How Does Green Finance Influence the Low-carbon Development of Agriculture? Utilizing Provincial Panel Data

Yan Yin
School of International Economics and Business, Nanjing University of Finance and Commerce, Nanjing, Jiangsu, China

Abstract: In this study, panel data of 31 provinces in China from 2013 to 2022 are selected. By adopting fixed-effects models, moderation-effect models, etc., it explores the influence and action mechanism of green finance on the agriculture low-carbon development. Taking the level of agricultural mechanization as a moderating variable, this paper examines its moderating effect and conducts heterogeneity tests from the dimension of geographical location. The research finds that: (1) Green finance can exert a significant positive influence on the agriculture low-carbon development; (2) The level of agricultural mechanization positively regulates the impact of green finance on the low-carbon development of agriculture; (3) The promotional effect of green finance on agricultural low-carbon development is particularly pronounced in the central region, but in the western region, there exists an initial investment effect.

Keywords: Green Finance; Low-Carbon Development; Agriculture; Moderating Effect; China

1. Introduction

Since China entered the 21st century, agriculture has attained remarkable achievements that have drawn global attention. During the period from 2013 to 2023, the average annual growth rate of the agricultural added value in China has reached 4.01%. The annual grain output has remained stable at over 630 million tons. In 2023, the total agricultural output value was 8.71 trillion yuan, registering a 77.9% increase compared to 2013. However, with the continuous development of agriculture, the environmental impact of greenhouse gasses such as carbon dioxide has been intensifying. In 2023, the total greenhouse gas emissions of China accounted for around 34% of the global total. Among them, agriculture accounted for 6.7% of the nation's emissions, becoming a key source of greenhouse gas emissions. China has committed to peaking its carbon dioxide emissions before 2030 and achieving carbon neutrality before 2060. In this context, green finance, as an emerging financial instrument, potentially exerts an influence on agricultural carbon emissions, thus becoming a new domain of exploration for scholars.

Green finance can cut down carbon emissions by holding back the overuse of chemical fertilizers[1]. Moreover, it can directly decrease the agricultural carbon emission intensity[2]. Technological advancements can significantly reduce agricultural carbon emissions and non-point source pollution[3-4], and can also counteract negative effects brought about by using chemical fertilizers[5], optimizing the industrial structure plays a crucial mediating role in this process[6]. Green finance is more helpful for large-scale industries to cut down carbon emissions[7]. According to the above analysis, although existing studies have comprehensively explored the mechanisms of green finance influencing low-carbon development in agriculture, further research is warranted regarding the effects of agricultural mechanization levels and different regions during the process of green finance facilitating agricultural carbon reduction. In light of this, this paper employs fixed-effects models and moderation-effects models to investigate the effect of green finance on the agriculture low-carbon development [9]. Taking the level of agricultural mechanization as a moderating variable, conduct in-depth research on the mechanism analysis. Additionally, explores its geographical heterogeneous impacts, aiming to support the national "dual-carbon" strategic objectives. It provides empirical references for enhancing the green finance policy system and solving the financing-related bottlenecks in the agricultural green transformation, thus, the competitiveness and sustainability of agriculture

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can be enhanced [10].

2. Hypotheses and Analysis

2.1 The Influence of Green Finance on Agriculture Low-Carbon Development

Green finance represents a decision-making mechanism that incorporates protection of the environment and sustainable development into the financial system, emphasizing the synergistic development between financial activities, environmental protection, and ecological balance. For agriculture, a complex and fundamental industry that is highly influenced by natural conditions, the following points are notable. Firstly, green finance can directly provide funds for the agriculture low-carbon development. For example, it can directly invest in green agricultural projects. Secondly, green finance can leverage macro policies to direct funds toward green projects, thus promoting the carbon-reduction development of agriculture. Examples include green credit provided by banks and green investment projects launched by enterprises. According to these, Hypothesis 1 is proposed: Green finance significantly promotes agriculture low-carbon development.

