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How Does Green Finance Affect the Sustainable Development of the Regional Economy? Evidence from China

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Abstract: The continuous expansion of green finance makes it a new scheme to stimulate economic vitality, but its stimulation path remains to be explored. Using the panel data of 30 regions in China from 2016 to 2020, this research utilized an entropy method to evaluate green finance and the sustainable development of the regional economy (SDRE), and then discussed their coupling coordination relationship and regional heterogeneity. The results show that: (1) The developments of green finance and SDRE in the eastern coastal regions are generally better than that of China's inland regions. (2) If green finance and SDRE are at a high level, their coupling coordination will be enhanced. Otherwise, the coordination effect will be weakened. (3) The influence of green finance on SDRE has evident regional heterogeneity, and the influence is positive in the echelon with a high degree of green finance.

Keywords: green finance; sustainable development of the regional economy; entropy method; coupling coordination model; fixed-effect regression

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1. Introduction

In recent years, the rapid development of extensive production has not only established the bridge for economic take-off but also exposed the severe problems of resource waste and environmental pollution. While looking for solutions to the issues of high energy consumption and high pollution, countries worldwide are actively exploring solutions [1,2]. In September 2015, the United Nations Sustainable Development Summit put forward 17 goals to achieve sustainable development in fifteen years, encouraging sustainable development through innovative and high-quality investment. Therefore, in pursuing the coordinated development of economy and ecology, how to effectively guide the economy from high-speed growth to sustainable development has become a frequently discussed topic.

As a positive measure of ecological development, green finance incorporates environmental impact into investment risk assessment and uses environmental incentives to drive economic decision making [3]. Establishing the green financial system has initiated new economic growth points and enhanced environmental protection to the economy [4]. It is also an inevitable choice to promote the sustainable development of the regional economy (SDRE). In China, the development of the policy system of green finance has broad prospects. The report of the 20th National Congress of the Communist Party of China pointed out that China would improve the incentive and restraint mechanism of green finance and lay a solid foundation for sustainable economic development. Therefore, analyzing the relationship between green finance and the SDRE can determine the characteristics of regional development and promote the balanced development of various regions in order to drive overall economic health.

As regards choosing the method to measure green finance and SDRE, some research adopted an innovative green finance development index system and found that green finance activities could effectively deal with environmental damage by optimizing resource allocation [5–10]. Mohsin et al. (2020) [7] comprehensively assessed the development level of the green economy in developed and developing countries by building a low-carbon financial index system. Ren and Wu (2022) [8] used the global Malmquist–Luenberger productivity index to measure China's green total factor energy efficiency and recommended promoting carbon neutrality. Wan et al. (2022) [9] used the national spatial model and neural network algorithm to analyze the incentive mechanism of green finance policies. Bai et al. (2022) [10] took economic growth and industrial structure as threshold variables to test the inhibition effect of green finance on carbon emissions.

Some studies proved that green finance played an accelerating role in carbon loss, and they confirmed that the long-term development of green finance would achieve economic decarbonization [11–15]. Flammer (2021) [12] believed in corporate green bonds' own significance in improving environmental conditions and promoting healthy economic development. Ye et al. (2022) [13] used green technology innovation as an intermediary factor to explore the mutual promotion between green finance and green development, and analyzed its spatial spillover mechanism and heterogeneity. Lin et al. (2022) [14] believed that green bonds as an emerging financial tool could broaden the financing channels and stimulate green innovation. Wang et al. (2022) [15] assessed the causal relationship between green finance and sustainable development on a global scale, which supported the interaction theory between these.

In terms of the relationship between green finance and SDRE, some scholars believe that the threshold mechanism of green finance is conducive to narrowing the regional gap of sustainable development. Nevertheless, the inhibition effect of green finance on carbon intensity is affected by the structure of factors in different regions [16,17]. Zhou et al. (2022) [18] studied the impact of green finance on regional ecological development in China, and they found boundary differences among the eastern, central, and western regions. Yin and Xu (2022) [19] found that if green finance lagged behind economic growth, it would have an insignificant support on economic growth.

To sum up, most studies support the role of green finance in promoting SDRE. However, a multi-dimensional measurement still needs to reflect the development of green finance and SDRE in different regions in China. How can we systematically measure the level of green finance and SDRE multi-dimensionally? How do we accurately classify the echelons of coupling coordination between green finance and SDRE? How can we interpret regional heterogeneity from the relationship between green finance and SDRE? The above problems still need to be explored. This study used an entropy method to process panel data of 30 regions in China from 2016 to 2020, divided the regional echelons to deeply excavate the coupling coordination between green finance and SDRE, and further confirmed the influence mechanism of green finance on the SDRE.

The remainder of this study is organized as follows. Section 2 describes the data source and index construction, followed by Section 3, which discusses the comprehensive development level measurement and coupling coordination analysis of green finance and SDRE. Section 4 explores the influence mechanism and regional heterogeneity between green finance and SDRE through fixed-effect regression analysis. Section 5 is the robustness test, and Section 6 presents the conclusions and expectations.

2. Data Source and Index Construction

2.1. Data Source

We selected the panel data of 30 regions in China from 2016 to 2020 (excluding Tibet, Hong Kong, Macao, and Taiwan, since data in these areas of China are incomplete) as the research sample of the relationship between green finance and SDRE. The relevant data sources in our research are as follows:

- Green credit data come from the China Stock Market and Accounting Research (CSMAR) database and China Financial Statistics Yearbook.
- Green stock data come from the Wind database.

