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RESEARCH ARTICLE

The Impact of Green Finance on China's Macroeconomic Resilience and Sustainable Development: An Empirical Analysis Based on 2011-2022 Provincial Panel Data

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Abstract
Macroeconomic resilience is important tomaintain a more persistent economic growth as well as overcomes the external shocks. Under GMM framework, this study selects the spatial panel data of 30 provinces in China from 2011 to 2022 to examine the macroeconomic resilience level within China. The results show that: 1) Green finance has a positive effect on China's macroeconomic resilience. (2) Technological innovation, industrial structure upgrading and risk management are important channels through which green finance can affect economic resilience. (3) In the process of green finance enabling economic resilience, there is a nonlinear impact on economic resilience and a significant threshold effect. (4) The impact of green finance on enhancing China's macroeconomic resilience is spatially heterogeneous, and the promotion effect is more significant in the provinces with high economic development level. The government should encourage and support green finance industries which will then support the sustainable and healthy development of China's economy and environment.

Keywords: green finance; economic resilience; GMM difference; mediating effect; multiple threshold effect

Introduction

With the outbreak of COVID-19, economies around the world have experienced strong negative reactions such as stagnation or even regression of economic development, rapid rise in unemployment, decline in overseas investment, decrease in cross-border e-commerce trade and changes in commodity prices, which have led to a serious decline in the resilience of the world macro economy. As the wave fades, so does the problem of how to reshape the world economy. Economic resilience is an important manifestation of an economy's resistance to shocks, resilience, restructuring capacity and innovation and development capacity aftershocks. Compared with other countries, China, as the world's second largest economy, has played a key role in the process of reshaping the

world economy in the post-epidemic era and achieved the first positive economic growth, which further demonstrates that China's economy has strong potential development space and strong economic resilience. The report to the 20th National Congress of the Communist Party of China (CPC) stressed the importance of green finance, raising the building of a green financial system to a national strategy and attracting more capital to the green sector. By optimizing resource allocation, improving carbon emission reduction efficiency and reducing financial risks, green finance provides strong support for promoting economic transformation and upgrading and achieving sustainable development. Sustainable development is broadly defined as development that meets the needs of present generations without jeopardizing the ability of future generations to meet their needs. With the continuous changes of The Times, the content and connotation of sustainable development are gradually refined, and there are more detailed requirements in ecology, energy and environment.Wang et al. (2016) argued that green finance promotes sustainable economic development by optimising resource allocation and promoting economic restructuring.Yao et al. (2023) found that green finance significantly enhanced China's macroeconomic resilience, especially in terms of its ability to cope with shocks, organisational coordination and innovation and transformation.However, the research on the impact and mechanism of green finance in regulating China's macroeconomic resilience is still relatively insufficient.

Based on the panel data of 30 provinces in China, this study uses the GMM difference model to explore the impact of green finance on China's macroeconomic resilience, and further analyzes the mediating effect, threshold effect and spatial heterogeneity, to provide a scientific basis for formulating and optimizing relevant policies. The rest of the study is as following. Chapter two summarizes the literature of this study and hypothesis. Chapter three discusses the methods and models used in this study. In chapter four, we present concrete empirical results and conclude our work in chapter five.

Literature Review

Research on the measurement of economic resilience

The definition of economic resilience is still not in consensus. Wan (2017) used GDP to measure economic resilience from three aspects: the rise and fall of the overall economy, the trend comparison before and after the shock, and the external impact model. Tan (2020) using economic maintenance and restorative measures such as regional economic resilience. Briguglio et al. (2006) extended economic resilience research elaboration to the area, choose 86 countries and regions, building contains macro, government regulation, social operation and four dimensions of market allocation of index system to measure the economy toughness. Martin (2012) chose the measurement form of a single index, and used the change of the number of employees in a place before and after the shock as the measurement of economic resilience. Brakman et al (2015), Giannakis and Bruggeman (2017) used the GDP of a place or the unemployment rate to construct a reverse indicator to replace the variable of the number of employees. Polese (2015) studied the economic resilience in urban research, and found that highly educated human resources, rich and vast market environment, multi-form structure and other aspects were the key factors affecting the development of urban economic resilience, that is, they were used as the screening criteria for measurement indicators. Doran and Fingleton (2018) examined direction to expand into the space, based on law of Verdun is hit with the fact that state economic system status difference, from the Angle of view of the differences in size and economic recovery measure economic resilience; Ubago et al. (2019) measured the economic resilience of the country as a whole from the three perspectives of industry, human resources and capital.

Analysis of the impact of green finance on China's macroeconomic resilience

At present, researches on macroeconomic resilience have not yet reached a consensus. First of all, the definition of macroeconomic resilience varies from each other. Wan (2017) used GDP to measure economic resilience from three aspects: the rise and fall of the overall economy, the trend comparison before and after the shock, and the external impact model. Tan Juntao (2020) using economic maintenance and restorative measures such as regional economic resilience, Briguglio et al. (2006) to economic resilience research elaboration to the area, choose 86 countries and regions, building contains macro, government regulation, social operation and four dimensions of market allocation of index system to measure the economy toughness; Martin (2012) chose the measurement form of a single index, and used the change of the number of employees in a place before and after the shock as the measurement of economic resilience; Brakman et al (2015), Giannakis and Bruggeman (2017) used the GDP of a place or the unemployment rate to construct a reverse indicator to replace the variable of the number of employees; Polese (2015) deeply studied the economic resilience in urban research, and found that highly educated human resources, rich and vast market environment, multi-form structure and other aspects were the key factors affecting the development of urban economic resilience, that is, they were used as the screening criteria for measurement indicators; Doran and Fingleton (2018) will research direction to expand into the space, based on law of Verdun is hit with the fact that state economic system status difference, from the Angle of view of the differences in size and economic recovery measure economic resilience; Ubago et al. (2019) measured the economic resilience of the country as a whole from the three perspectives of industry, human resources and capital. The definition of economic resilience is relatively unified. It measures the ability of national and regional economic systems to withstand external shocks, such as the ability to resist disturbances, the ability to restore and maintain the original state, and the ability to enhance public security and maintain social order. Moreover, economic resilience does not exist as an independent individual. It is closely related to a region's system, culture, science and technology, society and other aspects. It is the ballast stone of the resilience system and the barometer of the healthy and sound development of the economic system. In economic measure of resilience research, specific divided into use the single index such as GDP and employment measure, the fact that state compared with hit condition difference method, and contains the ability, the Angle of the composite index measure method. Is common among them, the more complex we measure method, related research covers the macro micro level, the internal influence mechanism, Pratt &Whitney financial Doberman, mediation effect, space, etc., and for how to improve the economic resilience, how to shrink regional economic resilience differences provide advice. In this paper, economic resilience is defined as the ability to cope with shocks, the ability to organize and coordinate, and the ability to innovate and transform. Adhere to the green sustainable development in our country, developing green finance, green finance in implementing the green development, boost the development of environmental protection industry, improve the pollution treatment system and played an important role in governance. Green financial development to optimize the capital of the guidance, to further enhance China's macroeconomic resilience to promote economic development in high quality. This study will from two aspects of direct effects and indirect effects (see research design Figure1.) green financial effect on our country's macroeconomic resilience theory mechanism.