2.2 The Moderating Effect of the standard of Agricultural Mechanization

The level of agricultural mechanization refers to the extent to which machinery replaces traditional power in agricultural production. Against the backdrop of green finance, the degree of agricultural mechanization can reduce agricultural carbon emissions. When agricultural machinery is relatively popular, the resources allocated to the low-carbon sectors of agriculture by green finance, through means such as credit support and subsidy-driven guidance, can be rapidly and effectively translated into the capacity to reduce carbon emissions in actual production. For instance, by reducing fuel consumption, the pollution caused by traditional agricultural machinery can be mitigated. This can further optimize the resource-allocation efficiency of projects supported by green finance, thereby doubling the promoting influence of green finance. Hypothesis 2 is proposed: The level of agricultural mechanization positively moderates the effect of green finance on agriculture low-carbon development.

3. Design of the Study

3.1 Model Establishment

To validate Hypothesis 1, this study constructs the following benchmark model:

$$ACE_{it}=\alpha+\beta GFI_{it}+\gamma Controls_{it}+\mu_i+\varepsilon_{it} \quad (1)$$

To validate Hypothesis 2, this study constructs the following moderation effect model:

$$ACE_{it} = \alpha + \beta GFI_{it} + \beta_1 mac + \beta_2 GFI_{it} \times mac + \gamma Controls_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

Among them, i and t stand for the province where the sample is from and the corresponding year, respectively. ACE_{it} represents the intensity of agricultural carbon emissions; GFI_{it} represents the green finance index; mac is the level of agricultural mechanization; $GFI_{it} \times mac$ is the interaction term; α , β , β_1 , β_2 , γ are coefficients to be estimated; $Controls_{it}$ are control variables; μ_i is the provincial fixed effect, and the random disturbance term is ε_{it}.

3.2 Definition of Variables

3.2.1 Dependent variable (ACE)

IPCC method is used in this study. The way to calculate it is to multiply the carbon emission coefficient by the relevant amount of carbon sources, the formula is:

$$C = \sum C_i = \sum T_i \times K_i \quad (3)$$

C is the total emissions of agricultural carbon, C_i shows total carbon emissions of the i carbon source, T_i stands for how much carbon source is put in, and K_i is the coefficient. The coefficients are based on Tian et al.[8], and ACE represents the natural logarithm of C. When the coefficient is negative, it indicates that green finance reduces total emissions and supports low-carbon development.

3.2.2 Explanatory variable (GFI)

Taking the level of environmental protection and the extent of resource utilization as criteria to measure its results is what makes green finance different from traditional finance. When constructing an indicator system, comprehensive factors need to be taken into account. The paper uses the entropy method for measurement and incorporates seven dimensions to construct the indicator system, as shown in Table 1.

3.2.3 Other variables

The moderating variable is the agricultural mechanization standard (*mac*). Drawing on the research of Fan[11] and taking the completeness and availability into account, the control variables are selected: agricultural structure (*as*), rural population size (*peo*), land scale (*ls*), and

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rural residents' income (*inc*). The definitions are displayed in Table 2.

Table 1. Green Finance Indicator System

	Green Dimensions	Definition
Green Finance	Credit	Total environmental protection credit / Total credit volume
	Investment	Environmental protection investment / GDP
	Insurance	Income from environmental insurance / Total premium income
	Bonds	Total issuance amount of green bonds / Total issuance amount of all bonds
	Funds	Total value of green funds / Total value of all funds
	Rights	Green rights trading / Total trading in the rights market

Table 2. Definitions of Key Variables

Type	Name	Symbol	Definition
Dependent Variable	Agricultural Carbon Emission Intensity	ACE	The natural logarithm of the total agricultural carbon emissions
Explanatory Variable	Green Finance Index	GFI	Calculated by the entropy method
Moderating Variable	Level of Agricultural Mechanization	mac	Total power of farm machinery / Area of crops planted
Control Variables	Agricultural Structure	as	Total agricultural output value / The combined output value of agriculture, forestry, animal husbandry, and fishing
	Rural Population Size	peo	The natural logarithm of the rural population
	Land Scale	ls	Total area of crops sown / Number of people working in agriculture, forestry, animal husbandry, and fishing
	Rural Residents' Income	inc	The natural logarithm of rural residents' disposable income

