

Research on Quantitative Relationships between Green Finance and the Low-Carbon Economy of China

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Abstract

Green Finance mainly promotes the development of the low-carbon economy through three paths of policy, targeted financing, and technological innovation in China. The low-carbon economy is to nurture the development of green finance by stimulating financial needs. Based on the relevant data from 2000-2022 of China, this article has established an index system for green finance and low-carbon economy. It uses a comprehensive evaluation model to define the development level of green finance and low-carbon economy. Economic evaluation dimensions have explored the coupling coordination relationship between the two systems. The results show that the rapid growth of the development of green finance and the low-carbon economy in China is currently presenting a state of high coupling and highly coordinated development, which shows that green finance has a significant targeted role in the low-carbon economy which proves the model's effectiveness in this paper.

Keywords

Green Finance, Comprehensive Scoring System, Carbon Transportation, Coordinated Development

1. Introduction

The development of the low-carbon economy has become an important direction since China has proposed “carbon-to-peak” and “carbon neutralization”. As a key means to achieve the two carbon targets, green finance has a significant effect on the development and impact of the low-carbon economy, and the relationship between green finance and the low-carbon economy has attracted much attention. Green finance refers to the financial system that incorporates envi-

ronmental and social responsibilities into risk management, investment and financing decision-making in financial activities, including financial instruments such as a variety of activities such as green industries and carbon emission reduction and pollution treatment [1]. Including four core financial instruments: green credit, green investment, green insurance, and green securities. The low-carbon economy is based on the economic model of low energy consumption, low pollution, and low emissions, and is born to achieve the dual goals of economic growth and ecological protection.

Specifically, green finance refers to investment and financing methods that transform financial instruments and funds into low-carbon, effective resources, environment friendly and sustainable development [2]. The emergence of green finance stems from sustainable development, and the goal is to promote the green growth of carbon emission reduction to achieve economic growth. The development of green finance has been actively responding to countries around the world. In China, Green Finance was officially included in the G20 agenda in 2016, becoming one of the focus of national economic development. Since then, the Chinese government has issued a series of policies, such as the “Green Bond Guide” and “Several Opinions on Promoting the Development of Green Finance”, etc., which aims to strengthen support for environmental protection industries and promote the development of green finance. In September 2020, China announced at the 75th UN General Assembly that China would strive to achieve “carbon peaks” by 2030 and achieve “carbon neutrality” by 2060 [3] [4] [5].

According to the data of the central bank in China as of the end of 2021, the balance of green loans of domestic and foreign currencies was nearly 16 trillion yuan, an increase of 33% year-on-year, which was 12.7 percentage points higher than the end of the previous year. The loans of the exclusive projects were 73 and 3.36 trillion yuan, respectively, accounting for 67% of the green loan; the scale of green bonds reached 1.16 trillion yuan, and the number of bond issuance continued to increase; The number is close to 100, with a total scale of about 800 billion yuan, an increase of 36% over the end of last year. During the same period, insurance funds were invested about 1 trillion yuan in “double carbon” and green development-related industries. It continued to innovate innovation in types of products such as pollution environmental risk guarantee, green industry risk guarantee, and green financial risk protection. One of the important goals of China’s green finance is to reach the peak of carbon dioxide emissions by 2030, and strive to achieve carbon neutrality by 2060 [6] [7].

China’s research on green finance and low-carbon economy mainly includes research on the energy optimization effect of green finance [8] and the study of intermediary effects and conduction pathways that drive economic growth [4]. Among them, Green Finance drives technological innovation and thus has more attention to conducting pathways that have positive influence on the low-carbon economy [9]. The impact of green finance on the economic level has also appeared in many research in 2023, indicating that the efficiency and effectiveness of the effect of green finance rose rapidly. The role of green finance on the

low-carbon economy first formulates the direction through policy. Therefore, whether the development of green finance effectively affects the development of the low-carbon economy is the most concerned issue for policy researchers.

This article mainly studies the coupling development relationship between green finance and low-carbon economy. By constructing a comprehensive scoring of the development level of the two systems by constructing a comprehensive evaluation system of green finance and low-carbon economy, using the entropy value method to calculate the weight of the indicator variables, and the comprehensive score is obtained. Time sequence research on the level of coupling and coordinated development is finally conducted, and the evolution curve of coupling coordination over time is drawn to study the dynamic evolution process of low-carbon and green finance coupling in China, then conclusions and suggestions are obtained.