Meng et al. (2023) constructed a high-quality economic development index and a green finance index, and found that green finance can significantly promote high-quality economic development, enhance technological innovation, promote industrial structure upgrading, and help enhance the impact of green finance on high-quality economic development. Li et al. (2023) empirically found that green finance can improve the economic resilience of the region and have a positive impact on the economic resilience of the surrounding regions through spatial spillover effect through the construction of spatial Dubin model. Yao et al. (2023) constructed an evaluation index system of green finance and macroeconomic resilience, and based on the system GMM model and the mediating

effect model, confirmed that green finance development can significantly improve China's macroeconomic resilience; Shi et al. (2022) argued that green finance can promote high-quality economic development, but there is a nonlinear relationship between the two and there is a threshold effect. Wen et al. (2022) argued that green finance affects high-quality economic development by supporting green innovation. Song (2023) further demonstrated the positive role of green finance in promoting economic resilience through grey correlation analysis.Liao (2024) pointed out that the realization of sustainable development goals cannot be achieved without the help and support of green finance, which can be regarded as a driving force for sustainable development from the perspective of economic development, social progress and ecological civilization optimization.However, as far as current research is concerned, the evaluation indicators of green finance and economic resilience are relatively simple and simple.

Analysis on transmission channels of green finance on China's macroeconomic resilience

Many scholars examined the green finance impacts as well as the transmission channelsthrough which that can affect economic resilience. Wang et al. (2020) found that green finance enhances regional economic resilience by promoting industrial transformation. Green finance can provide financial support for environmentally friendly and sustainable industries, so that these industries have more complete green innovation technology and can adapt to market changes and needs. Liu et al. (2021), taking China's provincial panel data from 2010 to 2019 as an example, verified that green finance effectively promoted high-quality economic development through three ways: enterprise technology innovation, industrial structure upgrading and green consumption; Xia et al. (2023), based on the fixed effect model, demonstrated that green finance can significantly promote corporate green innovation by promoting corporate technological innovation; Zhang et al. (2023) believed that the upgrading of industrial structure played a significant mediating effect in the process of green finance improving the efficiency of green economic development. Yao et al. (2023) empirically concluded that green finance promotes industrial upgrading and technological innovation to improve economic resilience.

In the process of achieving the goal of sustainable economic development, green finance plays a very important role as a "booster". The progress of the economy needs the assistance and guarantee of green finance, especially the value and role of green finance should be affirmed from the perspective of "green economy" development. In recent years, the rapid development and continuous progress of China's economy have had a profound direct and potential impact on the environment. The comprehensive strengthening of environmental protection work has also become an urgent key task. There is a very close connection between the proposal of the concept of "green finance" and the construction of an "environmentally friendly" economic development pattern. The impact of the continuous rise of green finance on sustainable economic progress can be analyzed from two aspects: First, it vigorously promotes the progress of green consumption; second, it realizes the continuous tilt and transfer of social resources towards green industries. The development of green finance has fundamentally replaced the coverage of the economy in the fields of green development and low-carbon development. While enterprises fulfill their responsibilities for green development, they also have more financial support and guarantees. Especially in the macro environment where market entities are developing towards diversification, financial institutions have shown more confidence and stronger motivation in the development of green finance. The comprehensive creation of a coordinated and interactive pattern between the financial market and the carbon market has also provided space for the value and role of green finance to be exerted and developed.

First, green finance helps to optimize the allocation of resources. The traditional economic development model tends to over-rely on industries with high energy consumption and high pollution, leading to over-exploitation of natural resources and environmental damage. The rise of green finance provides an opportunity for funds to flow to environmentally friendly and sustainable development areas. By financial institutions providing financial tools,

such as green loans, green bonds, funds can be more effectively guide to clean energy, energy conservation and emissions reduction, recycling economy and green industry, promote the optimization of economic structure and transformation. This will not only help reduce environmental pressure, reduce energy consumption and pollutant emissions, but also promote the development of new technologies and industries, foster a more competitive industrial chain and enhance the resilience of the economy.

Secondly, the guiding role of green finance can also promote the development of green consumption. While providing financing for green projects, green finance also promotes the supply and awareness of green products and services. Through the green standards, evaluation and information disclosure system established by financial institutions, they can provide investors with relevant information about green products and evaluate their environmental friendliness and sustainability. This provides consumers with a clearer choice, enabling them to consciously choose environmentally friendly and low-carbon products and services. This green consumption shift will not only help change the traditional consumption pattern of high energy consumption and high emissions, reduce resource waste and environmental pressure, but also promote new green industries and job creation, and promote sustainable economic development. Based on this, Hypothesis 1 is proposed in this paper.

Hypothesis 1: the development of green finance can from "the ability to cope with shocks", "the organization and coordination ability," and "innovation transformation ability three aspects significantly increased the macroeconomic resilience.

Analysis of the multi-threshold effect of green finance on macroeconomic resilience in China

The existing literature discusses very fewer about the threshold effect of green finance on macroeconomic resilience. Xiao et al. (2023) used the dynamic generalized panel model method to conduct nonlinear impact analysis to explore the mechanism of green finance promoting high-quality economic development through green technology innovation, and analyzed the regulating effect of green finance on the relationship between green technology innovation and high-quality economic development. The results show that GTE plays a partial intermediary role between different dimensions of green finance and high-quality economic development, among which GTE plays the strongest role in promoting high-quality economic development through green securities, followed by green credit and green insurance. Zhang et al. (2020), taking the Yangtze River Delta core urban agglomeration as an example, used panel data model to study that green finance and industrial structure upgrading are the direct driving forces for high-quality economic development; Industrial structure upgrading plays a partial intermediary role in the process of green finance promoting high-quality economic development, and is an important intermediary path, but the moderating effect is not significant. Ma (2018) believed that industrial structure, energy structure and transportation structure were the economic causes of severe pollution and large amount of carbon emissions in China. Therefore, it is necessary to change the polluting economic structure, and the main way to change the economic structure is to change the investment structure and increase green investment. We should accelerate the construction of green financial system through 12 channels, such as establishing green development fund, supporting the development of green credit, establishing green guarantee mechanism, and building incentive mechanism of green finance, so as to improve the return on investment and financing availability of green projects, and reduce the return on investment and financing availability of polluting projects. Since the implementation of the Western Development policy, Chen et al. (2018), the western region has made full use of its resource advantages and latecomer advantages to actively undertake the industrial transfer in the central and eastern regions, and the industrial structure has been optimized to a certain extent. As the most important ecological barrier and ecologically fragile region in China, the western region should abandon the development concept of "pollution first, treatment later", promote the optimization and upgrading of industrial structure with green finance, and achieve green development and high-quality economic development. On the one hand, green finance can promote

industrial upgrading. The emergence of green finance, guided by innovation, environmental protection and sustainability, provides financing support for the development of strategic emerging industries and high-tech industries. These industries involve fields such as clean energy, new materials and new energy vehicles, and are characterized by high added value, high-tech content, low pollution and low energy consumption. Through green loans, bonds and funds provided by financial institutions, social funds can be transferred to these sectors to accelerate the upgrading and transformation of the industrial structure, narrow the technological gap with developed countries, and improve the level of the industrial chain and its core competitiveness. In this way, economic development can be accelerated, while the impact on the environment and high consumption of limited resources can be reduced, and economic resilience can be improved.

