global climate change, worsening environmental pollution, and increasing ecological vulnerability, enhancing ecological resilience has become a central concern for governments and international organizations. Ecological resilience is not only a critical safeguard against external shocks such as natural disasters and climate change but also a key factor in promoting sustainable economic development and achieving a harmonious balance between the environment and the economy (Kassier, 2024). At the same time, as the global emphasis on green development deepens, green finance has emerged as a vital tool in guiding capital towards sustainable development projects, playing a potentially significant role in strengthening ecological resilience. Green finance refers to financial activities that support environmentally friendly projects and the low-carbon economy through financial instruments and market mechanisms (Lanqia et al., 2021). Its main forms include green credit, green bonds, carbon trading, and green insurance (Akomea-Frimpong et al., 2022). By supporting projects such as renewable energy, pollution control, and the efficient use of resources, these tools promote environmental protection and economic transformation, providing

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crucial financial backing for enhancing ecological resilience (Mishra et al., 2023). In the 2024 *Chinese Government Work Report*, it was stated that efforts should be made to "strengthen ecological civilization, promote green and low-carbon development, and advance comprehensive environmental governance". Against the backdrop of economic green transformation, what exactly is the impact of green finance on ecological resilience? Through what mechanisms does the development of green finance influence ecological resilience? Additionally, does the development of green finance in one region have spillover effects on the ecological resilience of other regions? Understanding these questions will help deepen our comprehension of the relationship between green finance and ecological resilience and clarify the role of green finance as a key tool for promoting ecological resilience. This will not only provide innovative insights into China's green development pathway but also offer robust policy recommendations for enhancing national ecological resilience and achieving the goals of ecological civilization.

Existing research on the relationship between green finance and ecological resilience is relatively limited, with most studies primarily focusing on the impact of green finance on the environment. Scholars have widely explored both the direct and indirect effects of green finance. In terms of direct impacts, research indicates that green finance, through financial policies, green bonds, green loans, and green investments, directly promotes environmental protection and ecosystem restoration. Governments use green finance policies to guide capital towards low-carbon industries and renewable energy projects (Zhang et al., 2021), effectively reducing financing for high-carbon sectors and facilitating the transition to a low-carbon economy (Banga, 2019). This reallocation of funds not only reduces pollutant emissions but also promotes the development of renewable energy and the improvement of environmental infrastructure (Kwilinski et al., 2023). Green bonds, as a significant financial instrument, provide direct funding for environmental projects, helping companies improve energy efficiency and reduce carbon emissions (Flammer, 2021). Additionally, green loans and green investments, by channeling funds into areas like clean energy and sustainable infrastructure, further improve environmental quality (Li et al., 2018). For instance, investments in clean energy reduce reliance on fossil fuels, driving the transformation of energy structures and effectively mitigating the threats posed by climate change (Ghezelbash et al., 2023). In terms of indirect impacts, green finance influences corporate and investor decisions through market signals, indirectly driving companies toward environmentally friendly transformations. For example, the capital market's preference for green financial instruments encourages companies to improve their environmental performance and adopt more sustainable production methods, thereby achieving sustainable development (Randjelovic et al., 2003). Furthermore, green finance has raised public awareness of environmental issues, fostering the growth of green consumption and green investments, which have indirectly generated positive effects on the ecological environment (Keshav et al., 2023). Although ecological protection projects supported by green finance may not directly alter ecosystems, the financial backing for initiatives such as forest restoration and water resource management has indirectly enhanced key ecosystem services like biodiversity, water quality, and climate regulation (Zhou et al., 2020). What is more, green finance also plays a significant indirect role in promoting environmental equity and social sustainability. By supporting North-South cooperation and providing sustainable development funding to low-income countries, green finance helps reduce

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environmental inequalities and strengthens the capacity of vulnerable communities to cope with environmental changes (Shabbir et al., 2020; Campiglio, 2016).

Although existing literature has extensively explored the impact of green finance on the environment, covering both the direct and indirect effects of green financial tools such as green bonds, green loans, and green investments, there is still a notable lack of research specifically addressing how green finance influences ecological resilience. More specifically: (1) Current studies rarely provide a comprehensive theoretical and empirical examination of the relationship between green finance and ecological resilience. Most research focuses on the short-term impacts of green finance on environmental quality, with limited attention to its effects on the longer-term and dynamic characteristics of ecological resilience; (2) Much of the existing research adopts a linear perspective when analyzing the direct impact of green finance on the environment, overlooking the non-linear effects that green finance may have on ecological resilience; (3) There is a significant gap in the literature regarding the mechanisms through which green finance affects ecological resilience. Understanding these mechanisms is essential for identifying how green finance can best enhance ecological resilience; (4) Existing research also lacks discussion on the spatial correlation between green finance and ecological resilience, meaning little is known about how the development of green finance in one region may influence ecological resilience in other regions.

In response to the limitations of existing research, this paper's research approach and marginal contributions are as follows:(1) This study systematically explores how green finance enhances ecological resilience by considering both the recovery capacity and stress resistance of ecosystems. By analyzing how policy guidance and financial allocation impact ecosystem resilience, this research expands the understanding of green finance's role in promoting ecological resilience; (2) The paper applies a threshold model to investigate how the impact of green finance on ecological resilience differs under varying conditions of capital allocation efficiency and policy implementation. This enriches the research perspective by exploring the nuanced effects of green finance on ecological resilience; (3) The study explores how green finance influences ecological resilience through intermediary variables like ecosystem service recovery and the regeneration of ecological resources. Additionally, it examines the moderating role of policy guidance and market signals in the relationship between green finance and ecological resilience, thus expanding research on the mechanisms of green finance's impact; (4) By building a spatial econometric model, this research examines the spatial spillover effects of green finance policies and financial allocations across different regions. This provides theoretical and policy support for regions to collaborate and enhance ecological resilience through green finance.

Theoretical analysis and research hypotheses

Research framework

Based on the theoretical deduction and hypothesis development discussed above (H1 to H5), this paper constructs a comprehensive conceptual framework to analyze the impact of green finance on ecological resilience. As illustrated in *Figure 1,* the framework delineates the direct transmission path, the dual intermediary channels of technological innovation and structural adjustment, the moderating role of government policy attention, and the non-linear threshold constraints. Furthermore, it incorporates the spatial dimension to account for regional spillover effects.

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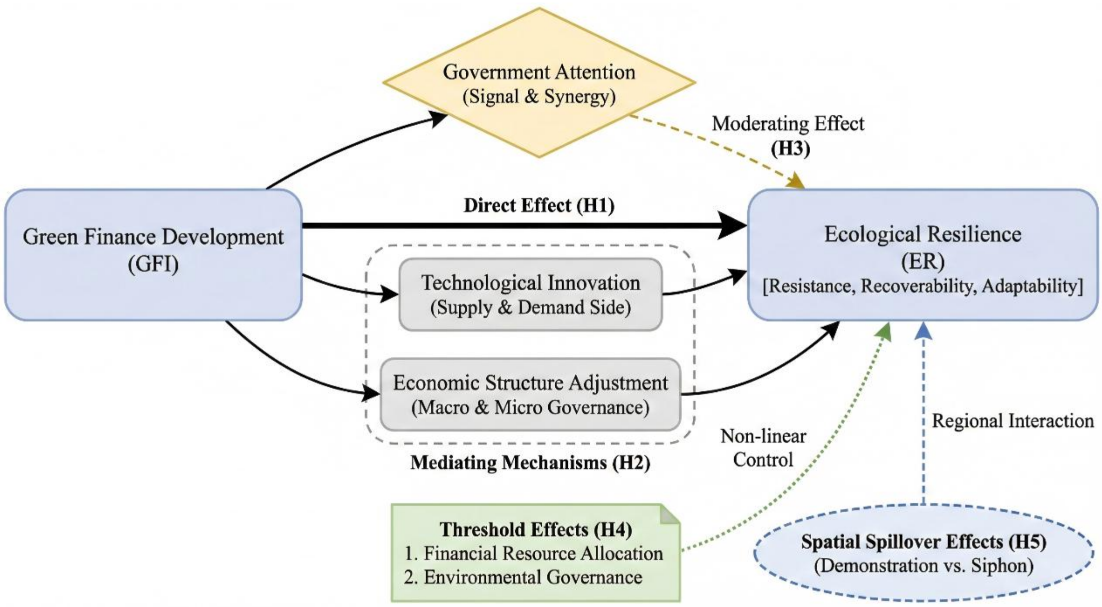

Figure 1. *Conceptual framework of the impact of green finance on ecological resilience*

The impact of green finance development on ecological resilience

Green finance is a financial model designed to support environmental protection and sustainable development by directing capital towards green industries and low-carbon projects (Khan et al., 2024). From the perspective of resource allocation theory, green finance drives the enhancement of ecological resilience through two core pricing mechanisms: “constraint” and “incentive”.

On the one hand, the constraint mechanism functions by raising the financing costs for high-pollution and high-energy-consuming industries. By strictly limiting capital flows into these traditional sectors, green finance forces the internalization of environmental costs, leading to lower emissions and improvements in the ecological environment (Liu, 2024). This financial pressure compels enterprises to fulfill their environmental responsibilities and optimize industrial structures, thereby accelerating the transition to a low-carbon economy (Liu et al., 2024b). The reduction in external environmental stress directly bolsters the ecosystem’s “resistance”—its capacity to maintain stability amidst disturbances.

On the other hand, the incentive mechanism operates by facilitating the efficient allocation of resources towards environmentally friendly technologies and industries through financial tools and policy incentives (Le et al., 2024). This directed financial support fosters the growth of clean energy and ecological restoration sectors, which reinforces the material basis of the ecosystem. Consequently, by guiding capital, green finance strengthens ecosystems’ ability to resist risks and recover from disturbances, further reinforcing their resilience (Cao et al., 2023). Based on this analysis, this paper proposes research hypothesis 1.

Hypothesis 1: The development of green finance can significantly enhance ecological resilience.

The mediating effect of green finance development on ecological resilience

The development of green finance enhances ecological resilience through various intermediary mechanisms. By supporting environmental projects and promoting

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sustainable development, green finance drives the transformation and upgrading of the green economy, which fundamentally alters corporate economic activities and production methods (Chen et al., 2023; Xu et al., 2024). These shifts impact the ecological environment not only through direct capital allocation but also through profound indirect pathways mediated by Technological Innovation (TI) and Economic Structural Adjustment (ESA). These mediators operate through multidimensional channels involving both supply-side production and demand-side consumption, as well as macro-allocation and micro-governance.

From the perspective of technological innovation, green finance drives ecological resilience by simultaneously transforming production modes and guiding consumer behavior. On the supply side, green finance channels funds into low-carbon and environmentally friendly sectors, providing long-term, low-cost financing that alleviates the severe financial constraints companies face in R&D activities. This financial support accelerates the dissemination and application of efficient and environmentally friendly technologies (Bhatnagar et al., 2022). Such innovation facilitates the transition of traditional high-pollution industries to low-carbon models, reducing pollution at the production level (Siddiqui et al., 2023). Crucially, on the demand side, technological innovation funded by green finance fosters the creation of green consumer products. The marketization of these products promotes the diffusion of green consumption concepts, increasing demand for eco-friendly goods, which reduces environmental stress from the source and further strengthens ecological resilience (Sibt-e-Ali et al., 2024).