- Green insurance data come from China Insurance Yearbook.
- Other green finance indices data come from China Statistical Yearbook.
- The data on the SDRE are all from the China Statistical Yearbook.

2.2. Construction of Green Finance Indices

Zeng et al. (2022) [20] chose the issuance of urban green bonds as green financial proxy indices. Lee and Lee (2022) [21] selected the main products of green finance, such as green-oriented credit, securities, insurance, and investment, to construct green finance indices. Ge et al. (2022) [22] mentioned that it is a bit far-fetched to use the number of clean projects as a proxy variable in the measurement of carbon finance.

Based on the research above, we built an index system from two aspects, including environmental protection fund support and government support, to measure the comprehensive development level of green finance (see Table 1).

Table 1. Measurement index system of green finance.

Primary Indices	Secondary Indices	Tertiary Indices	Computing Method	Attribute
Environmental protection fund support	Green credit	Interest scale of energy-intensive consuming credit	Interest expense of energy-intensive industries/Total industrial interest expense	−
		Regional green credit scale	Regional green credit balance/Loan balance of financial institutions	+
	Green stock	The market value of energy-intensive industries	The market value of six energy-intensive industries/Total A-share market value of China	−
	Green insurance	Agricultural insurance proportion	Agricultural insurance premium income/Total agricultural output value	+
		The proportion of environmental pollution investment	Investment in pollution control/Regional GDP	+
	Green investment	The proportion of investment in environmental infrastructure construction	Investment in environmental infrastructure construction/Regional GDP	+
	Carbon finance	Carbon emission intensity	Total carbon dioxide emissions/GDP	−
Government support	Emphasis on green finance	The proportion of the added value of the tertiary industry	The added value of the tertiary industry/GDP	+
		The proportion of turnover in the technology market	Technical market turnover/Regional GDP	+
	Support for green finance	The proportion of energy conservation and environmental protection expenditure	Financial expenditure on energy conservation and environmental protection/Total financial expenditure	+

Notes: In February 2020, the National Development and Reform Commission of P.R. China further defined the six energy-intensive industries as (a) petroleum, coal and other fuel-processing industry. (b) Chemical raw materials and chemical products manufacturing industry. (c) Non-metallic mineral products industry. (d) Ferrous metal smelting and rolling processing industry. (e) Non-ferrous metal smelting and rolling processing industry. (f) Power and heat production and supply industry. The attribute stands for index direction. "+" and "−" mean the positive and negative indices, respectively.

2.3. Construction of SDRE Indices

The premise of sustainable urban development is to realize the coordinated development of the three subsystems of economy, society and environment; therefore, the construction of a sustainable development index system should include four dimensions of ecology, society, economy and innovation [23]. Huan et al. (2021) [24] selected data from 15 countries committed to the United Nations Sustainable Development Goals (UNSDGS) and established country-level sustainable development quantification programs from four dimensions: social, economic, environmental, means of implementation, and cooperation. Based on the localization of the UNSDGS, Gao et al. (2021) [25] constructed a provincial-level sustainable development measurement system from three aspects: human well-being, resources and environment, and development power.

Based on the research above, this study comprehensively selected innovation ability, coordination and stability, green sustainability, dual openness, and achievement sharing as the secondary indices for measuring SDRE, containing 19 tertiary indices (see Table 2).

Table 2. Measurement index system of SDRE.

Primary Indices	Secondary Indices	Tertiary Indices	Computing Method	Attribute
Innovation ability	Input intensity	The proportion of R&D expenditure	R&D expenditure/GDP	+
	Output efficiency	Number of patent applications	—	+
Coordination and stability	Urban-rural gap	The ratio of disposable income of urban and rural residents	Urban residents' disposable income/Rural residents' disposable income	−
		The ratio of urban and rural consumption levels	Consumption expenditure of urban residents/Consumption expenditure of rural residents	−
	Industrial optimization	Industrial structure rationalization index	Value added of secondary industry/Value added of tertiary industry	−
	Development benefits	The proportion of the manufacturing industry	The added value of secondary industry/GDP	+
Green sustainability	Ecological environment	Solid waste discharge per unit of GDP	Industrial solid waste discharge/GDP	−
	Green health	Greening coverage rate of built-up area	—	+
	Waste treatment	Domestic garbage harmless treatment rate	—	+
Dual opening	International openness	Trade openness	Total volume of import and export trade/GDP	+
		Foreign direct investment	Total foreign direct investment	+
	Interregional openness	Interregional division of labor	Regional GDP/National GDP	+
Achievement sharing	Regional benefits	Number of hospital beds per 1000 people	—	+
		Medical supply	Health technicians per 1000 people	+
		Cultural supply	Financial expenditure on culture, sports and media/Total regional population	+
	Quality of people's livelihood	Per capita income level of residents	Per capita disposable annual income of residents	+
		Consumption welfare level of residents	Per capita consumption expenditure of residents	+
	Employment fluctuation	The registered urban unemployment rate	—	−
	Welfare guarantee	The proportion of social security and employment expenditure	Social security and employment expenditure/Public finance expenditure	+

Note: attribute stands for index direction. "+" and "−" mean the positive and negative indices, respectively.