On the other hand, green finance can promote technological innovation. The introduction of green finance can provide financial support and market promotion for innovative technologies such as new energy and environmental protection technologies. Research and development in these fields can not only reduce energy consumption and pollution, promote the development of environmental protection industry, but also foster new industries and drive the development of innovation. At the same time, financial institutions can also according to the green standards, assessment and disclosure of financial and non-financial information, form the ability of identification, risk evaluation and management of green, provide better protection for the technology innovation. Such green financial innovation not only helps to optimize the allocation of resources and promote economic development, but also speeds up the process of scientific and technological innovation and improves the level of industrial chain and market competitiveness, thus enhancing the innovation, resilience and sustainability of the economy. Based on this, Hypothesis 2 is proposed in this paper.

Hypothesis 2: Technological innovation and industrial structure upgrading act as intermediaries to affect the impact of green finance on China's macroeconomic resilience.

Green finance can promote the development of low-carbon and clean energy industries and promote the transformation and upgrading of economic structure. By guiding and supporting the development of green industries, the economy can improve its resource utilization efficiency and reduce its dependence on traditional industries with high pollution and high energy consumption, thus enhancing macroeconomic resilience.

Secondly, green finance can provide long-term and stable financial support to help enterprises make environment-friendly investments and innovate. This not only helps to reduce environment pollution and resource waste, can also enhance the enterprise the competitive ability and sustainable development ability. This non-linear impact can create a virtuous cycle between economic growth and environmental protection.

In addition, green finance can also promote the construction of ecological civilization, improve the ecological environment quality, improve the people's feeling and happiness. This kind of nonlinear positive affect can promote social stability and sustainable development, macroeconomic resilience to provide strong support for our country. Based on this, hypothesis 3 is proposed in this paper.

Hypothesis 3: As threshold variables, technological innovation, industrial structure upgrading and risk management make the impact of green finance on economic resilience have nonlinear characteristics.

Spatial heterogeneity analysis of green finance on China's macroeconomic resilience

There are also limited studies about the spatial differences on green finance impact on economic resilience. Xu et al. (2018) argued that green finance can through the enterprise capital formation mechanism, the signal transmission mechanism, the mechanism of feedback and credit has influence industrial structure, the empirical results show that the green finance mainly through direct funds to influence industrial structure, and regional differences, the eastern region because of its own resources advantage, the western region because of the policy advantages, Green credit

has significant effects on industrial structure upgrade, the effect is not obvious in the central region. Du and Zheng (2019) argued that green finance in developed regions played a greater role and had a significant effect on carbon emission reduction. Zeng (2021) set in the new crown pneumonia outbreak, from two aspects: resistance and resilience of the outbreak of the influence of the development of China's regional economic resilience, found in different quarter period, resistance have different strength, resilience, performance, the provinces domain also presents the different strength of economic resilience. Cheng (2022) found empirical green finance in the eastern economic resilience, big cities to promote effective, economic resilience to promote small and medium-sized cities of the Midwest, the effect is not significant, namely exists heterogeneity; Deng and Liu (2023) believed that from the perspective of the central and western regions, the role of green finance in promoting the high-quality economic development of the central and western regions was significantly higher than that of the eastern regions. Shang et al. (2023) used Dagum Gini coefficient and variance decomposition to reveal that the overall level of green finance in China is not high from the perspective of north-south space and structure, and the southern region is higher than the northern region. Du et al. (2023) points out that the green financial development imbalance in our country, far from the green level of financial development in our country overall. Song (2023) empirically found that there is a significant spatial correlation between green finance and economic resilience through the construction of spatial matrix. Most of the existing research focuses on the independent analysis of the correlation between green development and economic development, but the spatial research on the national scale is relatively scarce.

Firstly, regional natural resource endowments and environmental conditions are important factors affecting the role of green finance. There are differences in resource distribution and environmental status in different regions, which lead to different effects of green finance in different regions. On the one hand, in areas with rich resources and good ecological environment, such as coastal areas and ecological reserves, the application of green finance can better promote the rational use of resources and environmental protection, and improve the resilience of the economy. On the other hand, in areas with poor resources and serious environmental pollution, the application of green finance may face greater challenges and its effect on improving economic resilience may be relatively weak.

Second, the region's industrial structure and development level will also affect the role of green finance. There are differences in the industrial structure of different regions. Some regions may rely more on industries with high pollution and high energy consumption, while other regions may have realized the optimization of industrial structure and green transformation. Therefore, the application effect of green finance in different regions will also be different. For those regions that rely on industries with high pollution and energy consumption, the introduction of green finance can promote industrial transformation and upgrading in these regions and improve their resilience. However, for those regions that have optimized their industrial structure, the application of green finance has a relatively small effect on improving their resilience. In addition, the regional policy environment and the level of financial market development will also affect the role of green finance. There are differences in policy support and financial market development levels in different regions, which will directly affect the development and application of green finance. Some regions may have established a sound green finance policy and regulatory framework, providing better financial services and support, and green finance may have better application effects in these regions. While some regions may lack relevant policies and financial market development, and the application of green finance may face more difficulties. Based on this, hypothesis 4 is proposed in this paper.

Hypothesis 4: green finance function in the macroeconomic resilience of spatial heterogeneity.

Methodology

Data and Variables

Considering the availability of data, due to the Tibet autonomous region of the data in China 2011 years ago and the existence of a large number of the problem of the missing, so in this paper, based on 2011-2022 data of 30 provinces and autonomous regions municipalities directly under the central government data sample space for research. The data on environmental pollution, infrastructure, human capital, resource endowment, technological innovation and industrial structure upgrading come from China Statistical Yearbook, China Financial Statistical Yearbook, Financial Basic Data Center of the People's Bank of China, China Research Data Platform, China Public Policy and Green Development Database and Wind Database. The data related to the construction of the green finance evaluation system are from the Global Green Finance Big Data Platform of Central University of Finance and Economics, the websites of the Ministry of Science and Technology, the National Bureau of Statistics, the People's Bank of China and other authoritative statistical yearbooks, including the national and provincial statistical yearbooks, environmental status bulletin and some professional statistical yearbooks. "China financial yearbook", "China statistical yearbook of science and technology of the China energy statistical yearbook of China agricultural statistics yearbook" China industrial statistics yearbook "statistical yearbook of China's third industry. Some missing values were obtained by interpolation method.

One core explanatory variable, one core explained variable, two mediating variables and four control variables were selected.

Explained variables

Economic Resilience Evaluation Index (EcoRes, ER), according to the existing literature, there are two main methods to measure economic resilience: The first is the single index method, which is used by Chen et al. (2020) to define regional economic resilience based on the growth rate of the actual Gross Domestic Product (GDP) of each province.

The second method is to construct a comprehensive index system for measurement. The results reflected by the single index method vary greatly according to the changes of selected indexes, which cannot fully reflect economic resilience. In this study reference Yao et al （2023）method, on the basis of using the "ability to cope with shocks", "organization coordinated ability", "innovation transformation ability" three secondary index evaluation system to build economic resilience, the ability to cope with shocks "refers to the object of economy in the face of shock response capacity, "Organization coordinated ability" refers to the object of economy in the face of economic recession on technology updates, capital allocation, and labor to make the new configuration, transformation of "innovation ability" refers to the object of economy after a hit from the outside world, choice of transformation of the development of new methods and technology ability. The entropy method is used for calculation. The evaluation system is shown in Table 1.

Which is obtained by entropy value method "ability to cope with shocks" weight 0.218, organization and coordination ability, weight is 0.347, "transformation of innovation ability" weight is 0.435. The weight coefficients are shown in Table 2.