From the perspective of economic structural adjustment, green finance enhances ecological resilience by optimizing resource allocation and improving corporate environmental governance. At the macro level, the widespread use of financial instruments such as green bonds and green loans directs capital towards renewable energy, energy-saving, and environmental protection industries. This allocation mechanism drives a shift from traditional high-energy-consuming industries to a green, low-carbon economic structure (Liu et al., 2023a). Furthermore, at the micro level, the development of green finance imposes strict requirements for environmental information disclosure. To access green capital, enterprises are compelled to improve their environmental governance capabilities and transparency, which reduces industrial pollution risks and enhances the sustainability and adaptability of the economy, thereby actively enhancing ecological resilience (Ge et al., 2023). Based on the above analysis, research hypothesis 2 is proposed:

Hypothesis 2: Green finance enhances ecological resilience through technological innovation and economic structural adjustment.

The moderating effect of government attention on green finance

While green finance provides the necessary capital for ecological restoration, its efficiency is heavily contingent upon the policy environment. We posit that government attention to green finance (GFA) acts as a critical “catalyst” that moderates the relationship between green finance and ecological resilience through Signaling Theory and Policy Synergy, rather than merely reflecting standard governmental oversight.

First, government attention functions as a powerful *market signal*. High-intensity government attention (reflected in policy documents and work reports) signals a stable, long-term political commitment to sustainable development (Fu et al., 2023). According to signaling theory, this commitment reduces the “policy uncertainty” perceived by private investors. When the government sends a strong signal of support, financial institutions and

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enterprises are more confident in the potential returns of long-cycle ecological projects (Mudalige, 2023), leading to more active participation and higher investment efficiency. Second, government attention fosters policy synergy that amplifies the efficacy of financial resources. When the government attaches high importance to green finance, it typically mobilizes complementary administrative resources—such as tax incentives, green channels for project approval, and risk compensation mechanisms (Khan et al., 2024; Quatrini, 2021). This "resource bundling" effect ensures that green funds are not just allocated but are utilized effectively. Conversely, even with sufficient green capital, a lack of active government coordination may lead to resource mismatch or project delays. Therefore, active government attention ensures that green finance is directed more precisely towards high-impact ecological projects, thereby strengthening the ecosystem's capacity for self-recovery and adaptability. Based on the above analysis, research hypothesis 3 is proposed:

Hypothesis 3: The higher the government's attention to green finance, the more significant the positive impact of green finance on enhancing ecological resilience.

Threshold effect of green finance development on ecological resilience

The impact of green finance development on enhancing ecological resilience may exhibit a threshold effect. This suggests that under different levels of financial resource allocation efficiency and technological innovation, the influence of green finance on ecological resilience may vary. Therefore, it is essential to explore how green finance generates ecological benefits through these two factors under different conditions. Firstly, in terms of financial resource allocation efficiency, when the efficiency is low, green finance development often faces issues such as poor capital flow and an underdeveloped financial market (Han et al., 2023). This leads to insufficient innovation in green financial products and prevents capital from effectively reaching environmental projects, limiting the positive impact of green finance on ecological resilience (Goncharenko et al., 2021). As the efficiency of financial resource allocation improves, green finance becomes more dynamic, allowing capital to more efficiently support the upgrading and transformation of green technologies and industries (Zhao et al., 2024). This, in turn, optimizes industrial structure and facilitates the rational allocation of resources, reducing environmental pollution and further enhancing regional ecological resilience. Secondly, in terms of environmental governance levels, when the level of environmental governance is relatively low, the development of green finance, although providing some financial support, has a limited impact on improving ecological resilience due to the lack of sufficient policy incentives and environmental regulation (Xie, 2024). However, as environmental governance improves, green finance can more effectively support environmentally friendly projects, promote the application of green technologies, and reduce resource waste and pollution emissions, thereby significantly enhancing the ecological resilience of the region (Tan et al., 2024). Based on the above analysis, Research Hypothesis 4 is proposed:

Hypothesis 4: The impact of green finance development on ecological resilience is subject to a threshold effect influenced by financial resource allocation efficiency and environmental governance level.

The spatial spillover effects of green finance development on ecological resilience

While the administrative interconnectedness of Chinese provinces suggests potential regional interactions, the specific direction of green finance's spatial spillover on

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ecological resilience remains theoretically ambiguous, subject to the interplay between "diffusion effects" and "siphon effects".

On the one hand, green finance may generate positive "Demonstration and Diffusion Effects". As regional integration deepens, successful green finance practices and advanced environmental technologies can spread rapidly across borders. For instance, the cross-regional flow of capital facilitated by green credit policies allows neighboring provinces to bridge funding gaps for ecological governance (Yang et al., 2024). Similarly, the environmental technologies supported by green finance have strong spillover potential; when successfully applied in one province, these innovations can be adopted by neighboring enterprises through technology transfer, thereby collaboratively reducing pollution (Liu et al., 2024a). Furthermore, the development of green finance often triggers policy learning, where provinces share successful frameworks to create a synergistic regulatory environment (Li et al., 2024). On the other hand, however, green finance could theoretically trigger negative "Siphon Effects" or "Pollution Leakage". Financial hubs with mature green finance systems might attract high-quality green capital and talent away from neighboring less-developed regions, potentially hollowing out the neighbors' capacity for environmental governance. Additionally, strict green financing constraints in one province might force high-pollution enterprises to relocate to adjacent provinces with looser regulations, thereby worsening the neighbors' ecological resilience.

Given these competing theoretical forces—where close connections could lead to either mutual benefit or beggar-thy-neighbor outcomes—whether the development of green finance ultimately enhances or inhibits the ecological resilience of neighboring regions is an empirical question that requires rigorous verification. Based on this, the following research hypothesis is proposed:

Hypothesis 5: The development of green finance exhibits significant spatial spillover effects on the ecological resilience of neighboring regions.

Materials and methods

Model specification

Baseline model

Based on the theoretical analysis of the impact of green finance development on ecological resilience, we first establish a regression model using panel data to examine the effect of green finance development on urban ecological resilience. Considering the potential heterogeneity across different regions and time periods, the model can be specified as follows:

$$ER_{it} = \beta_0 + \beta_1 GFI_{it} + \sum_{n=2}^{k} \beta_n Control_{nit} + \mu_i + \gamma_t + \varepsilon_{it} \quad \text{(Eq.1)}$$

In this context, ER_{it} represents the ecological resilience index for city *i* in year *t*, while GFI_{it} denotes the green finance development level indicator for city *i* in year *t*. $Control_{nit}$ refers to a series of control variables. μ_i and γ_t represent the individual fixed effects and time fixed effects, respectively, which are used to control for heterogeneity across cities and common time-specific influences across years. ε_{it} is the random disturbance term.

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Mediating effect model

Based on the previous analysis, the development of green finance impacts ecological resilience through promoting technological innovation (TI) and economic structure adjustment (ES). Green finance not only directly affects ecological resilience but also indirectly enhances the resilience of ecosystems by fostering the development of green technologies and optimizing resource allocation. To examine the indirect effects of green finance on ecological resilience through technological innovation and economic structure adjustment, this paper adopts a mediation effect model for verification. First, a regression estimation is conducted to assess the impact of green finance development on ecological resilience. Second, technological innovation (TI) and economic structure adjustment (ESA) are treated as dependent variables, with green finance development as the core explanatory variable, to perform separate regression estimations. Lastly, with ecological resilience as the dependent variable, green finance development as the core explanatory variable, and technological innovation (TI) and economic structure adjustment (ESA) as the mediating variables, a regression estimation is conducted by incorporating these variables into the model (Cheng et al., 2023). The model is set as follows:

$$M_{it} = \theta_0 + \theta_1 GFI_{it} + \sum_{n=2}^{k} \theta_n Control_{nit} + \mu_i + \gamma_t + \varepsilon_{it} \quad \text{(Eq.2)}$$

$$ER_{it} = \pi_0 + \pi_1 GFI_{it} + \omega M_{it} + \sum_{n=2}^{k} \pi_n Control_{nit} + \mu_i + \gamma_t + \varepsilon_{it} \quad \text{(Eq.3)}$$

In this equation, M_{it} represents the mediating variables.

Moderating effect model

Based on the previous analysis, government attention to green finance (GFA) may play a moderating role in the relationship between green finance development and ecological resilience. The government's active attention and policy support in the green finance sector can facilitate the more efficient flow of funds into green industries, further amplifying the positive effects of green finance on environmental protection and ecological restoration. Therefore, this paper introduces government attention to green finance (GFA) as a moderating variable and constructs interaction terms to explore its moderating effect on the relationship between green finance development and ecological resilience. The moderating effect model (Raza et al., 2022) is set as follows:

$$ER_{it} = \delta_0 + \delta_1 GFI_{it} + \delta_2 GFA_{it} + \delta_3 GFI_{it} \times GFA_{it} + \sum_{n=4}^{k} \delta_n Control_{nit} + \mu_i + \gamma_t + \varepsilon_{it} \quad \text{(Eq.4)}$$

In this equation, GFA_{it} represents government attention to green finance.

Threshold model

To examine whether the impact of green finance development on ecological resilience exhibits nonlinear characteristics, this paper adopts a panel threshold model (Song, 2021), drawing on related research. Specifically, financial resource allocation efficiency (FRAE)

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and environmental governance level (EG) are considered as threshold variables, and both single-threshold and multiple-threshold panel models are constructed to detect how the influence of green finance development on ecological resilience varies under different threshold conditions. The models are set as follows:

Single-threshold model:

$$ER_{it} = \alpha_0 + \alpha_1 GFI_{it} \times I(Thr_{it} \le \sigma_1) + \alpha_2 GFI_{it} \times I(Thr_{it} > \sigma_1) + \sum_{n=1}^{k} \beta_n Control_{nit} + \mu_i + \gamma_t + \varepsilon_{it} \quad \text{(Eq.5)}$$

Multiple-threshold model:

$$ER_{it} = \alpha_0 + \alpha_1 GFI_{it} \times I(Thr_{it} \le \sigma_1) + \alpha_2 GFI_{it} \times I(\sigma_1 < Thr_{it} \le \sigma_2) + \cdots + \alpha_{n+1} GFI_{it} \times I(Thr_{it} > \sigma_n) + \sum_{n=1}^{k} \beta_n Control_{nit} + \mu_i + \gamma_t + \varepsilon_{it} \quad \text{(Eq.6)}$$

In these models, Thr_{it} represents the threshold variable, which can be either financial resource allocation efficiency (*FRAE*) or environmental governance level (*EG*). σ_n is the threshold value to be estimated, and *I ( )* is the indicator function, which takes the value of 1 when the specified condition is met and 0 otherwise. The other variables are consistent with those in the baseline regression model.