The ultimate orientation of Green Finance is to reduce carbon emissions, but through the simple regression test, it is found that the current carbon emission reduction role of green finance cannot obtain significant return results at the national level. The first is the deviation caused by the immature of the measurement system. The development of green finance in China is still in the stage of exploration and development [8] [9] [10] [11], and the acquisition of direct data on green finance is also very limited. Therefore, in order to quantify the green financial system Comprehensive calculation of dimensions. Chinese current calculation of carbon emissions has not formed a unified measurement method. The immaturity of the carbon displacement calculation system has also affected the study of the relationship between the two. Second, the efficiency of green finance still needs to be improved, and the development of green finance is uneven. Studies have shown that Chinese financial pilot policies in major carbon source industries (industry and agriculture) can have a significant impact [3] [12] [13], provincial data empirical research shows that green finance has a significant average processing effect on carbon emissions, but the heterogeneous performance of the carbon emission reduction effect of green finance is obvious [7] [14], green finance has different carbon emission reduction effects in different regions (central, western, and eastern regions) across the country [15] [16]. They all illustrate the uneven development of Chinese green finance, and the use of national data cannot be obtained by empirical significance.

In the process of combing the literature, it was found that the economic growth effect of green finance on the sustainable economic development of the economy was positive [11] [17]. Study the coupling coordinated development relationship between green finance and low-carbon economy and the different stages of development can be further explored. The effectiveness of financial instruments and policies provides important information for policy formulation. It is necessary to explore the development coordination and evolution direction between green finance and the low-carbon economy. This article uses the entropy value method to study the green finance and low-carbon economic indicators

system. By calculating the weights occupied by each indicator, the two index systems are comprehensively scored; and then the coupling and coordinated development relationship between the two systems is explored by the coupling coordination model.

The main goals of the paper are the following efforts: 1) This article establishes a relatively effective green finance evaluation system by using the available data through adding a new green funds dimension; 2) This paper has established a new low-carbon economy evaluation system by the inclusion of carbon transportation which are calculated by using the Statistics Bureau data. In order to improve the indicator systems, the rating dimension of green funds was added to the green financial evaluation system, and the evaluation dimension of carbon traffic was innovatively added to the low-carbon economy evaluation system. The reason is as follows: since carbon transportation has not been included in the evaluation system of the low-carbon economy in the current research, transportation is one of the largest sources of air pollution in the world. The energy consumption of the transportation industry accounts for 64% of the total oil consumption. The carbon economy is strongly grasped. Low-carbon transportation is an important part of the development of the low-carbon economy and is the main driver for the low-carbon economy. Based on this, this article is incorporated into the evaluation dimension of carbon transportation as a low-carbon economy. It is necessary to innovate and improve the previous indicator system. 3) By using the new indicator index systems, the coupling and coordination relationships and their evolution with time between green finance and low carbon economy are comprehensively investigated, and their policy indications are studied for the further development of the green and low carbon economy.

2. Related Literature Review

Green Finance refers to financial products and services that support low-carbon and sustainable economic transformation (G20 Green Financial Research Group, 2016). Low-carbon economy is a new economic model to reduce greenhouse gas emissions while ensuring economic growth (International Renewable Energy Agencies, 2020). Green Finance originated in European and American countries. In 1989, the concept of “green economy” was proposed by British scholar Pearce in 1989 to explore how financial activities support the sustainable development of the real economy [1]. The development of green finance in China started late. As early as 1999, Qiao Haishu [2] was defined. It aims to rationally distribute financial resources through the double consideration of environmental value and economic value destroy.

Green Finance has developed in many segments, which has derived rich and diverse green financial products, including green loans, green bonds, green funds, and so on. In Europe and the United States, green loans were first established by Citi Bank and other banks to establish the financing principles and relevant standards of green loans, including a series of borrowing standards for

green financing projects such as risk assessment and environmental benefits of green financing projects. In 2013, China introduced the “Green Credit Statistics System” to strictly require the review, evaluation and management procedures for green loans. It mainly provides loans for three types of green projects, including green energy-saving projects, green concept items, and pollution reduction projects. Green bonds are more disclosed than green loans. In order to prevent enterprises from using the “green project”, to obtain low cost funds to get extra advantage, reduce the efficiency of green finance, and monitor the “drifting green” behavior, China in 2015 in 2015 after the year, a series of green bond specifications such as the “Green Bond Issuance Guidelines”, “Green Industry Guidance Catalog”, and “Green Bond Principles” were released. Green Fund is a more direct investment in green projects. It pays attention to the ESG activities of enterprises. It is mainly led by the market abroad. It has raised funds through public offering or private equity to establish fund products and invest in green project portfolio. It is mainly led by the national fund in China established by the government, and appropriation from fiscal expenditure. First, it shows the state’s support, attention, and dominant role in the country’s development of green finance; second, the country-led method also well controls the financial risks of the early stage of green finance. It is more in line with the characteristics of China’s economy to gradually open up the market after the development and maturity of green finance and the improvement of laws and regulations.

The development driving force of green finance comes from natural environmental issues that cannot be ignored, including climate change, scarcity of resources, and environmental destruction. Climate change is currently one of the world’s largest challenges. The Convention on the United Nations Climate Change Framework indicates that promoting economic transformation to low-carbon economy is the most reliable solution [18] [19]. The lack of food and other resources and water pollution is another driving force for promoting low-carbon transformation. Finally, environmental regulations and policies such as carbon pricing and discharge targets are constantly encouraging enterprises to adopt more environmentally friendly methods for production activities, and encourage enterprises to invest in new energy research and development and green innovation technology.