3. Development and Coupling Coordination Measurement for Green Finance and SDRE

3.1. Development Level of Green Finance and SDRE

3.1.1. Entropy Method

Entropy value is a measure of uncertainty [26]. We used the entropy method to calculate the development of green finance and SDRE of 30 regions in China from 2016 to 2020. The calculation steps are as follows:

Before carrying out the entropy method, null and abnormal values should be eliminated. If the data direction is inconsistent, it is necessary to carry out data standardization based on positive and negative indices.

Positive processing:

$$y_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} \tag{1}$$

Negative processing:

$$y_{ij} = \frac{\max x_{ij} - x_j}{\max x_j - \min x_j} \tag{2}$$

where y_{ij} is the jth index of the ith sample after processing, $i = 1, 2 \ldots, n$, $j = 1, 2 \ldots, m$.

The more information there is, the smaller the uncertainty is, and the information entropy value is smaller. Therefore, calculate the proportion of the ith sample to this index under the jth index (b_{ij}) as follows:

$$b_{ij} = \frac{y_{ij}}{\sum\limits_{i=1}^{n} y_{ij}} \tag{3}$$

Calculate the entropy value e_j of the index b_{ij} as follows:

$$e_j = -k \sum_{i=1}^{\mathrm{n}} b_{ij} \ln(b_{ij}) \tag{4}$$

where k is related to the sample size n, $k = \frac{1}{\ln(n)}$, $0 \leq e_j \leq 1$.

The entropy method needs to combine the information utility value provided by the entropy value to determine the weight. Therefore, calculate the information utility value (d_j) of the jth index as:

$$d_j = 1 - e_j \tag{5}$$

Calculate the weight (ω_j) of each index as follows:

$$\omega_j = \frac{d_j}{\sum\limits_{i=1}^{m} d_j} \tag{6}$$

The sample data was multiplied by the corresponding weight and accumulated, which is the "comprehensive score". Calculate the comprehensive score (S_i) of each sample as follows:

$$S_i = \sum_{j=1}^{m} \omega_j y_{ij} \tag{7}$$

3.1.2. Comprehensive Score of Green Finance

We used the entropy method to calculate 10 tertiary indices of green finance, and the comprehensive scores of green finance development of 30 regions in China are shown in Table 3:

Table 3. The comprehensive scores of green finance.

Regions	2016	2017	2018	2019	2020	Mean	Rank
Beijing	0.572	0.603	0.610	0.625	0.641	0.610	1
Tianjin	0.185	0.205	0.198	0.302	0.275	0.233	9
Hebei	0.203	0.222	0.255	0.248	0.253	0.236	7
Shanxi	0.195	0.216	0.205	0.222	0.206	0.209	14
Nei Monggol	0.219	0.223	0.184	0.172	0.164	0.192	15
Liaoning	0.180	0.180	0.165	0.182	0.191	0.180	18
Jilin	0.152	0.171	0.174	0.226	0.205	0.186	17
Heilongjiang	0.177	0.170	0.157	0.176	0.187	0.173	20
Shanghai	0.294	0.301	0.304	0.334	0.327	0.312	2
Jiangsu	0.286	0.273	0.271	0.290	0.306	0.285	4
Zhejiang	0.241	0.230	0.230	0.243	0.268	0.242	6
Anhui	0.226	0.218	0.206	0.221	0.216	0.217	11
Fujian	0.148	0.144	0.147	0.154	0.160	0.151	25
Jiangxi	0.154	0.161	0.177	0.190	0.186	0.174	19
Shandong	0.284	0.271	0.259	0.274	0.282	0.274	5
Henan	0.156	0.227	0.221	0.231	0.211	0.209	13
Hubei	0.217	0.204	0.204	0.224	0.224	0.215	12
Hunan	0.178	0.186	0.182	0.197	0.209	0.190	16
Guangdong	0.286	0.296	0.298	0.330	0.346	0.311	3
Guangxi	0.137	0.124	0.113	0.120	0.151	0.129	27
Hainan	0.089	0.104	0.104	0.101	0.095	0.099	30
Chongqing	0.136	0.137	0.150	0.137	0.149	0.142	26
Sichuan	0.207	0.208	0.230	0.237	0.247	0.226	10
Guizhou	0.118	0.116	0.124	0.136	0.138	0.126	28
Yunnan	0.123	0.118	0.113	0.122	0.116	0.118	29
Shaanxi	0.221	0.220	0.212	0.253	0.260	0.233	8
Gansu	0.170	0.154	0.156	0.152	0.163	0.159	23
Qinghai	0.203	0.141	0.159	0.171	0.157	0.166	22
Ningxia	0.229	0.164	0.163	0.136	0.141	0.167	21
Xinjiang	0.161	0.172	0.134	0.173	0.147	0.157	24

Results in Table 3 show that green finance in Beijing, Shanghai, Guangdong, Jiangsu, Shandong, and Zhejiang have an excellent ranking from 2016 to 2020. Among the top five regions, it is worth noting that Guangdong's comprehensive score has increased from 0.286 to 0.346, with the fastest growth rate over 20%. This may be because these regions present the long-term stability of economic strength, and their strong economic resilience and rapid upgrading of their industrial structure have attracted a large amount of green capital investment, promoting a virtuous cycle between finance and green development.

The comprehensive scores of Hainan, Yunnan, Guizhou, and other regions ranked at the bottom of the list, with the scores all being lower than 0.15. However, according to the growth rate of the comprehensive scores, Guangxi has reached 10.22%, and Guizhou has reached 16.95%. Through the coordinated development of ecological protection and regional economic quality, the improved ecological efficiency has stimulated the potential of green finance, and the role of infrastructure optimization has gradually become prominent [27].