Spatial panel model

Before constructing the spatial econometric model, it is prerequisite to verify the spatial dependence of the variables. We employ the Global Moran's I index to quantify the spatial autocorrelation of ecological resilience across provinces. The calculation formula is as follows:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad \text{(Eq.7)}$$

where *n* is the number of provinces; x_i and x_j represent the ecological resilience of province *i* and *j*; $\bar{x}$ is the mean value; and w_{ij} is the spatial weight matrix.

To explore whether the development of green finance exhibits spatial spillover effects on ecological resilience, this paper builds a spatial econometric model (Du et al., 2021) by incorporating spatial interaction terms between green finance, ecological resilience, and a series of control variables based on the baseline regression model. The specific form is as follows:

$$ER_{it} = \beta_0 + \tau_1 W_{it} ER_{it} + \beta_1 GFI_{it} + \sum_{n=2}^{k} \beta_n Control_{nit} + \varphi_1 W_{it} GFI_{it} + \sum_{n=2}^{k} \varphi_n W_{it} Control_{nit} + \mu_i + \gamma_t + \varepsilon_{it} \quad \text{(Eq.8)}$$

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$$\varepsilon_{it} = \delta W_{it}\varepsilon_{it} + \upsilon_{it} \quad \text{(Eq.9)}$$

In these models, τ_1 represents the spatial autoregressive coefficient. φ_1 and φ_n denote the coefficients of green finance development level and the control variables, respectively, along with their spatial interaction terms. W_{it} is the spatial weight matrix, indicating spatial spillover effects.

Endogeneity and robustness models

To ensure the reliability of the estimation results, this study specifically addresses potential endogeneity issues and tests the robustness of the dynamic relationships.

Considering the potential reverse causality between green finance and ecological resilience, we employ the Two-Stage Least Squares (2SLS) method for identification. We utilize the number of telephones per 10,000 households in 1984 as the instrumental variable (IV). The two-stage estimation equations are set as follows:

$$\begin{aligned} &FirstStage: GFI_{it} = \delta_0 + \delta_1 IV_i \times Trend_t + \lambda Control_{it} + \mu_i + \nu_t + \check{n}_{it} \\ &SecondStage: ER_{it} = \beta_0 + \beta_1 \hat{GFI}_{it} + \gamma Control_{it} + \mu_i + \nu_t + \varepsilon_{it} \end{aligned} \quad \text{(Eq.10)}$$

The rationale for this selection is twofold: first, regarding Relevance (Path Dependence): The diffusion of green finance relies heavily on information infrastructure and regional financial depth. The number of telephones in 1984 serves as a crucial proxy for a region's historical information infrastructure and openness. According to the theory of technological path dependence, regions with better early communication infrastructure tend to accumulate higher levels of financial technology and institutional efficiency over time, which are foundational for the modern development of green finance systems. Therefore, this historical variable is positively correlated with current green finance levels. Second, regarding exogeneity (exclusion restriction): as a historical infrastructure indicator from nearly four decades ago, the direct impact of 1984 telephone density on the current ecological environment (e.g., pollutant emissions or ecosystem recovery capacity in 2023) has largely dissipated due to technological iteration and industrial shifts. It is unlikely to affect current ecological resilience through channels other than the path of economic and financial development. Thus, it satisfies the exclusion restriction required for a valid instrument. To adapt this cross-sectional data to panel analysis, we introduce a time-varying dimension by interacting the 1984 telephone data with the national trend of green finance development (or a time trend), following the methodology of Nunn and Qian (Nunn et al., 2014).

To account for the path dependence and inertia of ecological resilience, we construct a dynamic panel model by introducing the one-period lagged dependent variable as an explanatory variable:

$$ER_{it} = \alpha_0 + \rho ER_{it-1} + \beta_1 GFI_{it} + \sum \lambda_k Control_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad \text{(Eq.11)}$$

Variable description and measurement

Data sources

Considering data availability, this study uses panel data from 30 Chinese provinces over the period from 2013 to 2023 as the research sample. The primary data sources include the

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CSMAR database purchased by the research institution, the *China Statistical Yearbook*, the *China Environmental Statistical Yearbook*, provincial statistical yearbooks, and the national economic and social development statistical bulletins. Additionally, the data on government attention to green finance, measured by word frequency, is derived from government work reports and the Baidu Index. All variables were also subjected to winsorization to handle outliers. This study divides the total sample of 30 provinces into three subsamples: Eastern, Central, and Western regions, strictly following the standard economic classification by the National Bureau of Statistics of China. Specifically, the Eastern region comprises 11 provinces/municipalities: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the Central region comprises 8 provinces: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan; and the Western region comprises 11 provinces: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

Dependent variable: ecological resilience (ER)

Ecological resilience encompasses three core characteristics: resistance, adaptability, and recovery. Resistance refers to the ability of an ecosystem to maintain stability when facing external disturbances (Shao et al., 2024). Adaptability is the ability of the ecosystem to adjust its state to cope with environmental changes (Scarano, 2017), while recovery reflects the potential of the ecosystem to return to its original state after being damaged (Moreno-Mateos et al., 2020). Drawing on the research of Fan et al. (Hua et al., 2024), an ecological resilience evaluation framework consisting of resistance, adaptability, and recovery is constructed (see *Table 1*). After standardizing these specific indicators, this study employs the TOPSIS-entropy method to assign weights to each indicator and synthesize them into an overall ecological resilience index. This ecological resilience index not only reflects the stability of an ecosystem but also evaluates its capacity to respond to changes in the external environment.

Table 1. *Evaluation system of ecological resilience*

Target layer	Criterion layer	Indicator layer
Ecological resilience	Resistance	Per capita industrial wastewater discharge
		GDP per unit area
		Per capita industrial sulfur dioxide emissions
		Population density
		Per capita industrial smoke (dust) emissions
		Ratio of built-up area
		Domestic waste collection and transportation
	Adaptability	Total water resources
		Harmless treatment rate of domestic waste
		Centralized treatment rate of sewage plants
		Gas coverage rate
		General industrial solid waste comprehensive utilization rate
	Recoverability	Built-up area green coverage rate
		Number of public libraries per 10,000 people
		Per capita public green area
		Per capita water resources
		Per capita land area

Data sources: The data for industrial pollution (e.g., wastewater, SO2, smoke) and solid waste utilization are derived from the China Environmental Statistical Yearbook. Data for urban infrastructure and public services (e.g., green coverage, gas coverage, waste treatment) are sourced from the China Urban Construction Statistical Yearbook. Other socio-economic indicators (e.g., GDP, population, water resources) are obtained from the China Statistical Yearbook and provincial statistical yearbooks

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Independent variable: level of green finance development (GFI)

With the rapid development of green finance, its connotation and scope have become increasingly enriched. To comprehensively measure the development level of green finance, and considering that a single indicator is insufficient to capture its multidimensional characteristics, this study draws on the research framework of Liu et al. (2023b) and selects five dimensions for measuring green finance development: green credit (Zhou et al., 2024), green securities (Kassi et al., 2024), green insurance (Chen et al., 2019), green investment, and carbon finance (Guo et al., 2022) (see *Table 2*). The measurement of green finance development is primarily conducted by standardizing the relevant indicators and using the TOPSIS-entropy method to calculate the comprehensive index of green finance development.

Table 2. *Evaluation system of green finance*

Target layer	Criterion layer	Indicator layer
Green finance	Green credit	Proportion of green loans
		Proportion of interest expenses in high-energy industries
	Green securities	Market value proportion of environmental protection industries
		Market value proportion of high-energy industries
		Proportion of green bonds
	Green insurance	Proportion of agricultural insurance scale
		Agricultural insurance payout ratio
	Green investment	Proportion of public expenditure on energy-saving and environmental protection
		Proportion of foreign direct investment in energy-saving and environmental protection industries
		Proportion of risk investment in energy-saving and environmental protection industries
		Proportion of investment in pollution control and environmental protection
		Proportion of trading volume of clean development mechanism projects
	Carbon finance	Carbon intensity

Data sources: Data for Green Credit (e.g., interest expenses of high-energy industries) are derived from the China Industrial Statistical Yearbook and the CSMAR Database. Green Securities data are sourced from the CSMAR Database and Wind Database. Green Insurance data (e.g., agricultural insurance) come from the China Insurance Yearbook. Green Investment data (e.g., environmental protection expenditure) are from the China Statistical Yearbook. Carbon Finance (carbon intensity) is calculated based on energy consumption data from the China Energy Statistical Yearbook

Mediating variables: technological innovation (TI) and economic structure adjustment (ESA)

Regarding technological innovation (TI), green finance significantly enhances the level of technological innovation by promoting the research, development, and application of green technologies (Bai et al., 2023). Scholars typically measure the degree of technological innovation using the number of technology patents (Zhang et al., 2024a). In this study, the number of patents obtained at the provincial level is used as the measurement indicator. As for economic structure adjustment (ESA), green finance promotes economic structural transformation by optimizing resource allocation and encouraging traditional industries to shift toward green and low-carbon development (Wu et al., 2024). This study, drawing on the research by Wang et al. (2020), uses green GDP to measure the greening of the economic structure.

Moderating variable: government attention to green finance (GFA)

Government attention to green finance (GFA) plays a moderating role in the impact of green finance on ecological resilience. Through policy guidance and resource allocation,

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the government directs financial resources toward green industries, thereby amplifying the positive effects of green finance on environmental protection and ecological restoration. For instance, government support for financial tools such as green credit and green bonds can enhance the effectiveness of green finance, ultimately improving regional ecological resilience. To measure government attention to green finance, this study utilizes Python software to perform a statistical analysis of relevant keywords in government work reports from various regions. Keywords include "green finance," "green development," "low-carbon economy," and "environmental investment." By calculating keyword frequency, we quantify the degree of government attention to green finance in different regions. This measure is then used as a moderating variable, with the expectation that the higher the government's attention to green finance, the stronger the positive impact of green finance on ecological resilience.

Threshold variables: financial resource allocation efficiency (FRAE) and environmental governance (EG)

Regarding financial resource allocation efficiency (FRAE), numerous studies use the liquidity of financial markets and the efficiency of resource allocation as measurement indicators (Fan et al., 2022). In this study, we measure FRAE using the capital liquidity of financial markets and the efficiency of financial intermediary services. Specifically, we select the ratio of credit to GDP and the return on capital as key indicators (Ozhan, 2020). As for environmental governance (EG), this study measures the level of environmental governance using data related to government efforts in environmental regulation, policy implementation, and pollution control investments (Ma et al., 2022). Specifically, we use the proportion of special environmental funds to GDP and the treatment rates of industrial waste gas and wastewater as indicators.

Control variables

To account for other factors that may affect the relationship between green finance and ecological resilience, this study incorporates several control variables to minimize model bias and ensure the robustness of the results. The level of economic development is measured using the logarithmic value of real per capita GDP (lnPGDP), which helps control for the influence of economic growth on ecological resilience. The industrial structure (IS) is represented by the proportion of the value added by the tertiary industry to GDP, reflecting the impact of industrial optimization on ecological resilience. Energy intensity (EI) is measured by per capita energy consumption, controlling for the pressure that energy use places on ecosystems. Urbanization level (URB) is controlled through the proportion of urban population, indicating the influence of urbanization on ecological resilience. Lastly, the level of openness (OPE) is measured by the ratio of actual foreign direct investment to GDP, controlling for the potential effects of external openness on ecological resilience. The descriptive statistics of variables are presented in *Table 3*.