Core explanatory variables

Green finance level index (GFI) is based on the green finance evaluation system constructed by Zeng et al. (2014), which includes green credit, green insurance, green securities and green investment. This paper constructs a green

finance level system (see Table 3) from seven levels: green credit, green investment, green insurance, green bond, green support, green fund and green equity. Fyone, 2020), using the entropy TOPSIS method of green samples in 31 provinces, cities and autonomous regions municipalities directly under the central government to the financial index as an evaluation of local green financial level measurement data. Entropy weight TOPSIS method is a method formed by the combination of entropy weight method and TOPSIS model. It is a mathematical method used to judge the dispersion degree of an index. Its mathematical principle is divided into the following three steps:

Table 1. Evaluation system of economic resilience

First-level indicators	Secondary indicators	Calculation method
Economic Resilience (ER)	Ability to cope with shocks (ER-A)	A1. Per capita GDP (100 million yuan)
		A2.GDP (100 million yuan)
		A3. Number of people participating in unemployment insurance (ten thousand)
		A4. Number of people participating in urban basic medical insurance (ten thousand)
		A5. Foreign trade dependence (%)
		A6. Loan-to-deposit ratio of financial institutions (%)
	Organization and coordination ability (ER-B)	A7. Urbanization rate (%)
		B1. Per capita disposable income of residents (Yuan)
		B2. Fiscal self-sufficiency rate (%)
		B3. Unemployment rate (%)
		B4. Per capita GDP growth rate (%)
	Innovation and transformation capacity (ER-C)	C1. Sales revenue of new products of industries above designated size (RMB '000)
		C2. Share of technology Market contract turnover (%)
		C3. Share of R&D Expenditure (%)

Table.2 Weight results of economic resilience indicators using entropy weight method

item	Information entropy value e	Information utility value d	Weight coefficient w
Ability to cope with shocks (ER-A)	0.8393	0.1607	0.218
Organization and coordination (ER-B)	0.7987	0.2013	0.347
Innovation and transformation ability (ER-C)	0.9079	0.0921	0.435

First, the original matrix is forward transformed, that is, all indexes are transformed into very large indexes. Then, the matrix standard is forward transformed to eliminate the influence of different index dimensions. Suppose that there are n evaluation objects and m evaluation indicators (all of which have been positive), the positive matrix is as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & \cdots & x_{1m} \\ x_{21} & x_{22} & x_{23} & x_{24} & \cdots & x_{2m} \\ x_{31} & x_{32} & x_{33} & x_{34} & \cdots & x_{3m} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & x_{n3} & x_{n4} & \cdots & \\ & & & & x_{mm} & \end{bmatrix}$$

After that, the normalized matrix of each element is Z, where each element in Z is:.$z_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{n} x_{ij}^2}$Finally, we first determine the most value for subsequent calculation.

To define the maximum value:

$$Z_{max} = (Z_{1max}, Z_{2max}, \dots, Z_{max}) =$$

$$(max\{z_{11}, z_{21}, z_{31}, \dots, z_{n1}\}, max\{z_{12}, z_{22}, z_{32}, \dots, z_{n2}\}, \dots max\{z_{1m}, z_{2m}, z_{3m}, \dots, z_{nm}\})$$

Define the minimum:$Z_{min} = (Z_{1min}, Z_{2min}, \dots, Z_{min}) =$

$$(min\{z_{11}, z_{21}, z_{31}, \dots, z_{n1}\}, min\{z_{12}, z_{22}, z_{32}, \dots, z_{n2}\}, \dots min\{z_{1m}, z_{2m}, z_{3m}, \dots, z_{nm}\})$$

The score is then calculated from the base formula and normalized.

The greater the degree of dispersion is, the greater the influence of the index on the comprehensive evaluation is. The comprehensive evaluation system is as follows:

Table 3. Green finance level evaluation system

First-level indicators	Secondary index	Tertiary indicators	Calculation method
green Finance Level Index (GFI)	Green Credit	Percentage of credit for environmental protection projects	Total credit for environmental protection projects in the province/total credit for the province
	Green investment	Proportion of investment in environmental pollution control in GDP	Investment in environmental pollution control /GDP
	Green insurance	Degree of promotion of environmental pollution liability insurance	Income from environmental pollution liability insurance/total premium income
	Green bonds	Degree of green bond development	Total amount of green bonds issued/total amount of all bonds issued
	Green support	Fiscal environment Share of conservation spending	Fiscal expenditure on environmental protection/general budget expenditure
	Green fund	Percentage of green funds	Total market value of green funds/total market value of all funds
	Green equity	Depth of development of green rights	Total transaction amount of carbon trading, energy use rights trading, emission rights trading/equity market

Intermediary variables

Technological innovation, industrial structure upgrading and **risk management**. Green finance is to promote technological innovation, guide the flow of capital to the direction of scientific and technological innovation, develop advanced industrial technology, improve production efficiency, and achieve green and sustainable economic development. The technological innovation index of this study is measured by the expenditure of local finance on science and technology, and the upgrading of industrial structure is an important reflection highlighting the capital flow and the reallocation of production factors among different industries. The upgrading index of industrial structure in this study is measured by the ratio of the total output value of the local tertiary industry and the secondary industry. Risk management ability is an important embodiment of capital allocation, which is measured by the ratio of working capital to assets in this study.

Control variables

In this study, environmental pollution, infrastructure, human capital and resource endowment are selected as control variables and upgraded by referring to the calculation method of Wang Qizheng and Zhu Yingming. Environmental

pollution is measured by local financial expenditure on environmental protection, infrastructure is measured by local highway mileage, and human capital is measured by local resident population aged 14-65. Resources endowment in terms of local electric power consumption.

Descriptive statistics

Table4. Descriptive statistics

Variable type	Variable name	Symbols	Sample size	Maximum	Minimum	Average	Standard deviation	Median
Explained variable	Economic resilience	ER	362	1.97	-0.63	0.975	0.388	1.05
	Ability to cope with shocks	ER-A	362	0.733	0.309	0.412	0.078	0.392
	Organizational and coordination skills	ER-B	362	0.622	0.233	0.412	0.086	0.395
	Innovation and transformation capability	ER-C	362	0.740	0.339	0.512	0.064	0.332
Explanation/endogenous variables	Green Finance Index	GFI	362	0.768	0.073	0.26	0.14	0.237
Control/instrumental variables	Environmental pollution	EP	362	6.874	5.327	6.104	0.27	6.108
	Infrastructure	BI	362	5.608	4.082	5.082	0.369	5.198
	Human capital	HC	362	7.961	3.532	4.734	0.958	4.448
	Endowment of resources	RE	362	4.891	2.268	3.232	0.314	3.213
Mediating variable (Med)	Technological innovation	TI	362	7.068	4.575	5.906	0.475	5.889
	Upgrading of industrial structure	UIS	362	5.297	0.518	1.266	0.642	1.247
	Risk management	RM	362	8.149	6.181	7.313	0.847	7.147

Table 4. Descriptive statistical analysis shows that this study evaluates the data of different variables so as to understand their distribution and relative differences. The standard deviations of economic resilience, green finance index, environmental pollution, infrastructure, human capital, and resource endowment are all smaller than the mean, and the absolute values differ greatly. The standard deviation data in the table are generally small, indicating that the distribution of sample data is relatively concentrated. In addition, except for human capital, the variance of other variables is small, indicating that the fluctuation degree of the data is small and the stability is high.