Current research has found that green finance has a positive effect on technological innovation, green transformation, and carbon emission reduction. First of all, Zhao Lingyan and Yi Qingling believe that green finance can help improve the efficiency of green innovation [9]. The realization of the value of ecological products through the government influence mechanism and market impact mechanism has been studied [20]. The government’s influence mechanism is to use financial policy to guide the flow of fiscal capital and increase energy-saving and environmental protection expenditures. The market impact mechanism is to reduce the financing cost of high energy-consuming enterprises in energy conservation and emission reduction and technological innovation,

promote the green transformation of enterprises, and promote the realization of the value of ecological product value. Essence Many scholars have studied the carbon and emission reduction effects of green finance, and found that the carbon reduction of green finance is more significant in the pilot area of green reform and innovation or financial developed areas. The green finance positive role with the obvious regional differences indicates that the potential of green finance has not yet been fully developed, so the differences in green finance in various places are obvious, and the level of development is uneven.

There are many intermediary effects of green finance on the promotion of low-carbon economy: there are two main intermediary effects that have been widely recognized and have multiple empirical studies, which are the green transformation and technological innovation of the industrial structure. In the context of the “dual carbon” target and the low-carbon economy, the upgrading of the industrial structure is the process of turning the green transformation of various enterprises and industrial industries. After green transformation, the energy consumption, carbon emissions, and pollution emissions will be reduced accordingly. The low-carbon economy has been developed. Technological innovation is to improve energy use efficiency through the advancement of green technology and promote the development of the low-carbon economy. Research shows that the level of low-carbon technology affects the size of green finance on low-carbon economic support [21].

In 1965-1975, Western economists carried out a series of research around the “relationship between financial development and economic growth” and put forward the theory of financial development. Financial development is a change in financial structure. It is believed that there is a relationship between mutual promotion and mutual constraints between financial and economic development. Effective financial reform can effectively promote only development and form a virtuous circle. Qi Yikang research on the development of green finance and economic level found that there is an inverted U-shaped relationship between the scale of green finance and economic growth [4]. Green finance conducts effective assessments, and then studies the relationship between green finance and economic development. In other words, the development of financial systems and economy should be coupled and coordinated, and whether the effectiveness of economic development should be manifested as the level of coordination. Chinese scholar Li Xiaoxi and others conducted a research and explanation of the relationship between finance and sustainable development [22] [23]. They believed that sustainable development requires the support of financial support, and the healthy development of finance also depends on the sustainable growth of economic. Green Finance is the combination of financial and sustainable development. It uses financial support for green sustainable industries to promote the development of the low-carbon economy.

Coupling relationship between green finance and low-carbon economy has the following research results in China. As far as the national economic influence is concerned, many have studied the national and provincial panel data [11]

[12] [13] [14]. Coupling relationships and regional differences between green finance and low-carbon economy. Most of the construction of the green finance and the low-carbon economy is comprehensively evaluated through the method of indicator construction. The content of the indicators of green finance is relatively uniform, mainly involving green credit, green securities, green investment, and carbon finance. The method of constructing the indicator system of the carbon economy is relatively diverse, mainly divided into economic dimensions and low carbon dimensions. The conclusion about the development of regional differences is relatively uniform, that is, the level of coupling coordination in the eastern region is higher than that of other regions, thanks to high-level financial development in the eastern region; Energy-saving and emission reduction effects are even more obvious, which is related to the overall strategy of regional regional strategies in China since the 21st century (the western development, the revitalization of the Northeast, the rise of the central region, and the first in the east). (Such as setting up a nature reserve, etc.), in the construction of the east, pay more attention to economic benefits, excessive investment phenomena, and ignore the protection of the environment. In terms of local regional research, there is empirical research on data from Gansu, Northwest China and Shandong Province. It mainly focuses on the coordinated development of green finance and low-carbon economy in the administrative districts in the province and regions and analyzes regional differences in the coordinated development of the low-carbon economy. This investigates the imbalance between the development of green finance and low-carbon economy in the area in order to provide instructions for the efficiency of local green policies.

At present, the research on the promotion of green finance, the affecting path, and the intermediary effect mostly uses a single indicator evaluation method for the quantification of green finance and low-carbon economy. The dimension of the evaluation system has been considered comprehensively, but the green funds are not included in the green finance index and carbon traffic data is not included in the low carbon economy index. By adding green funds and carbon traffic data, this article will be more comprehensive in inspecting the development relationship between green finance and low-carbon economy and understanding the efficiency of green finance and the evolution of the development relationship between the two systems in these 20 years.

The remaining studies in this article are divided into the following parts: the third part is the theoretical analysis, stating the possible affecting path of green finance on the low-carbon economy; the fourth part will focus on empirical data, experimental design, and analysis of empirical results; Part five summarize the research conclusions and put forward relevant policy suggestions.