Empirical results analysis

General estimation procedures

To rigorously evaluate the impact of green finance on ecological resilience, this study adopts a systematic empirical strategy (*Fig. 2*). Initially, we mitigate the influence of outliers through winsorization and confirm the absence of multicollinearity and non-

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stationarity via Variance Inflation Factor (VIF) calculations and unit root tests. Subsequently, a two-way fixed effects model is established as the baseline specification based on the Hausman test results, supplemented by Instrumental Variable (2SLS) estimation and extensive robustness checks to address potential endogeneity issues. The analysis then deepens into transmission mechanisms and regional heterogeneity, concluding with a spatial econometric assessment where the Spatial Durbin Model (SDM) is identified as the optimal specification through rigorous diagnostic testing (including LM, Wald, and LR tests) to accurately capture spillover effects.

Table 3. *Descriptive statistics of variables*

Variable name	Variable abbreviation	Observations	Mean	Standard deviation	Min	Max
Ecological resilience	ER	300	0.028	0.024	0.013	0.152
Green finance index	GFI	300	0.061	0.045	0.012	0.319
Technological innovation	TI	300	5.164	1.828	1.391	9.796
Economic structure adjustment	ESA	300	3.140	0.425	2.265	4.157
Government attention to green finance	GFA	300	0.460	0.112	0.164	0.717
Financial resource allocation efficiency	FRAE	300	4.351	0.818	2.107	6.107
Environmental governance	EG	300	3.402	0.495	2.100	4.549
Log of per capita GDP	lnPGDP	300	4.712	0.252	3.958	5.218
Industrial structure	IS	300	0.008	0.013	0.000	0.087
Energy intensity	EI	300	0.640	0.141	0.282	0.955
Urbanization level	URB	300	0.066	0.075	0.004	0.419
Openness level	OPE	300	3.242	0.736	0.700	4.551

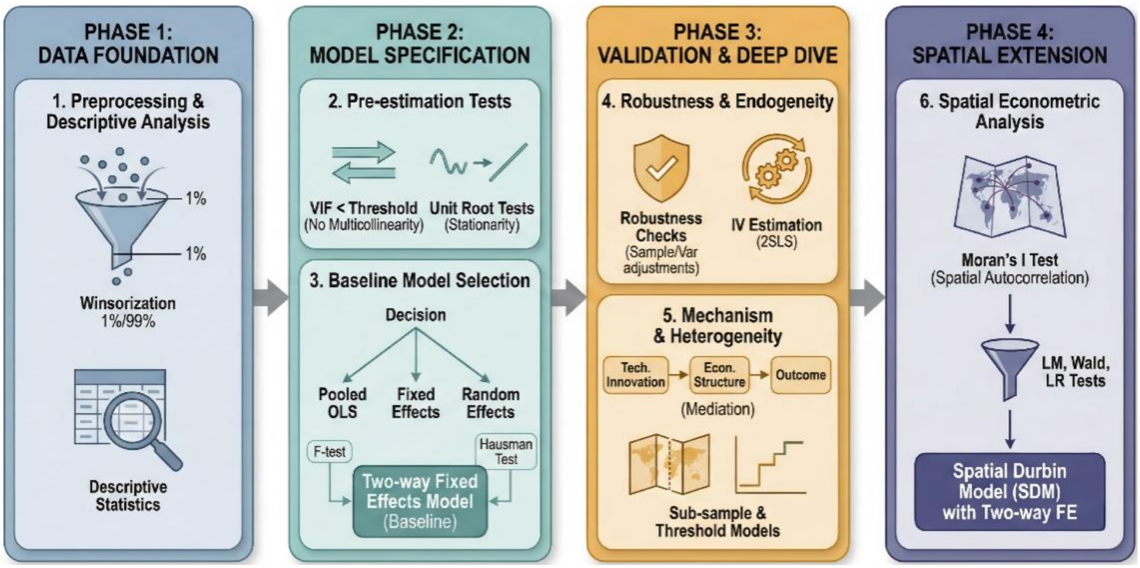

Figure 2. *Framework for general estimation procedures*

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Spatio-temporal evolution of green finance activities

To establish a comprehensive empirical context before delving into the econometric verification, this study first characterizes the spatiotemporal evolution of green finance activities and ecological resilience projects across China from 2013 to 2023. As visualized in *Figures 3* and *4*, the spatiotemporal distribution of green investments and the number of landed ecological resilience-related projects exhibits a high degree of consistency, revealing a distinct "East-leading, West-advancing" dynamic trajectory. Specifically, *Figure 3* highlights that while eastern coastal provinces—such as Guangdong, Jiangsu, and Zhejiang—maintain a dominant position in green capital mobilization due to their mature financial markets, there is a significant diffusion of investment intensity toward central and western regions (e.g., Sichuan and Hubei) following the implementation of the 2016 "Guidelines for Establishing a Green Finance System" and the announcement of the 2020 "Dual Carbon" goals. This trend suggests that macro-policy signals have effectively guided the cross-regional allocation of financial resources. Corroborating this, *Figure 4* demonstrates that these financial inputs are effectively translating into physical governance activities, with the number of ecological projects showing a steady accumulation consistent with investment flows. Notably, although the visualization captures a structural fluctuation in 2022—where project implementation in regions like Shanghai and Jilin experienced a temporary retraction attributable to the exogenous shocks of COVID-induced lockdowns and fiscal constraints—the trajectory exhibits a resilient V-shaped recovery by 2023. Collectively, these stylized facts not only validate the substantial expansion of green finance in supporting tangible ecological governance but also provide preliminary factual support for the positive nexus between green finance and ecological resilience, thereby setting a robust foundation for the subsequent baseline regression analysis.

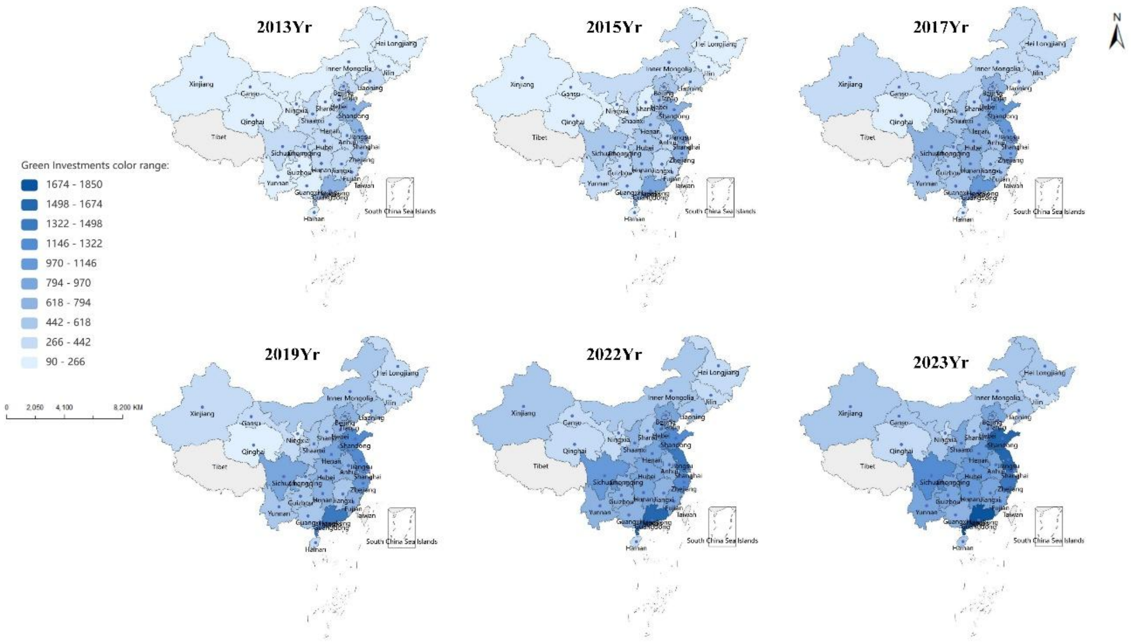

Figure 3. *Spatiotemporal evolution of green investment levels in China (2013–2023)*

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Baseline regression

To test Hypothesis 1, a regression analysis was conducted using *Equation 1*, with the results presented in *Table 4*. In *Table 4,* Column (1) displays the regression results without the inclusion of control variables, while Column (2) presents the results with control variables added. The findings indicate that the Green Finance Development Index (GFI) has a significant positive impact on ecological resilience, with the coefficient remaining significantly positive regardless of whether control variables are included. This suggests that the further development of green finance can effectively enhance ecological resilience, thus supporting Hypothesis 1. In Column (2), multiple control variables are introduced to improve the robustness of the regression model. The results show that the level of economic development (lnPGDP) has a significant negative impact on ecological resilience, which may indicate that economic growth exerts certain environmental pressures. The industrial structure (IS) demonstrates a significant positive effect on ecological resilience, indicating that industrial upgrading contributes to ecological improvements. Additionally, the level of openness (OPE) and urbanization level (URB) also exhibit positive effects on ecological resilience, suggesting that an open economy and orderly urbanization can support environmental improvements. Notably, the coefficient for energy intensity (EI) is significantly negative, indicating that increased energy consumption has a detrimental impact on the ecological environment.

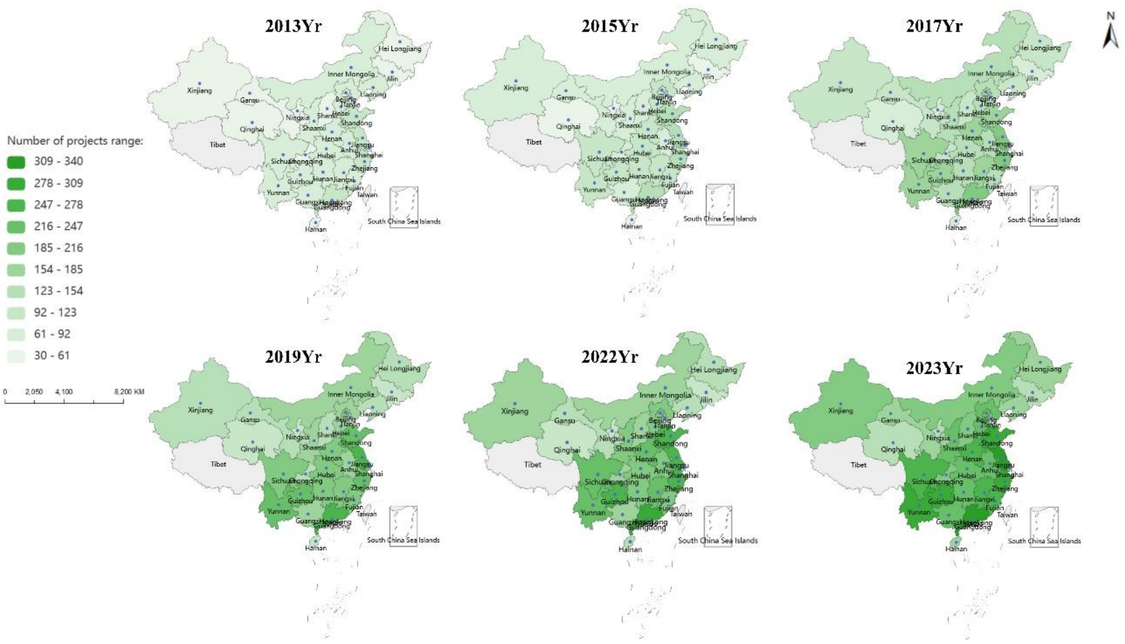

Figure 4. *Spatiotemporal evolution of the number of ecological resilience-related projects in China*

Robustness tests

Replacing the core explanatory variable

To verify the robustness of the impact of green finance development on ecological resilience, the study re-estimated the regression using an alternative indicator, specifically a composite score of green finance-related metrics. As shown in Column (1) of *Table 5,*

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the coefficient of the composite green finance score remains significantly positive with respect to ecological resilience, consistent with the results of the baseline regression. This finding further supports Hypothesis 1, indicating that the development of green finance can significantly enhance ecological resilience.