Econometric model

System GMM model

System GMM model using Generalized Moment estimator (Generalized Method of Moment, GMM) estimator Method in the construction of the random variables follow specific Moment assumption, rather than on the entire distribution assumption, the assumption is called the Moment conditions. In kGMM estimation, the number of parameters to be estimated is assumed to be, and the number of moment conditions is assumed to be. lAccording to the exact identification property, it can be obtained $k = l$that when, the number of parameters to be estimated is equal to the number of moment conditions; According to the over-identification property, the number of parameters to be estimated is less than the number of moment conditions. $k < l$GMM is a generalization of moment estimation. $0,$ GMMIn precisely identify cases, the objective function of minimum value is equal to the estimator and estimator equivalent; MMUnder the condition of excessive recognition, however, is no longer applicable, GMM can be effectively combined moment conditions, make the GMM is more effective than the MM.MM
In the GMM estimation, the parent moment condition is:, and the sample moment condition is:. The GMM mean estimate is obtained by solving the sample moment condition:

$E[y] - u = 0 \quad \frac{1}{N}\sum_{i=1}^{N} y_i - \hat{\mu}^{GMM} = 0,$

$$\hat{\mu}^{GMM} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

This study to explore the green financial impact on our country economic resilience, and test hypotheses (1), build econometric benchmark model type (1) as follows:

$$\mathrm{EcoRes}_{it} = \alpha 1 + \beta 1 \mathrm{EcoRes}_{it-1} + \Psi 2 \mathrm{GFI}_{it} + \theta 1 \mathrm{X}_{it} + \varepsilon_{it} \quad (1)$$

Among them, and represent the province and the year of the first provincial I t years toughness index of economy, for the first t provinces I economic toughness index in the lag issue of variables, for the first t in the provinces I green financial index, for the first t in the provinces I control variables, as random perturbation terms.$it\mathrm{EcoRes}_{it}\mathrm{EcoRes}_{it-1}\mathrm{GFI}_{it}\mathrm{X}_{it}\varepsilon_{it}$

Mediating effect model

In order to explore the mechanism of green finance affecting China's macroeconomic resilience, this study adopts two mediating variables, technological innovation and industrial structure upgrading, and constructs two models (2) -(3) based on Wen Zhonglin and Ye Baojuan.

$$\mathrm{Med}_{it} = \alpha 2 + \beta 2 \mathrm{Med}_{it-1} + \Psi 2 \mathrm{GFI}_{it} + \theta 2 \mathrm{X}_{it} + \varepsilon_{it} (2)$$

$$\mathrm{EcoRes}_{it} = \alpha 3 + \beta 3 \mathrm{EcoRes}_{it-1} + \Psi 3 \mathrm{GFI}_{it} +$$

$$\Psi 4\mathrm{Med}_{it} + \theta 3\mathrm{X}_{it} + \varepsilon_{it} \quad (3)$$

WhereMed_{it}, is the mediating variable of province i in year tΨ1, and the rest of the variables are the same as in Equation (1). To regression equation (1) to test whether green finance to the total effect of macroeconomic resilience significantly. If it is significant and positive, it indicates that the total effect of mediating effect exists. 2. Run regression on Equation (2) to test whether the coefficient of green finance on mediating variable is significant. Ψ2If it is significant and positive, it indicates that green finance promotes mediating variables. The third step is to conduct regression on Equation (3). If the coefficient, is significantly positive and the absolute value of the coefficient is less than the absolute value of the coefficient, it indicates that there is a partial mediating effect. Ψ3Ψ4Ψ3Ψ1If it is not significant or significant, it indicates that the mediating variable has played a full mediating role.Ψ3Ψ4

Table5. Types of GMM variables

Name	Variable type
ER	Dependent variable
GFI	Endogenous variables
EP	Instrumental variables
BI	Instrumental variables
HC	Instrumental variable
RE	Instrumental variables

Threshold effect model

In order to further explore the nonlinear relationship between green finance and economic resilience through technological innovation, industrial structure and risk management, the panel threshold model is constructed as shown in (4) - (5).

$$\mathrm{y_{it}} = \mu_{\mathrm{i}} + \beta_1' \mathrm{x_{it}} + \varepsilon_{\mathrm{it}} \mathrm{if} q_{it} \le \gamma$$
$$\mathrm{y_{it}} = \mu_{\mathrm{i}} + \beta_1' \mathrm{x_{it}} + \varepsilon_{\mathrm{it}}, \mathrm{if} q_{it} \ge \gamma \quad (4)$$

In the above formula, is the threshold variable (which can be part of the explanatory variables), is the threshold value to be estimated, and follows independent and identically distributed. $q_{it}\gamma\varepsilon_{\mathrm{it}}$The equation in the above equation can be written as follows:

$$\mathrm{y_{it}} = \mu_{\mathrm{i}} + \beta_1{}' \mathrm{x_{it}} \cdot \mathrm{I}(\mathrm{q}_{it} \le \gamma) + \beta_2{}' \mathrm{x_{it}} \cdot \mathrm{I}(\mathrm{q}_{it} > \gamma) + \varepsilon_{\mathrm{it}} \quad (5)$$

Where () is the indicative function, is the variable (which can be part of the explanatory variables), is the threshold value to be estimated, and follows independent and identically distributed. $\mathrm{I}q_{it}\gamma\varepsilon_{\mathrm{it}}$Its estimate principle is mainly based on the theory of minimum sum of squared residuals (SR).

Results and Conclusions

Research on the impact of green finance on China's macroeconomic resilience

GMM estimation results

Table 6. GMM estimation results

	Non-standardized coefficients		Coefficient of standardization	Z	P	R^2	Adjust R^2	Wald
	B	Standard error	Beta					
Const	1.054	0.064	-	16.503	0.000***	0.85	0.87	2.338
GFI	0.319	0.209	0.116	1.989	0.000***			
Dependent variable: Economic resilience								

Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively

Table 6 above shows the final results of GMM estimation. Firstly, the model passed the Wald chi-square test (Wald=2.338, p=0.000<0.05), which means that the model is valid. Secondly, the P value met the conditions and showed significant correlation. Finally, R squared were 0.85 and 0.87, the standard curve fitting degree of original data is very good, green financial macroeconomic resilience in the provinces of our country has positive role in promoting, China should continue to intensify efforts to unswervingly promote the development of green finance.

Excessive identification test

Table 7. Over-identification test results

inspection	Statistics	P
Hansen J test	10.006	0.819

Note: * * *, * *, *, respectively 1%, 5% and 10% significance level

The over-identification test is used to test whether the instrumental variables are exogenous variables. There are four instrumental variables involved in this study, namely "environmental pollution", "infrastructure", "human capital" and "resource endowment". As can be seen from Table 7, the over-identification Hansen J test shows that the null hypothesis is accepted (p=0.819) 0.05. Meanwhile, the over-identification Hansen J test shows that the null hypothesis (P = 0.819) is accepted. It proves that there is a strong correlation between the selected instrumental variables and the endogenous variables, and these instrumental variables can effectively explain the changes of the endogenous variables. This further verifies the rationality and reliability of our model, and provides an important reference for future policy making and decision-making.