On the whole, there are prominent regional differences in green finance development. The coastal and developed regions lead the process of green finance, while most central and western regions in China remain lagging.

3.1.3. Comprehensive Score of SDRE

Through the calculation of 19 tertiary indices of SDRE, we obtained the comprehensive score of SDRE of 30 regions in China. The results are illustrated in Table 4.

Table 4. The comprehensive score of SDRE.

Regions	2016	2017	2018	2019	2020	Mean	Rank
Beijing	0.310	0.323	0.343	0.368	0.353	0.339	5
Tianjin	0.206	0.208	0.214	0.213	0.216	0.211	8
Hebei	0.143	0.156	0.168	0.187	0.201	0.171	17
Shanxi	0.113	0.118	0.130	0.138	0.154	0.131	26
Nei Monggol	0.133	0.150	0.154	0.161	0.174	0.154	19
Liaoning	0.183	0.202	0.210	0.215	0.222	0.206	10
Jilin	0.122	0.125	0.139	0.151	0.170	0.141	22
Heilongjiang	0.127	0.137	0.142	0.150	0.174	0.146	21
Shanghai	0.347	0.381	0.387	0.402	0.405	0.384	4
Jiangsu	0.481	0.496	0.528	0.547	0.577	0.526	2
Zhejiang	0.343	0.360	0.383	0.408	0.429	0.385	3
Anhui	0.157	0.170	0.184	0.205	0.239	0.191	14
Fujian	0.192	0.207	0.217	0.235	0.248	0.220	7
Jiangxi	0.124	0.139	0.154	0.169	0.189	0.155	18
Shandong	0.313	0.330	0.326	0.326	0.380	0.335	6
Henan	0.165	0.177	0.189	0.205	0.221	0.191	13
Hubei	0.180	0.190	0.204	0.224	0.235	0.207	9
Hunan	0.170	0.189	0.200	0.218	0.234	0.202	12
Guangdong	0.551	0.635	0.669	0.692	0.726	0.655	1
Guangxi	0.107	0.122	0.131	0.146	0.170	0.135	24
Hainan	0.122	0.128	0.147	0.163	0.306	0.173	16
Chongqing	0.159	0.168	0.181	0.192	0.202	0.180	15
Sichuan	0.167	0.184	0.198	0.225	0.240	0.203	11
Guizhou	0.095	0.106	0.116	0.131	0.139	0.117	29
Yunnan	0.099	0.109	0.119	0.137	0.155	0.124	28
Shaanxi	0.120	0.143	0.145	0.174	0.179	0.152	20
Gansu	0.088	0.100	0.111	0.125	0.132	0.111	30
Qinghai	0.106	0.125	0.130	0.149	0.163	0.135	25
Ningxia	0.112	0.119	0.126	0.135	0.141	0.127	27
Xinjiang	0.123	0.130	0.135	0.151	0.150	0.138	23

Table 4 shows that Guangdong, Jiangsu, Zhejiang, Shanghai, Beijing, and Shandong are far ahead of each other in rankings, which may benefit from the favorable agglomeration function of the Bohai Economic Circle and the Zhuhai Economic Circle. Among them, Guangdong has the highest comprehensive score. Its score exceeded 0.5 every year. The possible causes of this result are as follows: the regional industrial division has provided the main driving force for Guangdong's regional economic collaborative development, and Guangdong's collaborative development level has evolved from the intermediate diffusion stage to the advanced symbiosis stage [28].

Table 4 also shows that the lower-ranked regions are concentrated in Gansu, Guizhou, Yunnan, Ningxia, etc., with average comprehensive scores ranging from 0.1 to 0.15. The causes of these results might be related to the geographical disadvantages since ancient times, the excessive dependence on the primary industry, which makes industrial restructuring a long process, and the gap in the level of sustainable comprehensive development.

Overall, there is a significant increase at the national level. The level of SDRE varies significantly among each region. Regions distributed in the eastern and coastal areas generally have a high ranking. In addition, the western and northeastern regions in China still have a large space for sustainable development.

3.2. Analysis of Coupling Coordination Degree between Green Finance and SDRE

To further identify the coupling coordination degree between green finance and SDRE in different regions, we established the coupling coordination degree model as follows:

$$C = 2 \times \sqrt{\frac{U_1 \cdot U_2}{(U_1 + U_2)^2}} \tag{8}$$

$$T = \beta_1 U_1 + \beta_2 U_2 \tag{9}$$

$$D = \sqrt{C \cdot T} \tag{10}$$

where U_1 and U_2 are the comprehensive scores of green finance and SDRE, β_1 and β_2 are the coefficients, respectively. C represents the coupling degree. T represents the coordination index, and D represents the coupling coordination degree.

We divided the coupling coordination degree D into four levels: low coordination ($0 < D \leq 0.3$, coordination level 1), basic coordination ($0.3 < D \leq 0.4$, coordination level 2), good coordination ($0.4 < D \leq 0.6$, coordination level 3), and excellent coordination ($0.6 < D \leq 1$, coordination level 4). Table 5 provides the coupling coordination degree between green finance and SDRE.

Table 5. Calculation results of coupling coordination.

