Analysis of the impact of green finance on regional economic development

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Abstract. With the gradual deterioration of global environmental problems, green finance has gradually become an important means to promote sustainable economic development. This paper aims to explore the impact of green finance on regional economic development, and analyze how it promotes the green transformation and upgrading of regional economy through such approaches as optimization of capital allocation, policy guidance and support. Through literature review and comparative study, it is found that green finance can not only guide capital to flow into the environmental protection industry and promote the R&D and application of green technologies, but also optimize the regional industrial structure, improve resource utilization efficiency and reduce environmental pollution. However, the development of green finance still faces many challenges, such as policy matching and information disclosure. To give full play to the role of green finance in regional economic development, it is necessary to strengthen policy guidance, improve the legal system, enhance international cooperation, and raise the awareness and capability of financial institutions in green investment. This paper provides a comprehensive overview of how green finance affects regional economic development, discusses the regional differences in the relationship between green finance and regional economic development through comparative analysis of data from four regions, and offers valuable insights for policymakers and financial institutions through in-depth research on this topic, so as to promote more sustainable economic development.

Keywords: green finance, regional economy, sustainable development, environmental protection

1. Introduction

Since the reform and opening-up, China's economic development has achieved remarkable accomplishments attracting worldwide attention. However, due to the excessive pursuit of economic benefits by various regions, environmental pollution problems such as water, land and air pollution have become increasingly severe under this development model. To effectively address these environmental issues, it is not only necessary to impose stringent end-of-pipe treatment measures, but also to give full play to the role of finance in resource allocation, directing more capital into the environmental protection industry to generate positive impacts. Hence, green finance emerged [1]. Green finance can improve the economic development environment, enhance the efficiency of resource utilization, promote the development of industries related to environmental protection and new energy, and also serve as an important support for achieving high-quality economic development. The

purpose of this paper is to analyze the relationship between green finance and regional economic development based on the current research status of regional economic development under the background of green finance, identify the influencing factors of green finance on regional economic development. Through comparative analysis of different regions, this paper analyzes the impact of green finance on regional economic development, and puts forward relevant conclusions and development suggestions based on such impact.

2. Literature review

2.1. Foreign research status

Some foreign scholars hold that green finance can create more market value and also guide governments to strengthen green investment in various aspects. Di H. conducted an empirical analysis on the relationship among green credit, environmental regulation, total factor productivity and low-carbon technological progress using panel data from 30 regions in China during 2009—2018. The research results show that improving carbon emission efficiency in China should focus on the central and western regions; there is a significant U-shaped curve relationship between green credit level and total factor productivity as well as low-carbon technological progress, while there is a significant inverted U-shaped curve relationship between the intensity of environmental regulation and total factor productivity as well as low-carbon technological progress [2]. Wei N. and Xiaohong D. pointed out that under the framework of sustainable development, green finance can be used as a tool to effectively promote industrial structure upgrading. Based on data from 2010 to 2019, the paper indicates that the development of green finance will exert an impact on industrial structure upgrading, and the overall network has been established and maintained a sound development momentum. The paper suggests that the government must improve the green finance management system as soon as possible, effectively utilize green finance to promote industrial optimization, and introduce policies according to the characteristics of each province to facilitate the coordinated development of green finance in various provinces [3]. Bo W. et al. regarded green finance as a cutting-edge financial strategy to support environmental improvement and green development, emphasizing its importance for low-carbon energy transition and high-quality development [4].

2.2. Domestic research status

Fu Siqi argued that economic development needs the support of green finance, advocating the establishment of a comprehensive and standardized green financial system, strengthening the control of pollutant emission costs, encouraging technological innovation to shift towards high-tech environmental protection industries, and guiding consumers to conduct green consumption, so as to direct capital flow into environmental protection undertakings [5]. Zou Yue emphasized that green finance is an important driving force for the upgrading of China's green industry, holding that it promotes green economic growth and structural transformation, and meanwhile provides support for green project investment and the cultivation of new economic growth points [6]. Chen Mei proposed that green finance is conducive to promoting regional development; by advocating public awareness of green consumption, changing consumers' consumption preferences, it drives the supply and demand mechanism of the market for green industries [7]. Ge Xuan found that China's green finance is insufficient in terms of guiding role, which has brought severe obstacles to the green development of regional economy, and called for exploring new development models to support the green growth of green finance and regional economy [8].