Endogeneity test

Table 8. Endogeneity test results

Test	Statistics	P
Statistics	1.545	0.014**

Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively

In this study, we conducted endogenous test, endogenous test results such as Table 8. , as is shown in the results show that the satisfactory results. After Hausman test and Durbin - Wu - Hausman test verification, we found that in the model there is no significant correlation between variables and the error term. This means that we study the causation is not interference by endogenous problems.

Parallel mediation effect

Considering the economic dependent and independent variables green financial index to toughness index regression coefficient, the influence of financial index and green by technology innovation and upgrade of industrial structure and risk management ability, determines the technological innovation, industrial structure upgrade and risk management ability for the intermediary variable. For the comprehensive analysis of the independent variable will pass intermediary variable to affect the dependent variable, this study will be technological innovation, industrial structure and risk management capacity upgrade as a intervening variable, build parallel mediation effect of regression model, judge the mediation effect, finally complete mediation effect test. In addition, to ensure the integrity of the mediation effect, this study will be technological innovation and upgrade of industrial structure and risk management ability as intermediary variable substitution, results such as Table 9-10. As shown in Table 9-10.

Table 9. Coefficient table of mediating effect regression model

	ER	TI	UIS	RM	ER’
Constant	0.567	0.434	-0.239	0.447	0.442
GFI	0.624	0.378	0.913	0.379	0.619
EP	-0.106	0.911	1.544	0.717	-0.179
BI	0.279	-0.487	-1.114	-0.583	0.292
HC	-0.007	0.023	0.04	0.017	-0.008
RE	-0.154	0.673	-0.832	0.682	-0.389
TI					0.236
UIS					-0.092
RM					0.247
Sample size	362	362	362	362	362
R^2	0.057	0.698	0.522	0.517	0.09
Adjust R^2	0.044	0.693	0.514	0.509	0.07
F	F(5,356)=4.317, P=0.001***	F(5,356)=164.735 , P=0.000***	F(5,356)=77.751 , P=0.000	F(5,356)=89.633, P=0.000	F(7,354)=5.022, P=0.000***

Note: ***, ** and * represent the significance level of 1%, 5% and 10%, respectively

It can be seen that the green finance level index has a positive role in promoting technological innovation, industrial structure upgrading and risk management ability, and the economic resilience evaluation index can also promote technological innovation, industrial structure upgrading and risk management ability; The level of green finance is determined by the level of technological innovation; But the three intermediary path negative influence on infrastructure development, high quality and economic development. The coefficient of the square term of the mediating variable is positive and significant at the level of 5%, indicating that its impact on the quality of economic development has significant nonlinear characteristics.

Table10. Summary results of mediating effect test

item	c Total effect	a	a(p-value)	b	b(p value)	a*b mediating effect value	a*b (Boot SE)	A * (z)	b a*b (p-value)	a*b (95%BootCI)	c' direct effect	Test conclusions
GFI=>TI=>ER	0.624	0.378	0.000***	0.236	0.002***	0.089	0.032	2.759	0.006***	0.041 - 0.167	0.619	Fully mediated
GFI=>UIS=>ER	0.624	0.913	0.000***	-0.092	0.022 * *	-0.084	0.047	-1.792	0.034**	0.202-0.018	0.619	Fully mediated
GFI=>RM=>ER	0.624	0.379	0.000***	0.247	0.001 * * *	0.077	0.034	1.247	0.003***	0.053-0.179	0.619	Full mediation

According to the coefficient of product inspection, by the above-mentioned P values, P values < 0.05, presents the significance, through the Bootstrap sampling inspection at the same time, this study found that in a * b the regression coefficient of 95% confidence interval does not include the number 0, further indicating partial mediating role. Specifically, in the impact of green finance on China's macroeconomic resilience, technological innovation and industrial structure upgrading as well as risk management ability as mediating variables show a full mediating effect in the impact of green finance on macroeconomic resilience. These results indicate that technological innovation and industrial structure upgrading as well as risk management capability play an important role in the process of green finance playing a role, which further strengthens our understanding of the relationship between these variables.

The threshold effect empirically

Threshold effect test

The results of this model are obtained under 300 bootstrapping (BS) sampling. For innovative technology, in a double threshold estimation, P value is 0.15, not through the test of significance, namely the model does not exist double threshold effect; In a single threshold estimation, F value is 65.83, significant under 1% level, the 95% confidence interval [6.5281, 6.5910], so the model is a single threshold, threshold effect analysis can be performed. For the upgrading of industrial structure, in a double threshold regression, P value is 0.00, F valuewere 96.05 and 80.75, significant under 1% level. In the first threshold value, the 95% confidence interval [0.9139, 0.9489]; In the second threshold value, the 95% confidence interval [1.4326, 1.4590]. So when the threshold variable is upgrade

of industrial structure, the model with double threshold, double threshold effect analysis can be performed. For the risk management ability, in a double threshold estimation, P value is 0.09, not through the test of significance, namely the model does not exist double threshold effect; In a single threshold estimation, F value is 74.74, significant under 1% level, the 95% confidence interval [7.5013, 7.5200], so the model is a single threshold, threshold effect analysis can be performed.

Threshold regression results

Threshold effect further, this research on panel test used to test whether a hypothesis 3, level of technological innovation and upgrade of industrial structure and risk management capability respectively through the test of single threshold, more than the threshold. On this basis, we set a single threshold regression model with technological innovation level and risk management ability as threshold variables, and set a multiple threshold model with industrial structure upgrading as threshold variables. The outcome of the model based on the threshold of the threshold of each variable regression as shown in Table11.

Table 11. Threshold regression model results

variable	ER		
	TI	UIS	RM
EP	0.086*** (2.85)	0.050*** (2.09)	0.062*** (1.69)
BI	0.766*** (3.00)	0.490*** (2.76)	0.742*** (2.91)
HC	-0.003*** (-1.39)	-0.011*** (-3.92)	-0.002*** (-0.96)
RE	0.202** (1.63)	0.117*** (1.24)	0.172** (1.36)
GFI(INNO<gamma1)	0.091*** (3.44)	0.063*** (2.40)	0.095*** (2.42)
GFI(gamma1<INNO<gamma2)	0.308*** (5.88)	0.336*** (10.95)	0.406*** (5.31)
GFI(INNO>gamma2)	-	0.650*** (9.13)	-
Constant term	-4.82** (-5.04)	-2.93*** (4.49)	-4.49** (-4.80)
Sample size	360	360	360
Number of provinces	30	30	30
R^2	0.705	0.779	0.711

Taking the benchmark regression results of threshold effect based on industrial structure upgrading in Table 11 as an example, the influence of green finance on economic resilience due to differences in industrial structure upgrading is significantly positive: when the innovation level is lower than the first threshold value of 0.9396, the influence coefficient of green finance on regional economic resilience is 0.636, which is significant at the level of 5%; When the threshold variable between first threshold and second threshold value, the core explanation variables

to explain the influence is positive significant, influence coefficient is 0.336, P value is 0.000, significant at 1% level; When innovation level is greater than the threshold value of 1.4491, the influence coefficient is 0.650, P value is 0.000, significant under 1% level. However, as the threshold value first increases and then decreases, the threshold variable has an optimal interval, that is, the threshold value is within [0.9574,1.4491].

At the same time, in order to intuitively present the regression effect and threshold effect, Figure 1 is the threshold effect test diagram based on each threshold variable.