Excluding specific samples

Considering the significant regional disparities in economic development levels and environmental governance capabilities, the study excludes the Xinjiang region to eliminate potential confounding factors. As shown in Column (2) of *Table 5,* the effect of green finance development on ecological resilience remains significantly positive even after excluding this region. This further demonstrates the positive contribution of green finance development to ecological resilience and confirms the robustness of the study's findings.

Table 4. *Baseline regression results*

Variable	**Ecological resilience**	
	(1)	**(2)**
GFI	0.134*** (0.009)	0.126*** (0.007)
lnPGDP		-0.002** (0.003)
IS		0.005*** (0.002)
OPE		0.003** (0.001)
EI		-0.005*** (0.001)
URB		0.002** (0.004)
Constant	0.020*** (0.002)	0.022*** (0.003)
City/Year Fixed Effects	Controlled	Controlled
R^2	0.932	0.955
Observations	300	300

***, **, and * denote significance levels at 1%, 5%, and 10%, respectively; values in "( )" represent robust standard errors; the same applies below

Changing the estimation model

To address potential endogeneity issues, the study employs a dynamic panel model, incorporating the lagged term of ecological resilience as an explanatory variable. As indicated in Column (3) of *Table 5,* the regression coefficient of green finance development remains significantly positive, and the lagged ecological resilience indicator is also positive. This suggests that the positive impact of green finance persists over time, providing additional evidence for the robustness of the analysis results.

Adjusting the sample period

To eliminate the potential effects of external shocks in specific years, the study excludes the year 2020 (due to the impact of COVID-19) and re-runs the regression

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analysis. As shown in Column (4) of *Table 5,* the coefficient of green finance development on ecological resilience remains significantly positive, consistent with the baseline regression results.

Addressing endogeneity

Despite efforts to control for factors influencing ecological resilience, there may still be endogeneity issues present. To address this, the study draws on methodologies from Xie et al. (Zhao et al., 2022) and Liu et al. (2021) and uses the number of telephones per 10,000 households in 1984 as an instrumental variable for the development level of green finance. This approach is based on the rationale that, on one hand, the number of telephones serves as a proxy for early communication infrastructure development, which reflects the potential for infrastructure and financial market development in each region and is closely related to green finance development (Pradhan et al., 2015). On the other hand, the historical development of communication infrastructure is unlikely to directly affect current ecological resilience, thus satisfying the exclusion restriction. To further validate the effectiveness of the instrumental variable, the study employs a two-stage least squares (2SLS) approach. In the first stage, the instrumental variable is introduced into the model to predict green finance development levels. In the second stage, the predicted values from the first stage are used as the core explanatory variable to analyze their impact on ecological resilience. Additionally, to rule out potential omitted variable bias, the study applies tests to identify weak instrumental variables to confirm the significance and exogeneity of the instrumental variable. The regression results are presented in Columns (5) and (6) of *Table 5*. The results indicate that the regression coefficient for green finance development estimated using the instrumental variable method remains significantly positive and passes the relevant tests for weak identification and weak instrumental variables. These findings are consistent with the baseline regression results, indicating that the research conclusions remain robust even after accounting for endogeneity issues.

Table 5. *Robustness test*

Variable	**Column (1)**	**Column (2)**	**Column (3)**	**Column (4)**	**Column (5)**	**Column (6)**
GFI	0.132*** (0.009)	0.174*** (0.011)	0.029*** (0.009)	0.155*** (0.015)	0.169*** (0.014)	0.153*** (0.011)
L1_ER			0.743*** (0.057)			
Kleibergen-Paap rk LM statistic					19.684 [0.000]	18.358 [0.000]
Kleibergen-Paap rk Wald F statistic					22.358 {17.24}	69.837 {17.24}
Constant	0.037*** (0.004)	0.018** (0.004)	0.006*** (0.002)	0.030** (0.009)	0.088*** (0.010)	0.091*** (0.010)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Province/year fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	0.942	0.955	0.968	0.959	0.957	0.948
Observations	300	290	270	210	300	300

"[ ]" indicates p-values, and "{ }" indicates the Stock-Yogo critical values at the 10% significance level for the weak identification test

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Heterogeneity analysis

Regional heterogeneity

Given the substantial differences in economic development and ecological environments among China's provinces, the impact of green finance development on ecological resilience may vary across regions. According to the geographic division standards of China's National Bureau of Statistics, the 30 provinces are categorized into two groups: Eastern and Central-Western regions. This division allows for an analysis of the differential effects of green finance development on ecological resilience in each region. As shown in Columns (1) and (2) of *Table 6,* the coefficients of green finance development are significantly positive in both the Eastern and Central-Western provinces, indicating that green finance development can significantly enhance ecological resilience in all regions. However, the regression coefficient in the Central-Western provinces is significantly larger than that in the Eastern provinces, and the difference between the two groups passes the Fisher combination test. This finding suggests that the enhancement effect of green finance on ecological resilience is more pronounced in the Central-Western provinces. A possible explanation is that, compared to the Eastern provinces, the Central-Western regions are relatively less developed. However, driven by policy support and the need for green transformation, these regions enjoy a latecomer advantage in developing green finance, which plays a more crucial role in improving the local ecological environment.

Table 6. *Heterogeneity analysis*

Variable	Eastern regions (1)	Central and Western regions (2)	Resource-based provinces (3)	Non-resource-based provinces (4)
GFI	0.068** (0.017)	0.196*** (0.027)	0.063** (0.019)	0.107** (0.016)
Constant term	0.028** (0.005)	0.007** (0.009)	-0.006 (0.004)	0.027** (0.005)
Control variables	Yes	Yes	Yes	Yes
Provinces/year fixed effects	Controlled	Controlled	Controlled	Controlled
R^2	0.863	0.842	0.877	0.913
Number of observations	130	170	100	200
F-statistic for Wald test	-0.068***		0.019***	

Resource endowment heterogeneity

Differences in resource endowments lead to varying economic development paths and industrial choices in different regions, which could also result in heterogeneous effects of green finance development on ecological resilience. Based on the classification standards for resource-based cities outlined in the "National Plan for Sustainable Development of Resource-based Cities (2013-2023)", this study first identifies and counts the number of resource-based cities in each province. The 30 provinces are then divided into two groups: resource-based and non-resource-based provinces, based on the proportion of resource-

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based cities within each province. This categorization is used to analyze the impact of green finance on ecological resilience under different resource endowment conditions. Furthermore, to account for differences in resource endowments, we classified the 30 provinces into Resource-based and Non-resource-based regions. Specifically, the Resource-based provinces include 12 regions characterized by a high dependence on mineral and energy extraction: Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. The remaining 18 regions are classified as non-resource-based provinces, which primarily rely on manufacturing, services, or diversified industries (e.g., Beijing, Shanghai, Guangdong, Jiangsu, Zhejiang, etc.). As shown in Columns (3) and (4) of *Table 6,* the coefficients of green finance development are significantly positive in both resource-based and non-resource-based provinces, indicating that green finance development can enhance ecological resilience across different types of provinces. However, the coefficient in non-resource-based provinces is higher than that in resource-based provinces, and the difference between the two groups passes the Fisher combination test. This result indicates that the enhancement effect of green finance on ecological resilience is more significant in non-resource-based provinces. A plausible reason is that non-resource-based provinces have a more diversified economic structure compared to resource-based provinces. Therefore, the development of green finance can better facilitate industrial transformation and green development, leading to improvements in the ecological environment.

Mechanism analysis

To thoroughly understand how green finance drives ecological resilience, this study examines the transmission mechanisms through Technological Innovation (TI) and Economic Structural Adjustment (ESA). While the regression results in *Table 7* statistically confirm these two mediating paths, it is crucial to delineate the specific micro-mechanisms and tangible project actions that underpin these statistical relationships, as highlighted in typical green finance project proposals.

From a macroeconomic perspective, the regression results indicate that green finance significantly promotes technological innovation. However, at the project implementation level, this mechanism operates by channeling funds into specific “Green Technology Upgrading Actions.” Unlike general R&D funding, green finance instruments, such as green bonds and special loans, strictly require proceeds to be used for designated environmental projects. Specifically, green finance supports the procurement and deployment of advanced pollution abatement equipment, such as ultra-low emission retrofits for thermal power plants and high-efficiency wastewater recycling systems for industrial parks. These specific engineering actions directly reduce the emission intensity of pollutants like sulfur dioxide and chemical oxygen demand, thereby significantly alleviating the external stress on ecosystems and enhancing their “resistance” to disturbances. Furthermore, green investment increasingly targets digital environmental monitoring technologies. By funding the installation of IoT-based ecological sensors and smart grid systems, green finance enables real-time monitoring of ecological indicators. This technological capability allows for rapid response to environmental accidents, thereby accelerating the ecosystem’s self-recovery process and enhancing its overall “recoverability.”

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The regression results also indicate that green finance optimizes economic structure, the underlying micro-foundation of which lies in the "Screening and Steering" function of financial institutions. Implementing the "Green Credit Guidelines," banks utilize strict environmental impact assessments as a veto criterion in loan approvals. This negative screening mechanism restricts capital flow to high-energy-consuming and high-pollution projects, such as outdated steel and coal capacity, forcing these industries to either exit the market or undergo low-carbon transformation. This reduction in heavy industrial intensity lowers the chronic pressure on regional natural resources from the source. In parallel, green finance effectively acts as a steering mechanism, guiding social capital towards eco-friendly industries with high ecosystem service value, such as ecological agriculture, eco-tourism, and renewable energy infrastructure. For instance, Green PPP (Public-Private Partnership) projects often focus on river basin management and wetland restoration. These projects not only generate economic returns but also physically expand ecological spaces, thereby enhancing the diversity and overall "adaptability" of the regional ecosystem.

In summary, green finance enhances ecological resilience not merely through abstract economic indicators but through concrete physical channels. By providing the necessary liquidity for technological hardware upgrades and enforcing industrial entry and exit mechanisms, green finance effectively translates financial capital into ecological assets. These specific actions collectively bolster the ecosystem's capacity to resist shocks, recover from damage, and adapt to changes, providing a robust explanation for the observed statistical relationships.