2.3. Literature commentary

It can be seen from the above studies that current research on green finance mainly focuses on its connotation and the necessity of its development, while there are relatively few studies on the impact of green finance on regional economy. Some domestic scholars have also made attempts to study the impact of green finance on economic development, while foreign scholars' research mainly focuses on creating more market value. Therefore, there are differences between foreign and domestic research findings. In terms of the research on green finance and regional economic development, its great significance can be observed. Some domestic scholars have studied the relationship between green finance and regional economic development, concluding that green finance is more conducive to promoting the high-quality development of regions. By advocating public awareness of green consumption, making them realize the important issues that may affect future life, and then cultivating relevant awareness of green consumption to change consumers' consumption preferences, thereby driving the supply and demand mechanism for the development of green industries through the market. However, they have not conducted an in-depth discussion on the influence mechanism between the two. In addition, judging from existing literature, there are relatively few comparative studies on green finance and regional economic development. Therefore, this paper mainly analyzes and discusses the impact of green finance on regional economic development based on China's domestic situation.

3. Empirical analysis of the impact of green finance on regional economic development

3.1. Variable selection

The most direct ways for green finance to affect regional economic development are financial support for industrial development and financial support for consumption. This study explores and analyzes the impact of green finance on regional economic development. From the perspective of overall regional economic development, green finance directly affects regional industrial development through green credit, green bonds, green insurance and green funds, which is reflected in quantifiable indicators as changes in regional GDP. Therefore, the variables selected in this paper are shown in Table 1 as follows:

Table 1. Variable selection

Variable Type	Variable Definition	Variable Symbol	Variable Explanation
Explained Variable	Regional Economic Development	Y1	Measured by regional GDP, with logarithm taken
Explanatory Variable	Green Finance	X1	Green finance index, i.e., the degree of green finance development
Control Variable	Per Capita Disposable Income	X2	Growth rate of regional per capita disposable income
	Total Social Investment	X3	Growth rate of regional total fixed asset social investment over the previous year (%)
	Labor Force Population	X4	Annual labor force population announced by the region, with logarithm taken

As shown in Table 1, in addition to the explained variable and explanatory variable, 3 control variables are selected, mainly including per capita disposable income, total social investment and labor force population.

Green finance not only directly affects regional economic development, but also indirectly affects regional economic development through its impact on local consumption level and per capita disposable income. The impact of green credit on regional total fixed asset social investment will be transferred to the overall regional infrastructure construction, thereby affecting the regional economic level. Labor force population is an important factor for regional economic development. Therefore, in addition to the explanatory variable of green finance and the explained variable of regional economic development, this paper selects three control variables closely related to green finance and regional economic development.

3.2. Hypothesis proposal

Generally speaking, the higher the level of green finance support, the higher the level of regional economic development. Relevant scholars at home and abroad have also pointed out that there is a positive correlation between green finance and regional economic development. Moreover, due to the differences in the implementation of green finance in various regions, there exists certain regional heterogeneity between green finance and economic development. Based on this, this paper puts forward the following hypotheses:

Hypothesis 1: There is a positive correlation between green finance and regional economic development.

Hypothesis 2: There is significant regional heterogeneity between green finance and economic development.

3.3. Model construction and sample data

Based on the theoretical analysis of the relationship between green finance and regional economic growth proposed earlier, there is a significant positive correlation between green finance and regional economic growth, i.e., China's green finance can promote the growth of regional economy. According to the variables listed in the above table, the mathematical regression model is established as Equation (1):

$$Y1it = \alpha_0 + \alpha_1 X_{1it} + \alpha_2 X_{2it} + \alpha_3 X_{3it} + \alpha_4 X_{4it} + \varepsilon_{it} \tag{1}$$

In the formula, α_0 represents the intercept term of the regression equation; other α represent the to-be-estimated coefficients corresponding to each variable; i represents the variation range of each province and city; t represents time. Since the data in the consulted database is only updated to 2022, the variation range from 2013 to 2022 is selected; ε_{it} represents the random error term. To ensure the rationality of the model results, this paper takes the logarithm of the variables of regional economic growth and labor force population. According to China's division of economic development regions, the regions are divided into four parts: Eastern, Central, Western and Northeast China, and the data of nearly 10 years from 2013 to 2022 are used as sample data for empirical analysis.