3. Theoretical Analysis

1) The impact of green finance on the low-carbon economy

At the current stage, many resource-intensive and technical dense enterprises in China have great pollution emissions problems, which are mainly caused by

insufficient low-carbon consciousness and restrictions on technology and production factors. Through the summary of relevant literature and the current status of Chinese development, the impact of green finance on the low-carbon economy can be summarized into three paths.

a) Financing path: Green Finance has broadened financing channels and attracted more funds to the low-carbon industry by using its resource allocation functions. The birth of green financial products meets the diverse financing needs of the low-carbon industry, thereby promoting their development in the direction of low-carbon. Different green financial instruments have different ways of impact on the low-carbon economy. For example, Green Credit can provide different credit lines for environmental protection enterprises and environmental pollution companies, and give corresponding policy support to invest funds into the low-carbon industry. Green bonds have provided strong support for low-carbon enterprises through their financing advantages in the capital market, strictly controlling pollution companies, and reducing problems caused by asymmetric information. Green insurance can invest in equity investment and debt investment, and set up industrial funds to invest and support the green industry. In addition, you can guide green consumption and develop low-carbon life through differentiated insurance amounts.

b) Technical path: Green Finance has driven the development of low-carbon economy by increasing low-carbon technology. The development of the low-carbon economy is based on innovation breakthroughs in low-carbon technology. However, the uncertainty of technology research and development brings great risks to it. Financial institutions combine the raised funds through risk and return analysis to invest in different low-carbon technology research and development projects. This not only reduces the risk of green investment, but also invests funds in multiple different projects, greatly dispersing the risk of technological innovation. The efficient allocation of resources and risk diversification ability of green finance are conducive to the development of low-carbon technology.

c) Policy path: Policy paths promote the development of low-carbon economy through hard indicators and soft means. The hard means is that the green financial policy can restrict companies that can restrict “high investment, high energy consumption, high pollution, low-efficiency” measures to restrict emissions through pollution fines and low-carbon transformation rewards. Essence Soft means are through policy guidance to improve the effect of green finance on the development of low-carbon economy, and strengthen the coordinated development of green finance and low-carbon economy. The main measures are the national carbon market, renewable energy targets, energy efficiency standards, carbon peak carbon neutralization targets, and a green financial system covering financial products such as green bonds, green loans, green insurance, and green funds. Through the issuance policy to support the development of the low-carbon economy, it advocates that enterprises focus on the efficiency of resources and carbon emissions, and advocate the development of various industries in the direction of the green industry.

2) The impact of low-carbon economy on green finance

Low-carbon economy is an economic model based on low energy consumption, low pollution, and low emissions. The effective utilization characteristics of the low-carbon economy and the guidance of ecological and sustainable development concepts have spawned the emergence of a large number of green manufacturers. The growth of the green industry has brought a series of financial demands and promoted the development of green finance.

There are three main aspects of the influence of low-carbon economy on green finance: First, the low-carbon economy requires the development of green finance. The top-level design of the Chinese government has guiding significance for the development content and direction of green finance. Under the “double carbon” plan, China has extended the “three major functions and five pillars” green financial development ideas. It clarifies the focus of the development of green finance and provides instructions for specific measures to develop green finance. Leveraging the three key functions of financial resource allocation, risk management, and market pricing, enhancing the green financial standard system, supervision, and information disclosure requirements, reinforcing green performance incentive constraints, developing financial products and market systems, and establishing a foundation for international cooperation are essential elements to unleash the full potential of green finance. The second is to put forward requirements for green financial instruments to enrich green financial products. For regional characteristics and industrial structure development, it is more suitable for differentiated, specialized, and complementary financial tools, and green financial instruments are used to help environmental governance. The third is to provide demand for green finance. The development of the economy is inseparable from the investment of funds and the tilt of resources. The low-carbon economic development policy encourages enterprises to green technology and develop green technology. A series of green financial needs and the development of green finance.

4. Empirical Analysis

1) Selection of data sources and variables

a) Data source

This article takes 2000-2022 as the sample interval, and the national data is selected as the research object. The data comes from authoritative databases including the National Bureau of Statistics, Wind Database, Financial Industry Association, and Automobile Industry Association, including “China Statistics Yearbook”, “China Industrial Statistics Yearbook”, “China Energy Statistics Yearbook”, “Annual Report of the China Automobile Industry Association”, “China Financial Statistics Yearbook” and other statistical yearbooks.