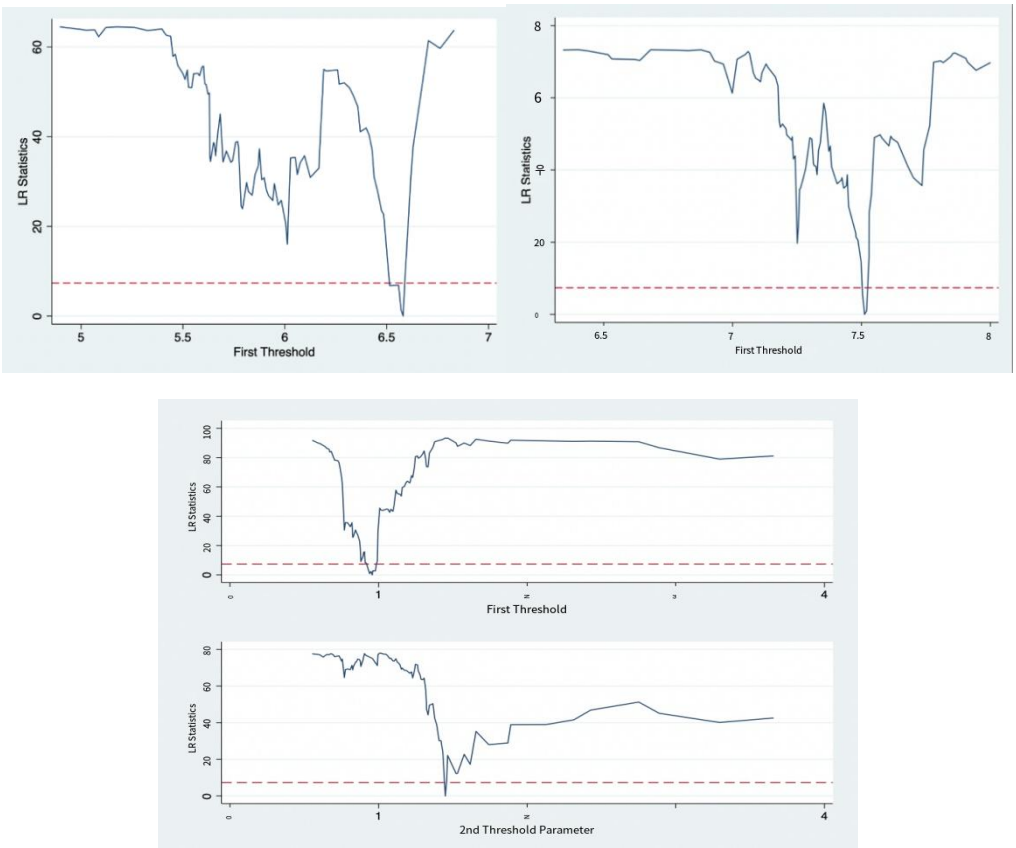

Figure 1. Threshold effect test diagram

Robustness test of threshold effect

The results of the robustness tests were all obtained under 300 bootstrapping (BS) sampling. For the threshold variables of technological innovation capability and risk management capability, both of them are significant at the level of 1% in the single threshold estimation, with 95% confidence intervals of [6.5281,6.5910] and [7.5013,7.5200], respectively. For industrial structure upgrading, in the double threshold estimation, the 95% confidence interval is [0.9116,0.9489] and [0.9272,0.9617]. Therefore robustness model has a single threshold for threshold effect analysis.

Table 12 uses the method of deleting the control variable "human capital". From the regression results, it can be seen that the threshold values change weakly, which are 6.5809, 0.9396, 0.9574 and 7.5120 respectively. Secondly, it can be seen from the observation coefficient that when the threshold variable is lower than or higher than the threshold value, the positive promoting effect of the growth unit of green finance development on economic

resilience is improved compared with the regression results of the threshold benchmark, and the significance level does not change much.

Table12. Robust regression results of threshold effect

Variables	ER		
	TI	UIS	RM
EP	0.083*** (2.70)	0.046*** (1.85)	0.060*** (1.61)
BI	0.749*** (2.99)	0.447*** (2.41)	0.731*** (2.93)
RE	0.206** (1.65)	0.137*** (1.34)	0.175** (1.38)
GFI(INNO<gamma1)	0.089*** (3.35)	0.065*** (2.49)	0.093*** (2.35)
GFI(gamma1<INNO<gamma2)	0.305*** (5.86)	0.318*** (11.06)	0.405*** (5.33)
GFI(INNO>gamma2)	-	0.607*** (8.06)	-
Constant term	-4.75** (-5.10)	-2.81*** (-4.15)	-4.44** (-4.87)
Sample size	360	360	360
Number of provinces	30	30	30
R^2	0.704	0.766	0.711

At the same time, in the coefficients of other control variables, green financial development is still positively promoting, and the coefficient and t value change little. In summary, the results of the robustness test and the benchmark regression results of the threshold effect have little change in the coefficients of the core explanatory variables, and there is no change in the significance and sign, so the benchmark regression results of the threshold effect are robust.

Spatial heterogeneity

Based on the spatial location of 30 provinces in China, according to the division method of the National Bureau of Statistics, the 30 provinces are divided into the eastern, central, western and northeastern provinces.

Table13. Two-way fixed effect results of the three provinces in Northeast China

Variables	Coefficients	Standard errors	t	P	R^2	F
const	69.299	20.764	3.337	0.005***	within=0.053 between=0.017 overall=0.035	F=15.313, P=0.000
GFI	3.932	2.202	1.786	0.004***		
EP	-0.429	0.544	-0.787	0.443		

BI	-6.805	2.78	-2.448	0.027**
HC	-1.75	1.999	-0.875	0.395
RE	-5.75	5.111	-1.125	0.278
TI	-0.929	0.275	-3.383	0.004**8
UIS	-0.906	0.151	-6.01	0.000***
RM	-0.703	0.187	-5.02	0.001***

Dependent variable: Economic resilience

Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively

Table14. Results of two-way fixed effects in the east

Variables of interest	Coefficients	Standard errors	t	P	R^2	F
const	-0.272	0.676	-0.403	0.688		
GFI	0.175	0.216	0.809	0.029**		
EP	0.022	0.153	0.142	0.888		
BI	0.453	0.131	3.465	0.001***		
HC	-0.014	0.03	-0.478	0.634	within=0.009	F=3.119,
RE	-0.6	0.174	-3.443	0.001***	between=0.569	P=0.005
TI	0.168	0.128	1.311	0.193	overall=0.192	
UIS	-0.037	0.045	-0.839	0.404		
RM	0.179	0.106	1.208	0.027**		

Dependent variable: Economic resilience

Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively

Table15. Results of two-way fixed effects in western China

Variables	Coefficients	Standard errors	t	P	R^2	F
const	2.878	1.002	2.872	0.005***		
GFI	-0.096	0.286	-0.334	0.039**		
EP	-0.95	0.34	-2.794	0.006***		
BI	0.573	0.222	2.579	0.012**	within=0.052 between=0.308 overall=0.156	F=2.426, P=0.025
HC	0.013	0.036	0.356	0.722		
RE	-0.254	0.265	-0.956	0.341		
TI	0.333	0.15	2.221	0.029**		
UIS	-0.176	0.117	-1.513	0.134		
RM	0.079	0.149	1.264	0.037**		