3.4. Variable basic analysis and model regression analysis

3.4.1. Descriptive statistics

Table 2 reflects the descriptive statistical results of 310 sample observations from 31 provinces in China during 2013—2022. The data are sourced from the *China Urban Statistical Yearbook*. It can be seen from the descriptive statistical results that there is a large range in the GDP development of various provinces, indicating that there are significant differences in the economic development levels of various provinces in China; the mean value of green finance (X1) is 0.7871, and the minimum value is 0.6604, indicating that the green finance of most provinces in the sample is at a moderate level. In addition to the core variables, there are also obvious differences in other variables among various provinces, which have certain representativeness. These differences may be related to the geographical environment, economic foundation, policy environment

and other factors of each province. For example, some developed coastal provinces may be more likely to introduce advanced green finance concepts and technologies, while some inland provinces may face greater difficulties due to geographical constraints.

Table 2. Basic statistical characteristics of main variables

Variable	Sample Size	Mean	Standard Deviation	Minimum Value	Median	Maximum Value
Y1	310	9.8601	0.9918	6.7193	10.0218	11.7685
X1	310	0.7871	0.0623	0.6604	0.7907	0.8995
X2	310	0.0736	0.0324	-0.0155	0.0866	0.1474
X3	310	2.0652	12.9367	-58.4000	3.2000	67.5000
X4	310	6.0332	0.8810	3.4340	6.1204	7.6701

3.4.2. Correlation analysis

Since this paper selects a large number of control variables, it is easy to have strong collinearity between control variables and explanatory variables. To avoid the adverse impact of this problem on the subsequent regression model, this paper conducts a multicollinearity test. The correlation results shown in Table 3 below indicate that the correlation coefficient between the explained variable of regional economic development level (Y1) and the explanatory variable of green finance (X1) is relatively large, and there is a significant correlation with other variables, showing a significant correlation state. However, the correlation coefficients between the variables selected in this paper are mostly less than 0.8, indicating that there is no multicollinearity between the explanatory variables.

Among them, the correlation coefficient between regional economic development level and green finance is 0.2132, indicating that there is a significant positive correlation between the explained variable of regional economic development level and the core explanatory variable of green finance.

Table 3. Correlation coefficient matrix

	Y1	X1	X2	X3	X4
Y1	1				
X1	0.2132*	1			
X2	-0.0549	0. 1002*	1		
X3	0.3166*	0.0928	-0.0511	1	
X4	0.9533*	-0.0237	-0.0944*	0.2845*	1

Note: * indicates significance at the 10% level

In addition, Table 4 shows that the VIF test provides an intuitive indicator of the degree of multicollinearity. The maximum value is 1.1 and the minimum value is 1.02, indicating that the VIF values corresponding to each influencing factor selected in this paper are all less than 10. Therefore, it can be concluded that the regression model established in this paper will not have the problem of multicollinearity.

Table 4. VIF values

Variable	X3	X4	X1	X2	Mean VIF
VIF	1. 1	1. 1	1.02	1.02	1.06
1/VIF	0.907949	0.910882	0.978434	0.980208	

3.4.3. Regression analysis of the impact of green finance on regional economy

The regression results of the fixed effects model in Table 5 reveal some important correlations. First of all, according to the results of the Hausman test, the *P*-values are all 0.000, indicating that the coefficient 3.5412 of the model has passed the test at the 1% significance level, which shows that green finance (X1) has a significant positive impact on the regional economic development level (Y1). In other words, under the condition that other variables remain unchanged, for every 1% increase in green finance, the regional economic development level will increase by an average of 3.5412%. This finding verifies the promoting effect of green finance on regional economic development level.

In addition, except for the labor force population (X4), the linear relationships between the growth rate of per capita disposable income (X2), total social investment (X3) and regional economic development level are not significant. Specifically, provinces with a higher labor force population also have a higher level of regional economic development. This finding suggests that local governments need to pay more attention to the rational allocation and utilization of labor resources in policy formulation and implementation to promote the sustainable growth of regional economy.