Among the low-carbon economic indicators system, sulfur dioxide emissions in the low-carbon economic indicators lacking data from 2000-2003 which are calculated based on the total control target of 10% reduction (2% per year) of

major pollutants such as sulfur dioxide emissions from 2000 and 2005. The data discharge of nitrogen oxides is missing from 2000-2005, which is estimated according to the average growth rate from 2006-2010. The annual sales of new energy vehicles in the carbon transportation indicators are missing for 2000-2009 using 0.01 million vehicles as the estimation. There are no authoritative statistics for carbon emissions while the IPCC emissions factor method is calculated. The specific calculation method is introduced below.

b) Comprehensive evaluation model construction

In order to quantify the level of green financial development (GF) and the low-carbon economy level (LCE), this study adopts a comprehensive evaluation model of Zhang Yuze and others [5]. After the min-max standardization, the indicator data(Operating layer) is used to calculate the indicator data weight of the influence on the development of green finance and the development (target layer) of low-carbon economy (target layer), these weights are used to calculate the weighted standardized index data to obtain a comprehensive score of green finance. The specific implementation method is as follows:

i) Use pole difference standardization to standardize the original indicators

For positive indicators:

$$X'_{ij} = (X_{ij} - X_{j\min}) / (X_{j\max} - X_{j\min}) \quad (1)$$

For reverse indicators:

$$X'_{ij} = (X_{j\max} - X_{ij}) / (X_{j\max} - X_{j\min}) \quad (2)$$

Among them, X_{ij} represents the value of the j indication in the year of i , and the $X_{j\max}$ and $X_{j\min}$ respectively represent the minimum and maximum values of the j indications in each sample, and X'_{ij} is the standardized index value.

ii) The impact weight of various indicators is obtained by using the entropy value method

Calculate the weight of the j in the i year R_{ij} :

$$R_{ij} = X'_{ij} / \sum_{i=1}^m X'_{ij}$$

Calculate index entropy value e_j :

$$e_j = \frac{-1}{\ln m} \sum_{i=1}^m R_{ij} \ln R_{ij}$$

Calculate index weight w_j :

$$w_j = \frac{g_j}{\sum_{j=1}^n g_j}$$

$$g_j = 1 - e_j$$

iii) Weighted the standardized indicator data after standardization, and obtained a comprehensive green financial score GF and low-carbon economic score LCE

$$GF_i = \sum_{j=1}^n w_j \times X'_{ij}, \quad LCE_i = \sum_{j=1}^n w_j \times X'_{ij} \quad (3)$$

$$(i = 1, 2, 3, \dots, m; \quad j = 1, 2, 3, \dots, n)$$

c) Selection of green financial variables (defined as GF)

In order to comprehensively evaluate the green financial system, this article has established 6 dimensional index systems including green credit, green investment, green insurance, green bonds, green funds and green equity which include almost all available financial products in the world. All are positive indicators. The selection of indicators mainly refers to the green financial index system of the papers [24] [25], with the new inclusion of green funds which are quite a large resource of the green finance, and the main content of green finance is shown in **Table 1**.

Table 1. Green financial index system.

Target	system layer	indicator content	index layer and unit	weight	nature
Green Financial	Green Credit	Environmental Protection Project Credit Proportion	Environmental Protection Project Credit/Total Credit	0.167	+
	Green Investment	Environmental Pollution Governance Investment proportion of GDP	Pollution Control Governance Investment/GDP	0.167	+
	Green Insurance	Environmental Pollution Responsibility Insurance	Environmental Pollution Insurance/total premium income	0.167	+
	Green bonds	Green bond issuance	total green bond issuance/total issuance of all bond issuance	0.168	+
	Green Fund	Green Fund Market value	Green Fund Total Market value/total market value of all funds	0.165	+
	Green equity,	green equity transactions	the total amount of carbon transactions, energy use rights, pollution-discharge rights/equity market transactions	0.165	+

Among them, environmental pollution control in green investment consists of environmental pollution control and industrial pollution control.

The entropy value method is used to calculate the weight of each system layer, and the results show that the six dimensions in this indicator system have a balanced impact on green finance, and the influence weight of green bonds is the greatest.

d) Selection of low-carbon economy variables (defined as LCE)

This study refers to the low-carbon economic development indicators containing carbon consumption, carbon emissions and carbon pollution in the reference [26]. By adding carbon transportation, the new four dimension evaluation system for low carbon economy is established. Carbon consumption is expressed through per capita energy consumption output ratio, which reflects

people's consumption and contribution ratio of energy, and is a reverse indicator. Carbon emissions are represented by carbon emissions (carbon emissions of unit GDP), and are reverse indicators. Carbon pollution is represented by the main product of carbon pollution-sulfur dioxide and nitrogen oxides and emissions. Carbon transportation is expressed in the proportion of railway transportation and the annual sales of new energy vehicles, and it is a positive indicator.

The consideration of increasing carbon transportation dimension is mainly because transportation is one of the largest sources of air pollution in the world. The energy consumption of the transportation industry accounts for 64% of the total oil consumption. Carbon transportation is an important part of the low-carbon economy and is currently low-carbon. Carbon transportation is currently the main driver of low-carbon economic development. The research on the influencing factors of Wang Jingtian and Ma Xiaoming [12] on the transportation industry's carbon emissions pointed out that the difference in the difference in transportation structure has a greater impact on carbon transportation. Due to railway transportation, the energy consumption strength and carbon emission efficiency in all traditional transportation methods are at the lowest, the increase in the proportion of railway transportation will reduce the carbon emissions of the overall transportation. Therefore, the proportion of railway transportation will be selected as one of the carbon transportation indicators. The study by Huang Zhihui and others [14] shows that the level of energy-saving technology in the transportation industry is significantly positive as the efficiency of carbon emissions. The application of new energy vehicles provides the most potential to transport carbon emission reduction measures. Another indicator of carbon transportation is shown in **Table 2**.