Dependent variable: Economic resilience

Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively

Table16. Results of two-way fixed effects in the middle part

Variables	Coefficients	Standard errors	t	P	R^2	F
const	-7.966	2.089	-3.814	0.000***		
GFI	0.864	0.339	2.549	0.013**		
EP	0.706	0.325	2.176	0.033**		
BI	1.551	0.413	3.757	0.000***	within=0.322 between=0.774 overall=0.47	F=8.097, P=0.000
HC	0.02	0.036	0.556	0.580		
RE	-1.394	0.314	-4.441	0.000***		
TI	0.246	0.155	1.59	0.117		
UIS	-0.829	0.187	-4.441	0.000 * * *		
RM	0.162	0.143	1.112	0.039**		

Dependent variable: Economic resilience

Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively

This study uses four groups of sample data to pass the two-way fixed effect test, and the test results are as follows: Table 15-18. Among them, the central and eastern provinces are the most significant, followed by the eastern provinces, and finally the western provinces. It shows that the development of green finance has a positive promoting effect on local economic resilience, and the positive promoting effect is the largest in the central and the three eastern provinces, followed by the eastern region and the weakest in the western region. Based on the analysis of the model conclusions, this study holds that different regions have different environmental resource endowments and basic economic development status, and the demand degree of green finance for environmental protection and sustainable use will also be different. The three provinces in central China and Northeast China have rich natural resources, and due to the prominent environmental problems, such as soil erosion, the demand for green finance is relatively large. The eastern region has more perfect infrastructure related to green finance, and follows the principle of green and high-quality development. Compared with the western region, the eastern region has more complete traditional financial and green financial systems, and more sufficient financial support, which can better play the positive role of green finance in promoting regional macroeconomic resilience.

Conclusions and policy recommendations

Using the relevant data of 30 provinces in China from 2011 to 2022, this paper examines the impact of green finance on China's macroeconomic resilience and the mediating effect of technological innovation and industrial structure upgrading. First, using the latest provincial data, this study proves that the development of green finance can greatly improve China's macroeconomic resilience and promote economic stability and sustainable development. Secondly, this study verifies that technological innovation, industrial structure upgrading, and risk management, as mediating effects, can further enhance China's macroeconomic resilience. Finally, green finance shows strong spatial heterogeneity in the process of promoting China's macroeconomic resilience. Based on the above conclusions, this study puts forward the following policy recommendations: The development of green finance can significantly enhance China's macroeconomic resilience, especially in terms of coping with shocks. Through diversified economic structure, efficient allocation of resources, risk management and reduction, green finance provides important support for sustainable economic development and resisting external shocks. By encouraging and supporting the development of green industries, green finance can promote the transformation of the economy to a low-carbon, environmentally friendly and sustainable direction, so as to reduce the vulnerability of the economy to specific industries or fields and improve the resilience of the overall economy to external shocks. Through the support of green finance, environmental protection and sustainable projects can obtain more funds and investment, so as to promote the effective use and conservation of resources to cope with the shortage of resource supply and price fluctuations; By introducing green financial instruments, such as green bonds and green insurance, enterprises and financial institutions can better assess and manage risks related to climate change, natural disasters, etc., reduce the vulnerability of the economy, and improve the ability to withstand shocks. The development of green finance can significantly enhance the resilience of China's macro economy in terms of organizational and coordination capabilities. Policy framework and standards, the participation of financial institutions, the establishment of multilateral cooperation and partnership can help improve the organization and coordination ability and promote the development of green finance, promote the sustainable development of economy, the efficient allocation of resources and risk management, improve the macroeconomic resilience and competitiveness. Government to formulate and implement green financial policy, for example, to set up the green financial fund, make green bonds issue guidelines, etc., provide direction and specification for the development of green finance, organization and coordination of all parties. Financial institutions such as banks, securities companies and insurance institutions promote the financing and investment of environmentally friendly and sustainable projects by providing green financial products and services. Financial institutions participate in the green finance market to achieve effective

allocation of resources and management of risks, and improve the resilience of the overall economy. All stakeholders, including governments, financial institutions, enterprises, social organizations and the public, should establish partnerships to jointly promote the development of green finance. For example, the government can provide policy support and market guidance, financial institutions can provide financing and risk management, enterprises can implement green projects, and social organizations and the public can provide supervision and participation. The development of green finance can significantly enhance the resilience of China's macro economy in terms of innovation and transformation capacity. Through innovative economic model and transformation capacity cultivation, green finance can promote the economy to achieve innovative transformation, improve adaptability and competitiveness, and enhance the economy's ability to resist risks and sustainable development. Enterprises and entrepreneurs should be encouraged to innovate in green technology, clean energy, environmental protection and other fields to foster new economic growth points and improve the economy's innovation and transformation capacity, to enhance macroeconomic resilience. Through the support of green finance, enterprises can obtain funds and resources to promote the transformation towards environmental protection and sustainability. Green finance can provide support services such as training and consulting to help enterprises improve their environmental management and sustainable development capabilities, so that they can better adapt to market changes and environmental requirements, enhance their ability to resist risks, and thus improve macroeconomic resilience.

By innovating the ways and means of green financial development, guiding financial capital to help the new track of green development, can provide support for the sustainable development of more industries and industries in our country, promote the progress of green technology, and have a positive role in transforming green technology into actual results. At the same time, we should further adhere to and increase scientific and technological innovation, and encourage green finance participants to innovate in technology. Financial institutions may set up a special department to financial product innovation, in order to satisfy the demands of enterprise technology innovation fund, the relevant government departments should strengthen the support of enterprise technology innovation, set up special funds or implement preferential tax policies, reduce the financing cost of enterprises, green technology innovation for enterprises to create a good financial environment. We should promote the resilience of the economy and form a replicable, promotable and sustainable green finance model. We will establish a sound green financial system, introduce capital into green and environmentally friendly industries with low energy consumption, promote sustainable and green economic development, increase economic growth potential and enhance economic resilience. At the same time, we will promote diversification of green products and accelerate the upgrading of green industries. With investment and financing support from green finance, traditional industries with high pollution and high energy consumption can be transformed and upgraded to green industries and clean technologies. The upgrading of industrial structure helps to improve the degree of resource utilization efficiency and environmentally friendly economy, reduce reliance on limited resources, improve the ability of the sustainable development of the economy. At the same time, the upgrade of industrial structure will also be able to develop new industries and jobs, to improve the toughness of the overall economy and innovation ability.

We will further consolidate the macroeconomic system and strengthen economic integration and complementarity among regions. Green finance for toughness at a higher level of regional economy region promoting effect is more effective and more prominent, the higher market openness of the eastern region will strengthen the green financial system innovation; In the resource-rich central region, it can mobilize social forces to promote the expansion of green finance financing scale; In the western regions along the Belt and Road, we can continue to increase investment in environmental governance with the help of preferential policies. The eastern region with developed green finance can guide the central and western regions to realize diversified green finance. Under the effect of green finance on economic resilience, it can promote a virtuous cycle of economic resilience intensity, form a

benign competition among various regions, build a high-level linkage system for green finance development, and subtly transfer the concept of green finance into the economic system. Thus, it can better promote economic resilience and generate high-high aggregation effect. In general, it is necessary to maintain a stable macroeconomic environment, optimize the information sharing mechanism, promote the reasonable aggregation, efficient flow and balanced diffusion of resources, promote the coordinated development of regional economy, get rid of the development pattern of weak resistance, and form a virtuous cycle and spatial optimization.

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