Year	C-Value	T-Value	D-Value	Coordination Level	Coupling Coordination Degree
2016	0.535	0.064	0.186	1	Low coordination
2017	0.937	0.183	0.414	3	Good coordination
2018	0.296	0.223	0.257	1	Low coordination
2019	0.991	0.777	0.878	4	Excellent coordination
2020	1.000	0.990	0.995	4	Excellent coordination

From a macro perspective, the average level of coupling coordination has risen from 0.186 to 0.995, showing a significant improvement. The national coupling coordination degree has moved from low coordination to excellent coordination, and the sustainable construction of China's regional economy has continued to improve.

It can also be seen from the results that there is time heterogeneity in the coupling coordination degree. From 2016 to 2017, continuous economic growth boosted the development of the green economy, and the national coupling coordination degree rose to good coordination. Then, the coupling coordination decreased in 2018 because the economy was in the initial transition period from high-speed development to high-quality development. In addition, the slowdown of economic growth and the adjustment of industrial transformation has reduced the degree of national coupling coordination in the short term. From 2019 to 2020, the coupling coordination degree of green finance and SDRE rapidly improved and reached excellent coordination with improving the quality of economic development.

To further analyze the regional differences in the coupling development of green finance and SDRE, we continued calculating the D-value of coupling coordination for the 30 regions of China (see Table 6).

To intuitively show the difference in coupling coordination between green finance and SDRE in each region, we created the combination Figure 1:

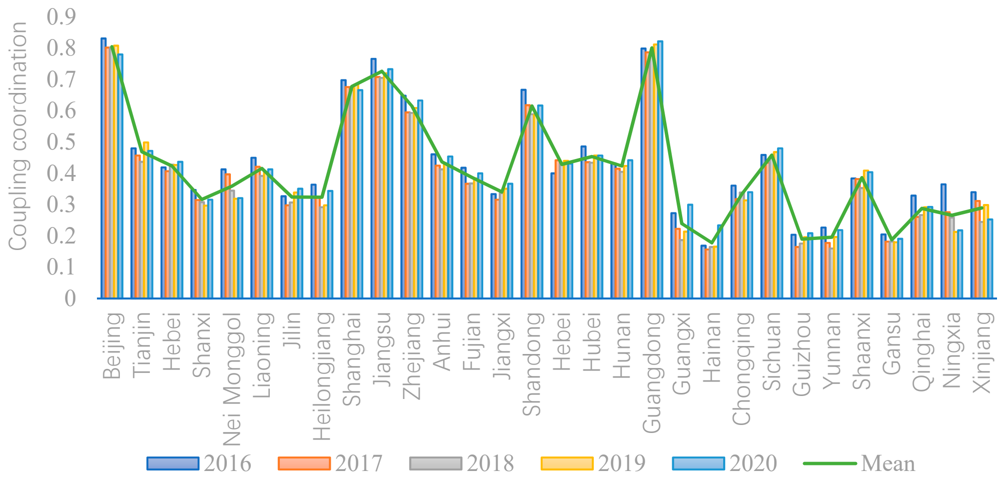

Figure 1. Coupling coordination degree of 30 regions.

According to Figure 1, the regions with rapid economic growth present higher scores of green finance and SDRE and possess better development synchronicity. Regions with a high degree of coupling coordination, such as Beijing, Guangdong, Jiangsu, Shanghai, Zhejiang, and Shandong, also barely show annual fluctuation.

Table 6. D-value of coupling coordination degree of 30 regions.

Regions	2016	2017	2018	2019	2020	Mean	Coordination Level	Coordination Situation
Beijing	0.831	0.802	0.802	0.808	0.780	0.805	4	Excellent coordination
Tianjin	0.480	0.457	0.437	0.499	0.472	0.469	3	Good coordination
Hebei	0.419	0.407	0.428	0.427	0.437	0.424	3	Good coordination
Shanxi	0.347	0.315	0.308	0.298	0.316	0.317	2	Basic coordination
Nei Monggol	0.413	0.398	0.345	0.319	0.321	0.359	2	Basic coordination
Liaoning	0.450	0.421	0.392	0.404	0.414	0.416	3	Good coordination
Jilin	0.327	0.298	0.307	0.339	0.351	0.324	2	Basic coordination
Heilongjiang	0.364	0.323	0.292	0.298	0.345	0.324	2	Basic coordination
Shanghai	0.698	0.676	0.665	0.683	0.666	0.678	4	Excellent coordination
Jiangsu	0.766	0.708	0.705	0.720	0.733	0.726	4	Excellent coordination
Zhejiang	0.648	0.595	0.593	0.609	0.633	0.616	4	Excellent coordination
Anhui	0.461	0.425	0.413	0.432	0.454	0.437	3	Good coordination
Fujian	0.417	0.367	0.368	0.384	0.400	0.387	2	Basic coordination
Jiangxi	0.334	0.316	0.337	0.351	0.367	0.341	2	Basic coordination
Shandong	0.667	0.618	0.589	0.587	0.617	0.616	4	Excellent coordination
Henan	0.400	0.442	0.432	0.440	0.431	0.429	3	Good coordination
Hubei	0.486	0.436	0.434	0.457	0.457	0.454	3	Good coordination
Hunan	0.432	0.415	0.405	0.424	0.442	0.424	3	Good coordination
Guangdong	0.799	0.787	0.786	0.812	0.822	0.801	4	Excellent coordination
Guangxi	0.273	0.223	0.187	0.214	0.299	0.239	1	Low coordination
Hainan	0.169	0.157	0.165	0.166	0.234	0.178	1	Low coordination
Chongqing	0.361	0.318	0.339	0.314	0.340	0.334	2	Basic coordination
Sichuan	0.459	0.434	0.451	0.468	0.480	0.458	3	Good coordination
Guizhou	0.204	0.165	0.176	0.197	0.208	0.190	1	Low coordination
Yunnan	0.227	0.178	0.160	0.198	0.219	0.196	1	Low coordination
Shaanxi	0.384	0.382	0.354	0.409	0.404	0.387	2	Basic coordination
Gansu	0.205	0.182	0.182	0.180	0.191	0.188	1	Low coordination
Qinghai	0.329	0.261	0.267	0.292	0.293	0.288	1	Low coordination
Ningxia	0.365	0.277	0.259	0.213	0.218	0.266	1	Low coordination
Xinjiang	0.340	0.312	0.245	0.299	0.253	0.290	1	Low coordination