Table 2. Low-carbon economic index system and calculation formula.

Target	system layer	indicator content	index layer and unit	weight	nature
Low-carbon economy	Carbon consumption	per capita energy consumption (standard coal)	per capita energy consumption (kg standard coal)/per capita energy output (kg standard coal)	0.205	-
	Carbon emissions	carbon emissions (ton)	carbon emissions (ton)/GDP (10,000 yuan)	0.188	-
	Carbon pollution	sulfur dioxide emissions strength	sulfur dioxide emissions (10,000 tons)/total energy consumption (10,000 tons standard coal)	0.212	-
		Nitrogen oxide emissions strength	nitrogen oxide emissions (10,000 tons)/total energy consumption (10,000 tons standard coal)	0.211	-
	Carbon transportation	transportation structure	Railway transport turnover (100 million tons)/total transport turnover (100 million tons)	0.168	+
		New Energy Application	New Energy Vehicle annual sales (10,000 vehicles)	0.016	+

Among them, the rotation of railway transportation in carbon transportation consists of passenger railway transportation and cargo railway transportation weekly volume.

The use of entropy values to calculate the weight of each system layer, and it is obtained that carbon pollution is still the biggest factor in the low-carbon economy, with a total weight of more than 40%. The annual sales index of new energy vehicles in carbon transportation affects the minimum weight, only 1.6%, indicating that the carbon reduction potential of new energy vehicles is still yet to be developed.

Statistics of carbon emissions intensity refer to the research of references [3] [27] [28] to treat carbon emissions and carbon emissions strength, and use the IPCC emissions factor method to calculate the carbon emissions. According to the 2006 IPCC National Greenhouse Gas List Guidelines and its 2019 update and revised version, the Intergovernmental Climate Change Special Committee (IPCC) formulated the National Greenhouse Gas (GHG) list guide [28]. The guide provides a number of ways to discharge and remove a country's greenhouse gas emissions and removal (sources may include but are not limited to energy, agriculture, forestry, and waste departments). Through comparison, the content of the carbon emission sources and exchange projects covered in the IPCC greenhouse gas list is basically the same as the content of the project statistics in the "National Energy Balance Table" in the Chinese Energy Statistics Yearbook. The total consumption (10,000-ton standard coal) calculates the carbon emissions of each year, the specific formula is as follows:

$$QCO_2 = StC \times EF \times GWP^1 \quad (4)$$

The "carbon (C)" emissions coefficient (unit: ton of carbon/ton bidding coal (TC/TCE)) of the "carbon dioxide (C)" of the 1-ton standard coal of the Energy Research Institute of China Development and Reform Commission is 0.67 for quality calculations, the quality of carbon dioxide generated per ton of standard coal is 2.68 tons ($=0.67 \times 48/12$, $mc = 12$, $MCO_2 = 48$), and the CO_2 emissions coefficient (ωCO_2) is 2.68. Data are closer to the actual value. The calculation formula can be deformed to:

$$QCO_{2,i} = StC_i \times \omega CO_2 \times GWP \quad (5)$$

2) Couple-coordination model

Coupling and scheduling models are commonly used and analyzed the coordinated development level. The higher the degree of coupling, the stronger the degree of interaction between the two systems. The coupling model of green finance and low-carbon economy in this study is:

$$C = \frac{2\sqrt{GF_i * LC_i}}{GF_i + LC_i}$$

¹ QCO_2 represents the amount of carbon dioxide, StC is standard coal consumption throughout the year; EF is an emission factor, indicating that the carbon dioxide emissions coefficient of standard coal consumers is consumed; GWP is the greenhouse benefit index of gas, and the greenhouse benefit index of carbon dioxide is 1.

At the same time, the coordination model is introduced to observe the degree of coordinated development between the two systems. The model is as follows:

$$D = \sqrt{T * C}, \quad T = \alpha GF_i + \beta LCE_i$$

Among them, C is the degree of coupling, D is the degree of coupling coordination, T is comprehensive development, GF_i is a comprehensive score of green finance, and LCE_i is a comprehensive score of low-carbon economy, respectively. α , β represents the degree of contribution of green finance and low-carbon economy to comprehensive development, which is set to 0.5 here.

With reference to the registration of the coupling degree and coordination of references [15] [16] the coupling degree is divided into four horizontal intervals, and the coordination is divided into five horizontal intervals. The specific division is shown below in **Table 3** and **Table 4**.

Table 3. Coupling level range C .

Low-level coupling	Antagonist coupling	Grinding coupling	high-level coupling
[0, 0.3]	(0.3, 0.5]	(0.5, 0.8]	(0.8, 1.0]

Table 4. Coordination level Horizontal interval D .