Table 5. Regression results of the impact of green finance on regional economic development level

	(1)	(2)
	Y1	Y1
X1	3.4649***	3.5412***
	(37.4451)	(36.7103)
X2		0.1432
		(0.7835)
X3		0.0003
		(0.5393)
X4		0.3107***
		(3.6365)
_cons	7. 1329***	5. 1872***
	(97.6365)	(9.5855)
hausman	0.000	0.000
Within R2	0.8345	0.8434

Note: *, **, *** indicate significance at the 10%, 5% and 1% levels respectively, and the values in brackets are t-values.

3.4.4. Heterogeneity analysis

To study the impact of different regions on green finance and regional economic development level, this paper divides the provinces in the sample into four regions: Northeast, Central, Western and Eastern China. The specific provinces included in each region are shown in Table 6 as follows.

The specific test results are shown in the model results, as presented in Table 7 below. The model results show that for provinces located in the Central, Western and Eastern regions, the study finds that there is an obvious positive correlation between green finance and regional economic development level, especially for provinces in the Central, Western and Eastern regions. The impact coefficients of green finance in these regions are 3.5186, 3.8723 and 3.3214 respectively, all significant at the 1% significance level, which is consistent with the regression results of the full-sample model. However, for provinces located in Northeast China, although the positive impact of green finance on regional economic development level exists, its t-value is not significant at the 10% significance level, suggesting that there is regional heterogeneity in the impact of green finance on economic development level in different regions, which verifies Hypothesis 2.

Further comparison of the impact coefficients of various regions on regional economic development level shows that the absolute value of the impact coefficient of green finance in the Western region is larger. On the contrary, for provinces in Northeast China, the impact of green finance on regional economic development level is not significant.

Table 6. Regional division of provinces

Region	Included Provinces (Regions)
Northeast China	Heilongjiang, Jilin, Liaoning (Northeast)
Central China	Henan, Shanxi, Hunan, Hubei, Anhui, Jiangxi (Central China, North China)
Eastern China	Beijing, Hebei, Jiangsu, Shanghai, Fujian, Shandong, Guangdong, Zhejiang, Tianjin, Hainan (East China)
Western China	Chongqing, Guizhou, Guangxi, Yunnan, Sichuan, Inner Mongolia, Ningxia, Shaanxi, Gansu, Xinjiang, Qinghai, Tibet (Northwest China, Southwest China)

Table 7. Regression results of the impact of green finance on economic development level in different regions

	(1) Northeast China	(2) Central China	(3) Western China	(4) Eastern China
	Y1	Y2	Y3	Y4
X1	0.9870	3.5186***	3.8723***	3.3214***
	(1.3494)	(17.5903)	(23.5470)	(20.9903)
X2	-0.1322	0.3416	0.2884	0.0812
	(-0.4745)	(0.9411)	(0.9400)	(0.2741)
X3	0.0011	0.0006	0.0011	0.0008
	(0.7932)	(0.4577)	(1.1493)	(0.7828)
X4	-0.3624**	-0.3648	0.2134	-0.0299
	(-2.7208)	(-1.2771)	(1.3149)	(-0.1807)
_cons	11.0007***	9.8211***	5.0049***	7.9871***
	(10.9028)	(5.2043)	(5.6239)	(7.1859)
Year*Province	Yes	Yes	Yes	Yes
N	30	50	120	110
Within R2	0.9016	0.9128	0.8518	0.8575

Note: *, **, *** indicate significance at the 10%, 5% and 1% levels respectively, and the values in brackets are t-values.

3.4.5. Robustness test

3.4.5.1. Outlier treatment

To ensure the robustness of the model results, considering the possible outliers in the survey data and differences between sample individuals, this study has taken a series of measures. In view of the fluctuations caused by the possible accidental behaviors of individuals in the treatment group, we have conducted winsorization on the dependent variable and core explanatory variable. After outlier treatment, a new panel regression analysis has been carried out, and the results are shown in Column 1 of Table 8. The results in Table 8 indicate that even after outlier treatment, the coefficient of green finance (X1) remains significantly positive. This robust result further supports the observation and interpretation of the promoting effect of green finance on regional economic development level.