However, the coupling coordination results of the northeast, central and western regions are inferior to those of the eastern coastal region, which is consistent with the comprehensive development level of green finance and SDRE calculated above. When the comprehensive level of green finance and SDRE is a "high–high" type, the coupling coordination between them is enhanced. When the comprehensive level of green finance and SDRE is a "low–high" or "low–low" type, the regional coordination effect will be limited. Take Fujian Province as an example. As a coastal area in southeast China, it has made brilliant achievements in economic development. However, the development of green finance in this region is relatively backward compared with other regions, making its coupling coordination relatively low.

According to the above coupling coordination results, we can obtain the average coupling coordination of each region. The 30 regions in the study sample can be divided into four echelons, the echelon of 1st to 4th, containing regions of excellent coordination, good coordination, basic coordination, and low coordination.

Table 7 displays the classification of echelons by the average D-value.

Table 7. Classification of echelon according to coupling coordination.

Echelons	Regions
1st	6 regions (Beijing; Guangdong; Jiangsu; Shanghai; Zhejiang; Shandong)
2nd	8 regions (Tianjin; Sichuan; Hubei; Anhui; Henan; Hebei; Hunan; Liaoning)
3rd	8 regions (Fujian; Shaanxi; Nei Monggol; Jiangxi; Chongqing; Jilin; Heilongjiang; Shanxi)
4th	8 regions (Xinjiang; Qinghai; Ningxia; Guangxi; Yunnan; Guizhou; Gansu; Hainan)

We used Amap (https://lbs.amap.com/, accessed on 1 January 2023) to make the spatial difference distribution map of the coupling coordination for each echelon. The left-side legend shows the range of coupling coordination values (see Figure 2). The D-value between green finance and SDRE in various regions is quite different. The coupling coordination between green finance and SDRE in eastern coastal areas and Beijing is relatively higher than in western inland, northeast, and central regions of China.

Figure 2. Spatial difference of coupling coordination among 30 regions. Notes: The map conforms to the national standards for surveying, mapping and geographic information stipulated by the State Bureau of Surveying and Mapping of China. We did not calculate the D-value of Tibet, Hong Kong, Macao, and Taiwan, as these regions' data were incomplete.

4. Panel Regression Analysis of Green Finance's Impact on SDRE

Referring to the research of Liu et al. and Tang et al. [29,30], we added scientific research input, urbanization rate, and education expenditure level as control variables to construct the model, taking the comprehensive level of SDRE as the explained variable and the development of green finance as the core explanatory variable.

Considering the imbalanced developmental level among 30 regions in China, to make the empirical analysis results more effective, we establish the following regression model as follows:

$$SDRE_{it} = \beta_0 + \beta_1 GFin_{it} + \beta_2 Invest_{it} + \beta_3 Urban_{it} + \beta_4 Education_{it} + \varepsilon_{it} \quad (11)$$

where i and t denote the index of region and year; $SDRE_{it}$ denotes the comprehensive level of regional economy sustainable development; $GFin_{it}$ denotes the comprehensive level of green finance development; $Invest_{it}$ is the control variable that represents the scientific research input; $Urban_{it}$ is the control variable that represents the urbanization rate; $Education_{it}$ is the control variable that represents the education expenditure level; and ε_{it} is the stochastic error term.

4.1. Descriptive Analysis

We utilized stata16 software for statistical characteristics analysis to observe the sequence stability of each statistical index. Table 8 shows the statistical description of the variables:

Table 8. The statistical description of variables.

Variables	Number	Mean	Standard Deviation	Minimum	Maximum
SDRE	150	0.218	0.128	0.088	0.726
GFin	150	0.211	0.093	0.089	0.641
Invest	150	0.023	0.016	0.005	0.068
Urban	150	0.623	0.106	0.446	0.893
Education	150	0.159	0.025	0.103	0.209

Through the analysis in Table 8, we found that the maximum and minimum comprehensive scores of green finance and SDRE differ exponentially, indicating that the degree of green finance and SDRE in each region is significantly unbalanced, and showing spatial differences. The standard deviation of the control variables *Invest* and *Education* is small, indicating that the level of scientific research input and education expenditure in each region has slight volatility. The high standard deviation of the urbanization rate reflects the unevenness of urbanization construction among regions.

4.2. Pearson Correlation Test

We calculated the correlation coefficient between variables to check their linear correlation. Table 9 displays the Pearson coefficient of variables.

Table 9. Pearson coefficient of variables.

Variables	SDRE	GFin	Invest	Urban	Education
SDRE	1	—	—	—	—
GFin	0.574 ***	1	—	—	—
Invest	0.790 ***	0.667 ***	1	—	—
Urban	0.594 ***	0.654 ***	0.650 ***	1	—
Education	0.217 ***	−0.022	0.156 *	−0.357 ***	1

Notes: * $p < 0.1$, *** $p < 0.01$.