Table 7. *Conduction path test results*

Variable	(1) Ecological resilience	(2) Technological innovation	(3) Ecological resilience	(4) Economic structure	(5) Ecological resilience	(6) Ecological resilience
GFI	0.154*** (0.009)	2.603** (0.504)	0.153*** (0.017)	0.053*** (0.016)	0.141*** (0.013)	0.120*** (0.013)
TI			0.0047*** (0.000)			
ESA					0.226*** (0.049)	
GFA						0.002*** (0.001)
GFI × GFA						0.050*** (0.007)
Constant	0.017*** (0.004)	1.589*** (0.446)	0.025*** (0.004)	-0.002** (0.006)	0.026*** (0.004)	0.034** (0.003)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Province/year fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	0.863	0.848	0.856	0.832	0.857	0.874
Observations	300	300	300	300	300	300

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Threshold effect analysis

To explore the nonlinear characteristics of the impact of green finance development on ecological resilience, this study employs a threshold model. The analysis conducts both single and double threshold tests based on the efficiency of factor allocation and the level of environmental governance. As shown in *Table 8,* the threshold regression results indicate that, before and after surpassing the threshold values, the coefficients for financial resource allocation efficiency (FRAE) and environmental governance level (EG) remain significantly positive and increase in magnitude. This finding suggests that as FRAE and EG levels improve, the marginal effect of green finance development on enhancing provincial ecological resilience becomes larger. A possible explanation for this is that higher efficiency in factor allocation improves capital mobility and resource allocation efficiency, providing a solid market foundation for the development of green finance. Simultaneously, a higher level of environmental governance, through policy support and regulatory incentives, increases the motivation of enterprises to invest in environmental technologies and green projects. The improvement in both areas enables green finance to more effectively direct resources towards green projects, thereby promoting the development of green industries and ultimately enhancing ecological resilience. Therefore, the impact of green finance development on ecological resilience exhibits a nonlinear pattern of marginal increasing returns, thus confirming Hypothesis 4.

Table 8. *Results of the threshold model regression*

Variable	Financial resource allocation efficiency	Environmental governance level
DEI × (FE ≤ 0.701)	0.125^{***} (0.016)	
DEI × (0.867 ≥ FE > 0. 701)	0.141^{**} (0.011)	
DEI × (FE ≥ 0.855)	0.168^{***} (0.015)	
DEI × (HC ≤ 0.093)		0.079^{**} (0.018)
DEI × (HC > 0.093)		0.149^{***} (0.013)
Control variables	Yes	Yes
Number of observations	300	300

Spatial effect test

Spatial correlation test

To examine the spatial effects of green finance development on ecological resilience, the study first tests for spatial correlation in ecological resilience using an adjacency matrix. The Moran's I index is employed for this purpose. The results indicate that, during the study period from 2013 to 2023, the Moran's I value for the ecological resilience index all pass the 1% significance level, indicating significant spatial correlation in ecological resilience. Furthermore, a Moran scatter plot is used to analyze the relative spatial distribution of ecological resilience across provinces. As shown in *Figure 5,* in the years 2013, 2018, and 2023, the ecological resilience of the provinces is predominantly

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concentrated in the first and third quadrants, exhibiting clear “high-high” and “low-low” clustering patterns. This suggests that provinces with high (or low) ecological resilience are often surrounded by neighboring provinces with similarly high (or low) levels of ecological resilience. Overall, the values of the Moran’s I index and the scatter plot both indicate a significant spatial correlation in ecological resilience, underscoring the necessity of employing a spatial econometric model for empirical analysis.

Selection of spatial econometric model

To select an appropriate spatial econometric model, this study first conducts a spatial correlation test on the panel data model. The results of the LM tests indicate a significant spatial dependence in the data, suggesting the need for a spatial econometric model for further analysis. In addition, to control for potential estimation bias caused by the inclusion of two-way fixed effects, the study conducts a Hausman test to determine whether to use a random effects model or a fixed effects model. The Hausman test results indicate that a two-way fixed effects model is more suitable than a random effects model. What is more, to identify the specific type of spatial econometric model, a comparison between the Spatial Durbin Model (SDM) and the Spatial Error Model (SEM) is conducted. The results of the Wald test and LR test show that the Spatial Durbin Model does not degenerate into a Spatial Lag Model or a Spatial Error Model. Therefore, this study ultimately adopts a two-way fixed effects Spatial Durbin Model (SDM) for empirical analysis.

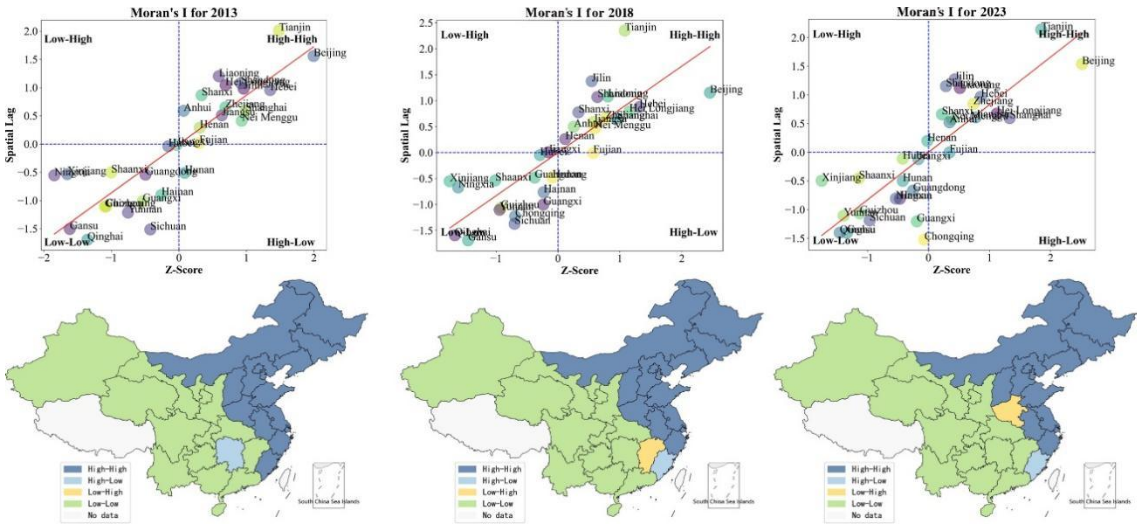

Figure 5. *Moran’s I scatter plot of ecological resilience of 2013, 2018, 2023 year*

Empirical analysis of spatial effects

To analyze the spatial spillover effect of green finance development on ecological resilience, this study employs a two-way fixed effects Spatial Durbin Model (SDM) to investigate the impact of green finance development on local and neighboring regions’ ecological resilience. The regression results under the two-way, time-fixed, and city-fixed effects are presented in Columns (1), (2), (3), and (4) of *Table 9*. The findings indicate a significant spatial spillover effect of green finance development on ecological resilience. This implies that green finance not only positively affects local ecological resilience but also significantly enhances the resilience of adjacent regions. The results in *Table 9* show

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that the coefficients for green finance development are significantly positive in both the direct effects and spatial lag effects, demonstrating that while green finance improves local ecological resilience, it also contributes positively to the restoration and resilience of ecosystems in surrounding areas. Specifically, the rho values remain significantly positive across different settings, indicating a substantial spatial correlation in green finance. This further supports the notion that green finance development exhibits spatial spillover effects on ecological resilience across different regions. Based on these results, Hypothesis 5 is strongly supported.

To gain a deeper understanding of the mechanisms through which green finance development impacts ecological resilience, the study further decomposes the effects into direct, indirect, and total spatial effects, as shown in *Table 10*. According to Columns (1) and (2) of *Table 10,* the direct, indirect, and total effects of green finance development on ecological resilience are all significantly positive, with all coefficients passing the statistical significance tests. This indicates that green finance development not only directly enhances local ecological resilience but also strengthens the resilience of adjacent regions through spatial spillover effects. The observed spatial spillover effect is likely due to the regional diffusion of investments facilitated by green finance in areas such as low-carbon industries, clean energy, and ecological protection. This diffusion allows neighboring regions to benefit from optimized resource allocation and improved ecological restoration capabilities brought about by green finance. Through the cross-regional flow of capital and technological diffusion, green finance development effectively enhances local ecological resilience while also improving the ecological adaptation and recovery capabilities of adjacent regions through regional cooperation. This results in a sustained improvement of the overall ecological environment across regions.

Table 9. *Regression results of spatial panel Dubin model econometric*

	Adjacency matrix		**Inverse distance matrix**	
Variable	**Bidirectional fixed effects (1)**	**Time fixed effects (2)**	**Province fixed effects (3)**	**Bidirectional fixed effects (4)**
DEI	0.145^{***} (0.006)	0.297^{***} (0.008)	0.142^{***} (0.004)	0.128^{***} (0.004)
WDEI	0.053^{***} (0.011)	-0.028 (0.013)	0.022^{***} (0.011)	0.245^{***} (0.057)
rho	0.045 (0.018)	0.409^{***} (0.025)	0.059^{*} (0.018)	-0.146 (0.106)
Control variables	Yes	Yes	Yes	Yes
W Control variables	Yes	Yes	Yes	Yes
Province	Controlled	Not controlled	Controlled	Controlled
Year	Controlled	Controlled	Not controlled	Controlled
Observations	300	300	300	300

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Table 10. *Effect decomposition results*

Variable	Adjacency matrix (1)	Inverse distance matrix (2)
Direct effect	0.141*** (0.006)	0.139*** (0.005)
Indirect effect	0.057*** (0.011)	0.211*** (0.050)
Total effect	0.203*** (0.014)	0.340*** (0.051)
Control variables	Controlled	Controlled

Discussion and conclusion

Discussion

This study provides empirical evidence for the positive nexus between green finance and ecological resilience. While previous literature has extensively verified the pollution-reduction effect of green finance (Zhang et al., 2021), this paper extends the boundary of research from "environmental quality" (a static state) to "ecological resilience" (a dynamic capability involving resistance, recovery, and adaptability).

First, regarding the transmission mechanism, our findings confirm that green finance enhances resilience primarily through technological innovation and economic structural adjustment. This aligns with the "Porter Hypothesis" framework discussed by Bai and Lin (2023), which suggests that appropriate financial regulation stimulates innovation. However, our mediation analysis (*Table 7*) offers a more granular insight: green finance acts as a "screening mechanism". By internalizing environmental externalities into financing costs, it forces high-polluting enterprises to exit (Structure Effect) while lowering the R&D cost for green enterprises (Innovation Effect) (Bhatnagar and Sharma, 2022; Liu, 2024). Unlike general financial deepening, green finance specifically targets the "financing constraints" of ecological projects, thereby directly enhancing the ecosystem's material basis for recovery.