3.4.5.2. Sample period adjustment method

This study also adopts the sample period adjustment method to conduct robustness test of the relevant model. Specifically, we exclude the data samples from 2013 to 2014, and re-use the data period from 2015 to 2022 for analysis to explore the relationship between green finance and regional economic development level. After adjusting the sample period, the coefficient corresponding to green finance is 3.1959, which is still significant at the 1% significance level. This shows that even if the sample period is adjusted, the linear characteristic between green finance and regional economic development level still exists. On the whole, the results obtained after adjusting the sample period are consistent with the previous conclusions, so the previous results are relatively robust.

Table 8. Robustness test of sample period adjustment method

	(1) Outlier Treatment	(2) Sample Period Adjustment
	Y1	Y1
X1	3.4703***	3. 1959***
	(36.4601)	(24. 1970)
X2	0.0831	-0.8455**
	(0.4619)	(-2.4795)
X3	0.0004	0.0007
	(0.7412)	(1.0559)
X4	0.2168**	0.1520
	(2.5777)	(1.5859)
_cons	5.8152***	6.5067***
	(10.9166)	(10.7033)
N	310	248
Within R2	0.8428	0.7988

Note: *, **, *** indicate significance at the 10%, 5% and 1% levels respectively, and the values in brackets are t-values.

3.5. Conclusions of empirical analysis

The research findings are as follows:

The descriptive statistical results show that the green finance of most provinces in the sample is at a moderate level. In addition to the core variables, there are also obvious differences in other variables among various provinces, which have certain representativeness. These differences may be related to the geographical environment, economic foundation, policy environment and other factors of each province.

The correlation analysis results show that the correlation coefficient between regional economic development level and green finance is 0.2132, indicating that there is a significant positive correlation between the explained variable of regional economic development level and the core explanatory variable of green finance, so Hypothesis 1 is valid. Moreover, since all VIF values are less than 10, there will be no multicollinearity in the regression model.

The regression analysis results verify the promoting effect of green finance on regional economic development level, and conclude that provinces with a higher labor force population have a higher level of regional economic development. This finding suggests that local governments need to pay more attention to the rational allocation and utilization of labor resources in policy formulation and implementation to promote the sustainable growth of regional economy.

The heterogeneity analysis divides the 31 groups of data into Eastern, Western, Northeast and Central regions according to their locations, suggesting that there is regional heterogeneity in the impact of green finance on economic development level in different regions, which verifies Hypothesis 2.

For the endogeneity test, considering that railway accessibility can reflect the economic development foundation of a city to a certain extent and has exogenous characteristics, the railway opening situation (open) of sample cities in 1933 is selected as the instrumental variable. After eliminating the endogeneity problem, green finance can still significantly promote industrial structure upgrading, so the regression results of this paper are not affected by sample selection bias.

The robustness test results obtained through methods such as outlier treatment and sample period adjustment are basically consistent with the previous ones. Therefore, it can be proved that the previous data are relatively robust.

In conclusion, the development of green finance is conducive to promoting the regional economic development level of China. From the results of the regional heterogeneity test, the promoting effect of green finance on economic development level has regional heterogeneity; the absolute value of the coefficient corresponding to green finance in the Western region is larger, while for provinces located in Northeast China, the impact of green finance on regional economic development level is not significant. Finally, through tests, it can be seen that the regression model of this paper is reliable.

4. Countermeasure and suggestion

The main factors influencing regional economic development by green finance include optimization of resource allocation, promotion of technological innovation, improvement of environmental protection awareness, and policy guidance and support.

However, in practice, the development of green finance still faces some challenges and problems, mainly including imperfect policy system, unsound market mechanism, slow update speed of financial products and services, and insufficient transparency. These problems restrict the promoting effect of green finance on regional economic development and need to be solved by taking effective countermeasures.

To give better play to the promoting effect of green finance on regional economic development, the following countermeasures and suggestions are put forward:

4.1. Improve the policy system

The government should formulate more comprehensive and specific green finance policies, including financial subsidies and tax incentives. Through providing policy incentives, more capital should be guided to flow into green industries and projects. At the same time, the government should strengthen policy publicity and implementation to ensure the effective implementation of policies. However, green finance also faces some challenges and problems in the development process. Therefore, in order to improve the policy system, the following policy suggestions are put forward.