The correlation coefficients among the variables were less than 0.8. The VIF test results of *Urban*, *Invest*, *GFin*, and *Education* are 3.180, 2.750, 2.140, and 1.650, respectively. All the variance inflation factors are less than 10, and the mean value is 2.43, indicating no serious multicollinearity.

Then, we conducted the Hausman test to select the random effect model or fixed-effect model. The Hausman test results show that the p-value < 0.01. Therefore, we chose the fixed-effect model.

4.3. Panel Data Regression Analysis

We discussed the influence of green finance on SDRE using the panel data of 30 regions in China from 2016 to 2020. By comparing the three regression models, including the ordinary least squares model (OLS), the random effect model (RE), and the fixed-effect model (FE), FE is finally determined as the model for this study. Table 10 provides the regression results of OLS, RE and FE.

Table 10. Regression results of OLS/RE/FE.

Variables	OLS	RE	FE	Controls
GFin	0.0103	0.1674 **	0.2033 **	N
	(0.0948)	(0.0776)	(0.0797)	
Invest	4.2718 ***	2.1161 ***	1.8032 ***	Y
	(0.6388)	(0.5143)	(0.5283)	
Urban	0.4077 ***	0.8352 ***	0.9580 ***	Y
	(0.1014)	(0.0874)	(0.0905)	
Education	1.2910 ***	0.5136 **	0.3581	Y
	(0.3056)	(0.2359)	(0.2382)	
Constant	−0.3390 ***	−0.4666 ***	−0.5190 ***	—
	(0.0876)	(0.0723)	(0.0737)	
R^2	0.6759	0.6517	0.6581	—
N	150	150	150	—

Notes: ** $p < 0.05$, *** $p < 0.01$.

According to the RE regression results, the core variable *GFin* shows positive feedback on the SDRE. The p-value of *Invest* is less than 0.01, and the coefficient is better than 2, meaning scientific research input plays a significant role in promoting the SDRE. As the Hausman test suggests the FE regression, we mainly discuss the FE results.

According to the FE regression results, the development of green finance ($p < 0.05$) can improve the comprehensive level of SDRE. Nevertheless, the coefficient is 0.2033. The coefficient of scientific research input is 1.8032 at the 1% significance level, indicating that it can vigorously promote SDRE. The level of education expenditure failed to show a significant impact, but the p-value of the urbanization rate was less than 0.01, meaning that it plays an important positive role.

4.4. Regional Heterogeneity Analysis

The geographical location and resource input of regions in China vary significantly, potentially affecting the relationship between variables. Therefore, we further explored the impact caused by regional differences based on the four echelons classification of Table 7. According to the Hausman test result, we selected the fixed-effect model for regression in different regions based on the green finance and SDRE levels. Table 11 provides the regression results of each echelon.

Table 11. Regression results of each echelon.

Variables	1st Echelon	2nd Echelon	3rd Echelon	4th Echelon
GFin	0.6947 **	−0.0894 *	0.0911	0.4125
	(0.3105)	(0.0481)	(0.0571)	(0.2744)
Invest	0.4537	0.1097	0.0325	6.5224 ***
	(0.9656)	(0.3964)	(0.4318)	(1.9537)
Urban	1.7988 ***	1.0807 ***	0.9184 ***	0.9005 ***
	(0.3463)	(0.0795)	(0.0598)	(0.2014)
Education	0.2261	−0.1753	0.1327	0.2038
	(0.6649)	(0.2029)	(0.1555)	(0.7068)
Constant	−1.2084 ***	−0.4193 ***	−0.4510 ***	−0.5183 **
	(0.2383)	(0.0620)	(0.0491)	(0.2183)
R^2	0.8325	0.9467	0.9363	0.5801
N	30	40	40	40

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Through the analysis of regression results, we can see that:

(1) Compared with other regions, green finance in the 1st echelon in which regions have a significant role in promoting the SDRE. The *p*-value is less than 0.05 and the coefficient is 0.6947. Due to the increasingly mature financial industry, sound green finance policies, the green finance market in China is prosperous. The urbanization rate is significant at the 1% level, with a coefficient of 1.7988, while the level of scientific research input *Invest* and education expenditure *Education* has no significant influence. That might be because the development level of scientific innovation and urbanization in the 1st echelon regions have been maintained in a high state. These impacts have not been fully revealed.

(2) Green finance shows a certain inhibition effect on the SDRE in the 2nd echelon regions, with a *p*-value less than 0.1 and a coefficient of −0.0894. The possible reason may be that the development of regional green finance in the 2nd echelon needs to catch up since the sustainable economy is still in the fundamental stage. An unreasonable industrial structure need to continuous restructure, superabundant energy-intensive industries also need more capital support for the transition to environmental friendly industries. In addition, the innovation cycle of scientific technology and education takes a long time to achieve; thus, it might not play an obvious role in the process of SDRE in the short term. Therefore, the coupling coordination between green finance and SDRE in the 2nd echelon needs to be strengthened.

(3) Due to the geographical disadvantages of the 3rd and 4th echelon regions, green finance has problems such as late start and policy lag. It plays a minor role in promoting regional sustainability. However, the control variable *Invest* has significant positive feedback in the 4th echelon, possibly due to new scientific research forces have been introduced in economically backward regions recent years. The influence of education expenditure level is insignificant because the period of education investment return is longer, and it is only a tiny link in the SDRE.