3.3 Data Source

This article picks the panel data of 31 provinces in China. The time period is from 2013 to 2022. *China Statistical Yearbook*, *China Insurance Yearbook*, *China Rural Statistical Yearbook*, *China Agricultural Yearbook*, *China Financial Yearbook* and other relevant sources are the main sources. To circumvent the impact of extreme values and address the issue of heteroscedasticity, logarithmic transformations are performed on some of the data. Moreover, the linear interpolation method is utilized to deal with certain missing values.

4. Empirical Analysis

4.1 Benchmark Regression

Results are presented in Table 3. Whether we include the control variable or not, the coefficient of GFI is significantly negative, which proves Hypothesis 1. The basic idea is that green finance can distribute money to projects that support the green development of agriculture. And it can direct capital to green agricultural projects. This really helps cut down carbon emissions.

Table 3. Results of the Benchmark Regression

	(1)	(2)
GFI	-1.354***	-0.451***
	(-14.306)	(-3.419)
_cons	5.728***	8.009***
	(144.488)	(8.388)
Controls	NO	YES
N	310	310
R^2	0.424	0.588

***p<0.01, **p<0.05, *p<0.10

4.2 Moderation Effect Test

The results of the moderating effect are in Table 4. The coefficients of both interaction term *GFI* × *mac* and explanatory variable *GFI* are significantly negative, this validates Hypothesis 2. This shows that the moderating variable plays a positive role in this research. The basic principle is that the guiding role of green finance in terms of funds can drive the coordinated upgrading of industrial chain links such as agricultural machinery manufacturing, energy supply, and agricultural services, enabling green financial resources to be rapidly and effectively transformed into actual capabilities to reduce carbon emissions in agricultural production.

Table 4. Results of the Moderation Effect Test

	(1)	(2)
GFI	-0.451***	-0.466***
	(-3.419)	(-3.646)
mac		0.122**
		(2.301)
GFI × Mac		-0.057***
		(-3.629)
_cons	8.009***	7.280***
	(8.388)	(7.750)

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N	310	310
R^2	0.588	0.620

***p<0.01, **p<0.05, *p<0.10

4.3 The Endogeneity Treatment

To mitigate potential endogeneity problems, this study lagged the green finance development index by one period. Look at Table 5. The estimated coefficient of Column (2) is-0.502. It passed the test at the 1% level. This matches the conclusion of the benchmark regression.

Table 5. Results of Endogeneity Treatment

	(1)	(2)
	GFI	*ACE*
L. GFI	0.659***	-0.502***
	(12.552)	(-3.591)
_cons	0.154***	9.134***
	(7.154)	(9.350)
N	279	279
R^2	0.389	0.634

***p<0.01, **p<0.05, *p<0.10

4.4 The Robustness Test

This study conducts robustness tests through three methods to ensure the credibility: replacing explanatory variables, handling omitted variables, and implementing two-sided winsorization. In Table 6., Column (1) presents the situation where the green finance index in the benchmark model is substituted with government green support. The observed results remain significant. The results after incorporating the degree of crop disaster (Affected area / Total sown area of crops) are shown in the Column (2). This indicates a clearly negative coefficient, and the regression results continue to hold strong, reflecting consistent and reliable patterns. Column (3) shows the outcomes after performing 1% and 99% winsorization on the data, the result of *GFI* is-0.399 and significant, validating the conclusion.