4.1.1. Improve the green finance standards and certification system
The government should promote the establishment of a unified green finance standards and certification system to ensure the standardization and transparency of the green finance market. This helps to reduce the difficulty of evaluating green projects and improve the support of financial institutions for green projects.

4.1.2. Provide financial support and preferential policies
The government can set up green funds to provide financial support for green projects; offer tax incentives to encourage enterprises and financial institutions to participate in green finance activities; and establish a green

finance reward mechanism to commend and reward enterprises and financial institutions that have performed outstandingly in the field of green finance.

4.1.3. Strengthen green finance supervision and risk prevention and control

The government should establish and improve the green finance supervision system, strengthen the supervision and risk prevention and control of the green finance market. At the same time, promote financial institutions to strengthen internal risk management to ensure the sound development of green projects.

4.1.4. Promote the innovation and diversified development of green finance

The government should encourage financial institutions to carry out innovation in green financial products and services to meet the financing needs of different types of enterprises and projects. At the same time, promote the integration of green finance technology with new technologies such as the Internet and big data to improve the intelligent and professional level of green finance.

In a word, the government should promote the healthy development of regional economy under the influence of green finance through measures such as improving standards, providing financial support, strengthening supervision and promoting innovation, so as to provide strong support for ecological civilization construction.

4.2. Improve the market mechanism

Establish and improve the green finance market system, including diversified financial tools such as green credit, green bonds and green funds. Strengthen cooperation and competition among financial institutions to improve service level and efficiency. At the same time, strengthen market supervision to prevent financial risks.

4.3. Innovate financial products and services

Encourage financial institutions to strengthen the innovation of green financial products to meet the financing needs of different types of enterprises and projects. Promote the integration of green finance technology with new technologies such as the Internet and big data to enhance the intelligent and professional level of green finance. At the same time, focus on the management and control of innovation risks to ensure the sustainable development of financial innovation.

4.4. Monitoring, evaluation, feedback and adjustment

Establish a scientific monitoring and evaluation system to conduct a comprehensive and objective evaluation of the development of green finance. Through collecting and analyzing data, timely find out problems and deficiencies, and take effective measures to improve and adjust. At the same time, pay attention to the application of monitoring and evaluation results to provide useful reference for policy formulation and adjustment.

In summary, to give better play to the promoting effect of green finance on regional economic development, it is necessary for the government, financial institutions and enterprises to work together, continuously improve the policy system, market mechanism, talent training and other aspects, and strengthen international cooperation and exchanges to jointly promote the progress and innovation in the field of green finance and promote the sustainable development of regional economy [9].

5. Conclusion

Green finance plays an important role in regional economic development. By providing financial support, guiding resource allocation, innovating financial products and services, it promotes the development of green industries, optimizes resource allocation, drives innovation, and enhances international cooperation and exchanges. These positive impacts are conducive to promoting the sustainable development of regional economy.

However, in practice, the development of green finance still faces some challenges and problems, such as imperfect policy system, unsound market mechanism, slow update speed of financial products and services, and insufficient transparency. These problems restrict the promoting effect of green finance on regional economic development. To give better play to the promoting effect of green finance on regional economic development, this paper puts forward a series of countermeasures and suggestions, including improving the policy system, perfecting the market mechanism, innovating financial products and services, and implementing monitoring, evaluation, feedback and adjustment.

By implementing these countermeasures and suggestions, the progress and innovation in the field of green finance can be promoted, and the sustainable development of regional economy can be facilitated. At the same time, it requires the joint efforts of the government, financial institutions and enterprises to continuously improve the policy system, market mechanism, talent training and other aspects, strengthen international cooperation and exchanges, and jointly promote the progress and innovation in the field of green finance.

In conclusion, the impact of green finance on regional economic development is complex and multi-dimensional. In practice, it is necessary to deeply understand the mechanism of action of green finance and take effective countermeasures and suggestions to better exert the promoting effect of green finance on regional economic development.

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