Out of coordination	Low-degree coordination	Moderate coordination	High coordination	Extreme coordination
[0, 0.3]	(0.3, 0.5]	(0.5, 0.6]	(0.6, 0.8]	(0.8, 1.0]

3) Analysis of empirical results

The calculation results of the standardization value of low-carbon economic indicators are shown in **Table 5**, and the six dimensions of the low-carbon economy and the development and evolution of the low-carbon economy and the low-carbon economy from 2000 to 2022 can be observed. Among them, carbon consumption, carbon emissions, carbon pollution 1 and carbon pollution 2 are all reverse indicators. The larger the original data indicates that the carbon consumption/emissions/pollution, the more serious. The carbon consumption from 2000-2016 shows a downward trend, indicating that the per capita carbon consumption during this period is large, and the growth rate of carbon resources is greater than the growth rate of carbon output. It has a serious consumption of carbon and has a negative impact on the low-carbon economy. From 2017-2022, the rise in carbon consumption is obvious, indicating that the balance of carbon production-consumption is gradually optimized, and a positive impact on the low-carbon economy has a positive impact. The carbon emissions and carbon pollution conditions performed well during the research period of 2000-2022, which had a positive impact on the low-carbon economy, decreased carbon emissions intensity, decreased carbon pollution intensity, and optimistic about development trends. In terms of carbon transportation, Wang Jingtian and Ma Xiao have shown that the proportion of railway transportation has declined year by year [12]. The increase in railway transportation proportion can effectively

reduce the intensity of carbon emissions. Promoting the development of the low-carbon economy shows that it can also be optimized in terms of transportation structure to accelerate the development of the low-carbon economy.

Table 5. Comprehensive scoring results of Green Finance (GF) and Low-Carbon Economy (LCE).

	2000	2001	2002	2003	2004	2005
GF_i	0.001	0.041	0.076	0.129	0.169	0.193
LCE_i	0.371	0.407	0.420	0.459	0.483	0.467
	2006	2007	2008	2009	2010	2011
GF_i	0.217	0.267	0.307	0.362	0.373	0.422
LCE_i	0.477	0.498	0.553	0.528	0.584	0.557
	2012	2013	2014	2015	2016	2017
GF_i	0.448	0.485	0.529	0.543	0.577	0.623
LCE_i	0.554	0.578	0.560	0.555	0.532	0.571
	2018	2019	2020	2021	2022	-
GF_i	0.658	0.693	0.754	0.772	0.835	-
LCE_i	0.614	0.652	0.653	0.683	0.744	-

Carbon Transportation 2 (sales of new energy vehicles) only started effective sales data after 2009, growing rapidly in 2013-2022. This is because China began to produce large-scale production after 2009 and entered the public view. Before 2008, Chinese new energy settings are still in the stage of research and development and small-scale trial trials. The application of new energy vehicles can reduce carbon emissions in transportation. However, the impact of new energy vehicle sales on the low-carbon economy at present is only 0.016. The weight in all indicators is the lightest, and the degree of influence in the low-carbon economy system is limited. Return to find that the sales of new energy vehicles are positively correlated with carbon emissions (the correlation coefficient is as high as 0.209, which is significant at 99.99%), and new energy vehicle sales are negatively related to the intensity of carbon emissions (related coefficient -0.003 , which is significantly at 95% level). Explain that the increase in sales of new energy vehicles can represent the rise in industrial development to a certain extent, and the increase in carbon emissions will increase. At the same time, the increase in sales of new energy vehicles can also reduce the strength of carbon emissions. The inhibitory effect of emissions intensity is very meager. Although the application of new energy does not produce carbon emissions during use, it still involves a large amount of carbon consumption and carbon emissions during the manufacturing process. In order to achieve the purpose and role of new energy vehicles to effectively reduce carbon reduction and emission reduction Innovation and technology optimization reduce carbon emissions in the production process, and reduce the carbon emissions of the manufacturing process

to further play the role of new energy vehicles to promote the low-carbon economy.

By observing the data and comprehensive scores of green financial indicators, you can clearly observe the steady development of green finance towards the unified development trend between 2000 and 2022. See **Table 5** for specific data

From 2000 to 2003, the coupling of the national green finance and low-carbon economy rose rapidly (see **Table 6**), rising rapidly from low-level coupling in 2000 to high-level coupling, and maintained a high level of coupling (see **Table 6**). To a certain extent, the validity of the green financial and low-carbon economic systems constructed in this article is verified. From 2003 to 2022, the overall high-level coupling state and stable performance show the strong interaction development of green finance and low-carbon economy across the country. The comprehensive development of green finance and low-carbon economy has gradually increased in China over the past 20 years.