Table 6. Results of Robustness Test

	(1)	(2)	(3)
GFI		-0.453***	-0.399***
		(-3.438)	(-2.943)
dis		-0.081	
		(-1.411)	
GS	-8.494*		
	(-1.780)		
_cons	8.162***	8.103***	8.543***
	(8.430)	(8.481)	(8.748)
N	310	310	310
R^2	0.575	0.591	0.565

***p<0.01, **p<0.05, *p<0.10

4.5 The Heterogeneity Test

The influence of green finance on low-carbon development in agriculture shows heterogeneity due to geographical differences. We look into this issue according to the regional division criteria of the National Bureau of Statistics. Table 7. shows the results. The coefficients for the East, West, and Northeast are not statistically significant. Noticeably, the coefficient for the West is positive. But for the Central, the coefficient shows that green finance has a more obvious effect in helping the central region's agriculture develop in a low-carbon way. Instead, in the West, this could accidentally make carbon emissions go up. The underlying reason is that the West region generally has a relatively weak environmental base. During the early stage of the low-carbon transition, an initial investment effect emerges, resulting in an increase in carbon emission intensity. Nevertheless, this serves as a foundation for future carbon emission reduction efforts. As a major agricultural production area in China, the Central region benefits from substantial policy and financial support for its development. Consequently, green finance can be more effectively utilized to drive progress. In the East region, the portion of the service sector in the economy is high, and the relatively small share of agriculture, coupled with stringent environmental regulations, render the results insignificant. In Northeast China, the industrial structure is predominantly heavy, and the development of green finance has a relatively late start. As a result, its carbon emission problems are likely to be more intricate and challenging to resolve effectively through green finance in the short term.

Table 7. Results of Heterogeneity Test

	East	Central	West	Northeast
GFI	-0.319	-0.158**	0.168	-0.173
	(-1.649)	(-2.051)	(1.188)	(-1.507)
_cons	6.988***	6.052***	8.497***	7.369***
	(3.238)	(3.019)	(5.977)	(5.490)
N	100	60	120	30
R^2	0.678	0.874	0.584	0.753

***p<0.01, **p<0.05, *p<0.10

5. Conclusions and Suggestions

5.1 Conclusions

Based on these, here are the findings:

Green finance actively boosts the agriculture low-carbon development.

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When it comes to the impact of green finance on the agriculture low-carbon development, the regulating effect of the agricultural mechanization level is positive.

Green finance has a pretty obvious promoting effect on the low-carbon development of agriculture in the central region. But in the western region, there's still an initial investment effect.

5.2 Suggestions

Based on these, here are some suggestions:

Enhance the green financial system and rural green financial services. Establish a comprehensive rural financial system that caters to the entire value chain. Develop green pledge-based financing instruments and improve the rural financial risk mitigation mechanism. This will solidify the foundation for the development of green finance. Given its significance as an effective method of attaining China's "dual-carbon" goals, continuous efforts should be made to advance green finance.

Use technological innovation to drive green development. Try hard to get businesses and farmers to adopt low-carbon technologies. Improve efficiency of resource utilization by formulating unified technical standards. Explore innovative technologies that can effectively reduce agricultural pollution and carbon emissions, thereby aligning agricultural development with the "dual-carbon" objectives.

Adopt a region-specific green finance development strategy. Central Region: Intensify efforts in green development and capitalize on the demonstration role of model areas. Eastern Region: Facilitate the integration of financial institutions and other tertiary industries with grass-roots agriculture to pioneer new low-carbon development paths for the agricultural sector. Western Region: Adopt a long-term perspective and introduce appropriate buffer policies to alleviate the short-term pressure of high carbon emissions. Northeastern Region: Improve the green finance risk compensation mechanism to alleviate concerns regarding low-carbon transformation and steadily promote industrial transformation and upgrading.

It should be pointed out that this research has certain limitations. For instance, the construction of the relevant indicator system requires further refinement. There is also a lack of in-depth exploration into the factors contributing to the differences in agricultural low-carbon levels across various regions. Moreover, specific and practical suggestions for reconciling the conflict between sustainable agricultural development and carbon reduction have not been fully elaborated. Future research will focus on addressing these aspects.

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