5. Robustness Test

We launched the robustness test from three aspects:

(1) The explained variable lags one phase to prove the original regression model's reliability.

(2) To confirm the rationality of the empirical analysis, the comprehensive level of SDRE was divided into two groups: the high stage and the primary stage.

(3) To further verify the impact of green finance on the SDRE, the explanatory variable green financial development level was divided into two groups: good level and laggard level.

The results are as follows:

(1) Results of the explained variable lag one phase. According to test I in Table 12, the regression results of lagging the explained variable *SDRE* for one phase show that the core explanatory variables *GFin* and the control variables *Invest*, *Urban*, and *Education* are significantly verified, with *p*-values of less than 0.01. It proves that the original regression model is reliable.
(2) Grouping regression results of SDRE. The panel data were divided into two groups according to the median of the SDRE: the high stage and the primary stage for the robustness test. According to test II in Table 12, green finance significantly impacts the SDRE in the two stages, which have passed the robustness verification. The *GFin*'s coefficient in primary stage is 0.0492, while in high stage is 0.6906, meaning that green finance has a more substantial promoting effect on the SDRE at the high stage.
(3) Group regression results of green finance. According to test III in Table 12, green finance is divided into two groups of regression: good level and laggard level. In the group of good level, green finance has a significant positive role in promoting SDRE. The *p*-value of *GFin* is less than 0.05, and the coefficient is 0.2258. Additionally, the control variables *Invest*, *Urban*, and *Education* are significantly verified with *p*-values of less than 0.01, which means our model can be considered stable. However, the green finance of the laggard level group has an insignificant impact on the SDRE, which may be due to the deviation effect caused by their low comprehensive ranking and relative imbalance. This finding corroborates the studies mentioned in the literature review [19]. The results show that the laggard level of green finance cannot be effectively connected with industrial restructuring and SDRE, resulting in the insignificant support of green finance on economic growth.

Table 12. Regression results of the robustness test.

	Test I	Test II		Test III	
	Lagged SDRE	**High Stage**	**Primary Stage**	**Good Level**	**Laggard Level**
GFin	0.2491 ***	0.6906 **	0.0492 *	0.2258 **	−0.1112
	(0.0707)	(0.2886)	(0.0295)	(0.1120)	(0.2261)
Invest	1.2251 ***	0.5705	0.2946	1.6262 ***	4.0222 ***
	(0.4159)	(0.8557)	(0.2671)	(0.5785)	(1.1082)
Urban	0.9618 ***	1.7460 ***	0.7819 ***	1.2809 ***	0.7273 ***
	(0.0824)	(0.3148)	(0.0335)	(0.1418)	(0.1343)
Education	0.6594 ***	0.2380	−0.2652 **	1.0105 ***	−0.5206
	(0.1812)	(0.6092)	(0.1017)	(0.3084)	(0.3904)
Constant	−0.5805 ***	−1.1351 ***	−0.2765 ***	−0.8396 ***	−0.2294 *
	(0.0602)	(0.2130)	(0.0301)	(0.1058)	(0.1149)
R^2	0.7483	0.8296	0.9134	0.7878	0.6069
N	120.0000	41.0000	109.0000	75.0000	75.0000

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6. Conclusions and Expectations

As an emerging economic activity, green finance can effectively control and reduce carbon emissions, promote the upgrading of energy-intensive industries from the capital level, and help the economy achieve sustainable development.

This study carried out an in-depth analysis of green finance's influence mechanism on SDRE, seeking a new scheme to accelerate the process of sustainable development. We used the entropy method to process panel data of 30 regions in China from 2016 to 2020 and tested the coupling coordination and regional heterogeneity between green finance and SDRE. Then, we divided the regional echelons according to coupling coordination and constructed a panel regression to empirically analyze the relationship between green finance and SDRE. The main conclusions are as follows:

1. According to the comprehensive scores of green finance and SDRE calculated using the entropy method, the overall levels of green finance and SDRE have steadily improved

from 2016 to 2020. Generally, most eastern coastal regions have been leading the ranking, while the development score of the central and western regions has increased but still lags significantly behind the former.

2. The coupling coordination analysis shows that the eastern coastal region is mainly in good or excellent coupling coordination, the central regions are mainly at the basic coupling stage, and the western inland regions are mainly at a low level. The difference depends on the development level of green finance and SDRE.
3. According to the analysis of regional heterogeneity, green finance has the most significant positive impact in the 1st echelon, followed by an insignificant role in the 3rd and 4th echelons. Nevertheless, it has a certain inhibition effect in the 2nd echelon, showing vigorous characteristics of regional heterogeneity.

This research measures the level of green finance and SDRE from a multi-dimensional system and accurately divides the echelons according to the coordination effect between green finance and SDRE. It provides theoretical support and effective suggestions for seeking suitable, characteristic, and diversified economic development modes for each region that considers the dual objectives of economic development and environmental protection. However, some aspects still need improvement, such as some regions' green finance data not being fully disclosed and the database for measuring green finance development being limited.

Moreover, future research needs to extend the period of research data and explore the impact mechanism of green finance and sustainable development in different economic cycles. Research on sustainable development can also be refined from the macro to the micro level. The sustainable development of the economy can be explored from the perspective of corporate responsibility, corporate behavior, and corporate innovation. The post-COVID-19 era has shown great potential in enabling green development, and this theme could also be the focus of future sustainable development research.

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