Second, the spatial analysis reveals a significant positive spillover effect, rejecting the "Pollution Haven" or "Siphon Effect" hypotheses in this context. Theoretically, there was a concern that green finance might drive polluting industries to neighboring regions (pollution leakage) or siphon capital away from them (Zhang et al., 2024b). However, our results (*Table 9*) support the "Demonstration and Diffusion Effect." This suggests that as green finance matures in one province, it facilitates the cross-regional transfer of green technologies and establishes a model for regulatory coordination (Yang et al., 2024).

Third, the heterogeneity analysis offers a "Latecomer Advantage" perspective. We observed that the marginal impact of green finance is stronger in Central and Western regions than in the Eastern coastal areas. This contrasts with the view that financial development requires a high threshold of economic maturity. A plausible economic explanation is the law of diminishing marginal returns: Eastern regions have already achieved high levels of environmental governance (Wang et al., 2022), making further resilience improvements more capital-intensive (Jiang et al., 2023). In contrast, the Central and Western regions, being in the early stages of green transformation, exhibit higher sensitivity to green capital injection, where even moderate financial support can yield substantial ecological benefits (Wang et al., 2025).

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Conclusions

Based on panel data from 30 provinces in China from 2013 to 2023, this study systematically analyzes the direct impact, mediating pathways, moderating effects, and spatial spillover effects of green finance on ecological resilience by employing panel regression models, threshold models, mediation effect models, and the Spatial Durbin Model (SDM). The main conclusions of this study are as follows: (1) Green finance development significantly enhances ecological resilience, and this conclusion holds even after a series of robustness tests. In terms of specific mechanisms, green finance development promotes the dissemination of green technologies and the low-carbon transformation of high-pollution industries through technological innovation and economic restructuring. Moreover, government policy guidance further amplifies the positive impact of green finance on ecological resilience; (2) The impact of green finance development on ecological resilience exhibits heterogeneity based on geographic location and resource endowment. The study indicates that the effect of green finance on enhancing ecological resilience is more pronounced in the Central-Western regions and non-resource-based provinces compared to the Eastern regions; (3) There are significant threshold effects of financial resource allocation efficiency and environmental governance levels on the impact of green finance on ecological resilience. The findings show that, before and after crossing the threshold values, the marginal effects of green finance on enhancing ecological resilience exhibit a nonlinear pattern of increasing returns; (4) There is significant spatial correlation in ecological resilience across provinces, and the development of green finance exhibits notable spatial spillover effects. This suggests that green finance not only improves local ecological resilience but also enhances the resilience of neighboring regions through regional cooperation and capital and technology diffusion.

Suggestions

Based on the findings of this study, the following three key policy recommendations are proposed to improve ecological resilience:

(1) The study highlights that government policy guidance plays a vital role in leveraging green finance to boost ecological resilience. Therefore, the government should effectively fulfill its macro-control functions by formulating and implementing a series of incentive policies and regulatory measures for green finance. These policies should aim to guide capital flows towards low-carbon and environmentally friendly sectors, thereby optimizing resource allocation and promoting a low-carbon economic transition. Specifically, the government should increase policy support for green financial instruments, such as promoting the development of green credit, green bonds, and carbon trading markets. Financial institutions should be encouraged to increase funding support for energy-saving and environmental protection industries as well as green technological innovation. Moreover, the government should improve environmental laws and regulations, enhance the supervision and incentive mechanisms for corporate environmental behavior, and especially impose stricter penalties and provide transition support policies for high-pollution and high-energy-consuming industries to motivate their shift towards greener and low-carbon practices. In addition, the government needs to establish a comprehensive environmental governance system that facilitates cross-departmental and cross-regional coordinated management to ensure the consistency and continuity of policy implementation. This includes strengthening environmental quality

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monitoring, establishing robust pollution accountability mechanisms, and creating an efficient policy feedback and adjustment mechanism. These measures not only aim to effectively raise corporate awareness of environmental responsibility and foster a consensus on green development across society but also ensure the successful implementation of green finance policies, thereby further enhancing overall ecological resilience.

(2) This study demonstrates that the enhancement effect of green finance on ecological resilience exhibits a significant nonlinear characteristic. Specifically, the positive impact of green finance on ecological resilience becomes more pronounced as the efficiency of financial resource allocation improves. Therefore, improving the efficiency of financial resource allocation is crucial to unlocking the full potential of green finance. To achieve this, both the government and financial institutions should focus on enhancing market liquidity and optimizing the allocation of financial resources. This would facilitate the effective channeling of funds into high-yield, low-pollution green industries and projects. Building and refining a multi-level green financial market system is essential to increasing the flexibility and transparency of capital markets. For instance, financial institutions should improve green credit approval mechanisms and expand the supply of green bonds and green funds, thereby providing diversified financing channels for green projects and enterprises. Additionally, the government should establish investment incentives and risk protection mechanisms for green projects at the policy level, aiming to attract more private capital into green investments. By implementing these measures, financial institutions can better allocate resources to support green development, while the government can create a favorable policy environment to enhance the overall efficiency and effectiveness of green finance in promoting ecological resilience.

(3) The findings of this study indicate that the impact of green finance on ecological resilience is more pronounced in the Central-Western regions and non-resource-based cities, with a clear spatial spillover effect. Therefore, provinces and cities should enhance policy coordination in green finance and establish cross-regional cooperation mechanisms to promote the diffusion of green technologies and the cross-regional flow of capital. Specifically, the government should promote the unification of green finance policies and information sharing across regions to eliminate policy barriers between regions. The Central-Western regions should fully leverage their “latecomer advantage” by forming complementary partnerships with the Eastern regions in terms of policy support and technology promotion. This includes strengthening regional scientific and technological cooperation to facilitate joint research and the dissemination of green technologies. Additionally, efforts should be made to explore the establishment of cross-regional green development funds to efficiently allocate resources and investment returns. Such a fund would enable regions to jointly contribute and share in the benefits of green projects, thereby enhancing overall ecological resilience and environmental adaptability across regions.

Limitations and future research

Despite the comprehensive analysis conducted in this study, there are still some limitations that offer avenues for future exploration. This research is based on panel data from 30 provinces in China spanning the period from 2013 to 2023. Although the dataset is extensive, the study may not have fully accounted for characteristics at the city level. Future research could expand the dataset by incorporating more recent data and conducting more granular analyses at the city or county level to better capture regional

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dynamics. Additionally, while this study examines the specific pathways through which green finance affects ecological resilience using a mediation effect model, establishing a clear causal relationship remains challenging. Although instrumental variables were employed to partially address endogeneity issues, future studies could consider leveraging more rigorous experimental evidence or natural experimental methods to further validate the causal link between green finance and ecological resilience.

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REFERENCES

[1] Akomea-Frimpong, I., Adeabah, D., Ofosu, D., Tenakwah, E. J. (2022): A review of studies on green finance of banks, research gaps and future directions. – Journal of Sustainable Finance & Investment 12: 1241-1264. 10.1080/20430795.2020.1870202.

[2] Bai, R., Lin, B. (2023): Nexus between green finance development and green technological innovation: a potential way to achieve the renewable energy transition. – Renewable Energy 218: 119295. https://doi.org/10.1016/j.renene.2023.119295.

[3] Banga, J. (2019): The green bond market: a potential source of climate finance for developing countries. – Journal of Sustainable Finance & Investment 9: 17-32. 10.1080/20430795.2018.1498617.

[4] Bhatnagar, S., Sharma, D. (2022): Evolution of green finance and its enablers: a bibliometric analysis. – Renewable and Sustainable Energy Reviews 162: 112405. https://doi.org/10.1016/j.rser.2022.112405.

[5] Campiglio, E. (2016): Beyond carbon pricing: the role of banking and monetary policy in financing the transition to a low-carbon economy. – Ecological Economics 121: 220-230. https://doi.org/10.1016/j.ecolecon.2015.03.020.

[6] Cao, Z., Tao, L. (2023): Green finance and economic resilience: investigating the nexus with natural resources through econometric analysis. – Economic Analysis and Policy 80: 929-940.

[7] Chen, H., Yao, M., Chong, D. (2019): Research on institutional innovation of China's green insurance investment. – Journal of Industrial Integration and Management 4: 1950003. 10.1142/s2424862219500039.

[8] Chen, M., Song, L., Zhu, X., Zhu, Y., Liu, C. (2023): Does green finance promote the green transformation of China's manufacturing industry? – Sustainability 15: 6614.

[9] Cheng, Y., Zhang, Y., Wang, J., Jiang, J. (2023): The impact of the urban digital economy on China's carbon intensity: spatial spillover and mediating effect. – Resources, Conservation and Recycling 189: 106762. https://doi.org/10.1016/j.resconrec.2022.106762.

[10] Du, G., Yu, M., Sun, C., Han, Z. (2021): Green innovation effect of emission trading policy on pilot areas and neighboring areas: an analysis based on the spatial econometric model. – Energy Policy 156: 112431. https://doi.org/10.1016/j.enpol.2021.112431.

[11] Fan, Y., Chen, S. T. (2022): Research on the effects of digital inclusive finance on the efficiency of financial resource allocation. – Frontiers in Environmental Science 10. 10.3389/fenvs.2022.957941.

[12] Flammer, C. (2021): Corporate green bonds. – Journal of Financial Economics 142: 499-516. https://doi.org/10.1016/j.jfineco.2021.01.010.

[13] Fu, C., Lu, L., Pirabi, M. (2023): Advancing green finance: a review of sustainable development. – Digital Economy and Sustainable Development 1: 20. 10.1007/s44265-023-00020-3.