Table 6. Coupling degree coordination results.

year	Coupling C	level	Comprehensibility	Coordination D	level
2000	0.104	low	0.186	0.139	Out
2001	0.577	grind	0.224	0.359	low
2002	0.720	grind	0.248	0.423	low
2003	0.828	high	0.294	0.493	low
2004	0.877	high	0.326	0.535	moderate
2005	0.910	high	0.330	0.548	moderate
2006	0.927	high	0.347	0.567	moderate
2007	0.953	high	0.383	0.604	high
2008	0.958	high	0.430	0.642	high
2009	0.982	high	0.445	0.661	high
2010	0.975	high	0.479	0.683	high
2011	0.990	high	0.490	0.696	high
2012	0.994	high	0.501	0.706	high
2013	0.996	high	0.531	0.727	high
2014	1.000	high	0.544	0.738	high
2015	1.000	high	0.549	0.741	high
2016	0.999	high	0.554	0.744	high
2017	0.999	high	0.597	0.772	high
2018	0.999	high	0.636	0.797	high
2019	1.000	high	0.673	0.820	Extreme
2020	0.997	high	0.704	0.838	Extreme
2021	0.998	high	0.728	0.852	Extreme
2022	0.998	high	0.790	0.888	Extreme

The coordinated development level of green finance and low-carbon economy between 2000 and 2007 is from low coordination development to a high level of coordination, indicating that the positive effect of green finance on the development of the low-carbon economy is increasingly obvious, and the efficiency of green finance has increased. It demonstrates that green finance targetedness gradually improves. After 2007, the two systems maintained a high level of development, and jumped to the level of extreme coordinated development in 2019 which verified the effectiveness of green financial policies. Green finance to encourage new energy vehicle production and consumption may contribute a significant portion of the coordination between green finance and low carbon economy. The key implication of the coordination effect study of green finance and low carbon economy is lying on the importance of the government policy: in order to develop low carbon economy which is vitally important for the world climate, it is highly effective by encouraging the development of green financial products and add more strict regulation for the financial resources to be used for green purpose.

Analysis of the return of green finance and the comprehensive score of low-carbon economy found that it has a positive correlation between the two at 99.99%, which confirms the mutual promotion of green finance and low-carbon economy. The regression coefficient of green finance for the low-carbon economy is 0.344 and the regression coefficient of low-carbon economy to green finance is 2.59, indicating that the improvement of the comprehensive score of green finance has a lower efficiency of the improvement of the comprehensive score of the low-carbon economy. As shown in **Table 6**, the rise of the low-carbon economy is relatively gentle, and the current comprehensive score of green finance is ahead of the low-carbon economy.

5. Conclusion and Suggestions

This article conducts an empirical analysis based on the Chinese national data of 2000-2022. It is found that the high-coupled and extremely coordinated development between Chinese green finance and the low-carbon economy in China. The addition of the two index variables of carbon transportation reveals that China can also reduce carbon emissions and promote the development of the low-carbon economy through the optimization of the structure of the transportation and increase the proportion of railway transportation, especially the high speed railway which is applying a lot of low carbon technology; Technology innovation and optimization reduces energy consumption and carbon emissions in the process of manufacturing new energy vehicles to further give play to the potential of new energy vehicles in promoting the development of low-carbon economy and carbon reduction.

In the process of further developing the low-carbon economy, the establishment of the carbon market, the improvement of green financial laws and regulations, and innovation in green financial products are very important for further

optimizing the coordinated development of green finance and low-carbon economy. At present, the dominance of international carbon emission reduction strategy is still in the hands of Western countries. The Economic Cooperation and Development Organization (OECD) proposed an advocacy plan for carbon pricing, which over-emphasizes the role of carbon pricing in carbon emission reduction, but this kind of carbon pricing is designed according to carbon emissions, and is uniformly applied to economies at different stages of development. The practice lacks fairness. The dominant issue is the unevenness of the development level of the carbon market. The EU's carbon market has been operating since 2005, and Chinese carbon market has not started until 2021. Chinese carbon market system and the establishment of a carbon pricing system are far from complete, and their experience lags behind Western countries, so it lacks international discourse rights. Therefore, improving the carbon market system is currently the top priority of Chinese low-carbon economy.

In terms of the improvement of green financial laws and regulations, it is for Chinese government to release the guidelines for green financial activities and strict supervision requirements to control the risks of the initial stage of financial development, and resist the "fake green" cheating financial behavior. Improving the establishment of a green financial market system, formulating green financial standards and low-carbon economic indicators, and promoting financial institutions to carry out green financial business, etc., could further improve the coordinated development efficiency of green finance and low-carbon economy.

In terms of innovation of green financial products, we can learn from foreign experience. For example, a community-based fund-the Home Investment Trust Fund (HIT). With HIT, the promotion of these energy projects is undertaken, and at the same time, HIT provides a platform for investment in these projects. HIT is widely used in Japan, allowing people to invest a small amount of funds into wind power and solar power projects. At the same time, local banks can use the information provided by HIT to evaluate these projects. If the project performs well and is welcomed by individual investors, these energy projects will have the opportunity to get loans from the bank.

Finally, the conclusions and development and evolution characteristics of this study only explain the coordinated relationship between China's national-level green finance and low-carbon economic development. As for the different countries and area's applications, it may need modification of the indices system.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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