[14] Ge, P., Liu, T., Huang, X. (2023): The effects and drivers of green financial reform in promoting environmentally-biased technological progress. – Journal of Environmental Management 339: 117915. https://doi.org/10.1016/j.jenvman.2023.117915.
[15] Ghezelbash, A., Khaligh, V., Fahimifard, S. H., Liu, J. J. (2023): A comparative perspective of the effects of CO2 and non-CO2 greenhouse gas emissions on global solar, wind, and geothermal energy investment. – Energies 16: 3025.
[16] Goncharenko, N., Shapoval, V. (2021): Eco-innovation financing as an element of a "green" economy formation in the globalization conditions of sustainable development. – Green, Blue and Digital Economy Journal 2: 15-23.
[17] Guo, Q., Su, Z., Chiao, C. (2022): Carbon emissions trading policy, carbon finance, and carbon emissions reduction: evidence from a quasi-natural experiment in China. – Economic Change and Restructuring 55: 1445-1480. 10.1007/s10644-021-09353-5.
[18] Han, Y., Wang, Q., Li, Y. (2023): Does financial resource misallocation inhibit the improvement of green development efficiency? Evidence from China. – Sustainability 15: 4466.
[19] Hua, F., Cuiwei, Z. (2024): Research on the coupling coordination relationship between urbanization and ecological resilience in southwest China. – Research of Soil and Water Conservation 1-13. 10.13869/j.cnki.rswc.2025.02.034.
[20] Jiang, H.-D., Purohit, P., Liang, Q.-M., Liu, L.-J., Zhang, Y.-F. (2023): Improving the regional deployment of carbon mitigation efforts by incorporating air-quality co-benefits: a multi-provincial analysis of China. – Ecological Economics 204: 107675. https://doi.org/10.1016/j.ecolecon.2022.107675.
[21] Kassi, D. F., Li, Y., Gnangoin, T. Y., Tuo, S. J., Gnahe, F. E., Shaikh, R., Yongjie, D. (2024): Green credits, green securities, renewable energy, and environmental quality: a comparative analysis of sustainable development across Chinese provinces. – Environment, Development and Sustainability 26: 1-37. 10.1007/s10668-023-03717-9.
[22] Kassier, L. (2024): Interconnected or disconnected? A review of sustainability, resilience, and sustainable business model constructs in the academic business literature. – Journal of the Knowledge Economy. 10.1007/s13132-023-01712-z.
[23] Keshav, M., Arjun, K. (2023): "Green Finance": a powerful tool for sustainability. – Social Science Journal for Advanced Research 3: 1-7. 10.54741/ssjar.3.6.1.
[24] Khan, H. H. A., Ahmad, N., Yusof, N. M., Chowdhury, M. A. M. (2024): Green finance and environmental sustainability: a systematic review and future research avenues. – Environmental Science and Pollution Research 31: 9784-9794. 10.1007/s11356-023-31809-6.
[25] Kwilinski, A., Lyulyov, O., Pimonenko, T. (2023): Spillover effects of green finance on attaining sustainable development: spatial Durbin model. – Computation 11: 199.
[26] Lanqia, S., Yanlib, L. (2021): On the mechanism of green economy and green finance. – Generations 3: 75-79.
[27] Le, X., Ding, X., Zhang, J., Zhao, L. (2024): Has green finance enhanced the ecological resilience level in the Yangtze River Economic Belt? – Sustainability 16: 2926.
[28] Li, L., Ma, X., Ma, S., Gao, F. (2024): Role of green finance in regional heterogeneous green innovation: evidence from China. – Humanities and Social Sciences Communications 11: 1011. 10.1057/s41599-024-03517-0.
[29] Li, Z., Liao, G., Wang, Z., Huang, Z. (2018): Green loan and subsidy for promoting clean production innovation. – Journal of Cleaner Production 187: 421-431. https://doi.org/10.1016/j.jclepro.2018.03.066.
[30] Liu, H., Liu, Z., Zhang, C., Li, T. (2023a): Transformational insurance and green credit incentive policies as financial mechanisms for green energy transitions and low-carbon economic development. – Energy Economics 126: 107016. https://doi.org/10.1016/j.eneco.2023.107016.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2402_24272458

[31] Liu, N., Deng, M., Cao, X. (2021): Does the E-commerce transformation of cities promote green and high-quality development? Evidence from a quasi-natural experiment based on national E-commerce demonstration cities. – J. Financ. Econ 47: 49-63.
[32] Liu, Y., Deng, W., Wen, H., Li, S. (2024a): Promoting green technology innovation through policy synergy: evidence from the dual pilot policy of low-carbon city and innovative city. – Economic Analysis and Policy 84: 957-977. https://doi.org/10.1016/j.eap.2024.10.005.
[33] Liu, Y., Huang, H., Mbanyele, W., Wang, F., Liu, H. (2024b): Does the issuance of green bonds nudge environmental responsibility engagements? Evidence from the Chinese green bond market. – Financial Innovation 10: 92. 10.1186/s40854-024-00620-8.
[34] Liu, Z. (2024): Assessing the role of green finance in enhancing rural economic resilience and environmental sustainability. – Frontiers in Management Science 3: 82-89.
[35] Liu, Z., Zhang, X., Wang, J., Shen, L., Tang, E. (2023b): Evaluation of coupling coordination development between digital economy and green finance: evidence from 30 provinces in China. – PLoS ONE 18: e0291936. 10.1371/journal.pone.0291936.
[36] Ma, Y., Chen, H., Zhao, Y., Li, Z. (2022): Research on China's environmental governance mode: quality driven or quantity driven? – Frontiers in Environmental Science 10: 901936.
[37] Mishra, K., Kannaujia, A. (2023): "Green Finance": a powerful tool for sustainability. – Social Science Journal for Advanced Research 3: 1-7.
[38] Moreno-Mateos, D., Alberdi, A., Morriën, E., Van Der Putten, W. H., Rodríguez-Uña, A., Montoya, D. (2020): The long-term restoration of ecosystem complexity. – Nature Ecology & Evolution 4: 676-685. 10.1038/s41559-020-1154-1.
[39] Mudalige, H. M. N. K. (2023): Emerging new themes in green finance: a systematic literature review. – Future Business Journal 9: 108. 10.1186/s43093-023-00287-0.
[40] Nunn, N., Qian, N. (2014): US Food Aid and Civil Conflict. – American Economic Review 104: 1630-66. 10.1257/aer.104.6.1630.
[41] Ozhan, G. K. (2020): Financial intermediation, resource allocation, and macroeconomic interdependence. – Journal of Monetary Economics 115: 265-278. https://doi.org/10.1016/j.jmoneco.2019.07.001.
[42] Pradhan, R. P., Arvin, M. B., Norman, N. R. (2015): The dynamics of information and communications technologies infrastructure, economic growth, and financial development: evidence from Asian countries. – Technology in Society 42: 135-149. https://doi.org/10.1016/j.techsoc.2015.04.002.
[43] Quatrini, S. (2021): Challenges and opportunities to scale up sustainable finance after the COVID-19 crisis: lessons and promising innovations from science and practice. – Ecosystem Services 48: 101240. https://doi.org/10.1016/j.ecoser.2020.101240.
[44] Randjelovic, J., O'rourke, A. R., Orsato, R. J. (2003): The emergence of green venture capital. – Business Strategy and the Environment 12: 240-253. https://doi.org/10.1002/bse.361.
[45] Raza, S. A., Khan, K. A. (2022): Impact of green human resource practices on hotel environmental performance: the moderating effect of environmental knowledge and individual green values. – International Journal of Contemporary Hospitality Management 34: 2154-2175. 10.1108/ijchm-05-2021-0553.
[46] Scarano, F. R. (2017): Ecosystem-based adaptation to climate change: concept, scalability and a role for conservation science. – Perspectives in Ecology and Conservation 15: 65-73. https://doi.org/10.1016/j.pecon.2017.05.003.
[47] Shabbir, M. S., Wisdom, O. (2020): The relationship between corporate social responsibility, environmental investments and financial performance: evidence from manufacturing companies. – Environmental Science and Pollution Research 27: 39946-39957. 10.1007/s11356-020-10217-0.
[48] Shao, X., Zhang, Y., Ma, N., Zhang, X., Tian, J., Xu, Z., Liu, C. (2024): Drought-induced ecosystem resistance and recovery observed at 118 flux tower stations across the globe. – Agricultural and Forest Meteorology 356: 110170.

https://doi.org/10.1016/j.agrformet.2024.110170.
[49] Sibt-E-Ali, M., Xiqiang, X., Javed, K., Javaid, M. Q., Vasa, L. (2024): Greening the future: assessing the influence of technological innovation, energy transition and financial globalization on ecological footprint in selected emerging countries. – Environment, Development and Sustainability. 10.1007/s10668-024-05076-5.
[50] Siddiqui, A., Siddiqui, M., Kautish, P. 2023. Green Finance and Low Carbon Technology Innovation: Current Research and Future Outlook. – In: Shahbaz, M., Dong, K., Balsalobre-Lorente, D., Gedikli, A. (eds.) Recent Developments in Green Finance, Green Growth and Carbon Neutrality. Chap. 12. Elsevier, Amsterdam.
[51] Song, Z. (2021): Economic growth and carbon emissions: estimation of a panel threshold model for the transition process in China. – Journal of Cleaner Production 278: 123773. https://doi.org/10.1016/j.jclepro.2020.123773.
[52] Tan, X., Cheng, S., Liu, Y. (2024): Green digital finance and technology diffusion. – Humanities and Social Sciences Communications 11: 389. 10.1057/s41599-024-02902-z.
[53] Wang, F., Wang, R., Wang, J. (2020): Measurement of China's green GDP and its dynamic variation based on industrial perspective. – Environmental Science and Pollution Research 27: 43813-43828. 10.1007/s11356-020-10236-x.
[54] Wang, J., Li, X., Zhang, T., He, C., Zhu, L. (2025): The impact of green finance reform and innovation policies on green investors in China. – Finance Research Letters 83: 107709. https://doi.org/10.1016/j.frl.2025.107709.
[55] Wang, K., Elahi, E., Zhang, Y., Wang, D., Khalid, Z. (2022): A development of green finance and regional eco-efficiency in China. – Sustainability 14: 15206.
[56] Wu, X.-q., Wen, H.-x., Nie, P.-y., Gao, J.-x. (2024): Utilizing green finance to promote low-carbon transition of Chinese cities: insights from technological innovation and industrial structure adjustment. – Scientific Reports 14: 16844. 10.1038/s41598-024-67958-y.
[57] Xie, Y. (2024): The interactive impact of green finance, ESG performance, and carbon neutrality. – Journal of Cleaner Production 456: 142269. https://doi.org/10.1016/j.jclepro.2024.142269.
[58] Xu, T., Zhu, Z., Chen, T. (2024): the impact of green finance on promoting industrial structure upgrading: an analysis of Jiangsu Province in China. – Sustainability 16: 7520.
[59] Yang, X., Zhu, L., Wei, T. (2024): The effect of green credit policy on carbon emissions based on China's provincial panel data. – Scientific Reports 14: 24142. 10.1038/s41598-024-73942-3.
[60] Zhang, M., Zhu, X., Liu, R. (2024a): Patent length and innovation: novel evidence from China. – Technological Forecasting and Social Change 198: 123010. https://doi.org/10.1016/j.techfore.2023.123010.
[61] Zhang, S., Wu, Z., Wang, Y., Hao, Y. (2021): Fostering green development with green finance: an empirical study on the environmental effect of green credit policy in China. – Journal of Environmental Management 296: 113159. https://doi.org/10.1016/j.jenvman.2021.113159.
[62] Zhang, Y., Zhang, J., Liu, Y. (2024b): Does green finance promote the improvement of regional eco-efficiency? Direct and spillover effects. – Frontiers in Environmental Science 12. 10.3389/fenvs.2024.1506734.
[63] Zhao, J., He, G. (2022): Research on the impact of digital finance on the green development of Chinese cities. – Discrete Dynamics in Nature and Society 3813474. https://doi.org/10.1155/2022/3813474.
[64] Zhao, X., Zeng, B., Zhao, X., Zeng, S., Jiang, S. (2024): Impact of green finance on green energy efficiency: a pathway to sustainable development in China. – Journal of Cleaner Production 450: 141943. https://doi.org/10.1016/j.jclepro.2024.141943.
[65] Zhou, X., Tang, X., Zhang, R. (2020): Impact of green finance on economic development and environmental quality: a study based on provincial panel data from China. –

Environmental Science and Pollution Research 27: 19915-19932. 10.1007/s11356-020-08383-2.
[66] Zhou, X., Dai, M., Liu, L. (2024): Green credit, carbon emission trading and corporate green innovation: evidence from China. – Pacific-Basin Finance Journal 86: 102445. https://doi.org/10.1016/j.pacfin.2024.102445.

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