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Green finance and agricultural carbon emission reduction: Based on the regulatory effect of environmental regulation

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Abstract: *Agricultural development occupies a large proportion in our country, and the realization of carbon emission reduction in agriculture has a significant role, and green finance provides the important financial guarantee for agricultural carbon emission reduction and sustainable development. Whether green finance can promote agricultural carbon emission reduction is a question worthy of our attention. In this paper, we systematically analyze and demonstrate the interaction between green finance and agricultural carbon emission reduction in China by using China's provincial data from 2008 to 2022. It is found that green finance effectively promotes agricultural carbon emission reduction, and agriculture-related loans and agricultural insurance have more obvious effects on carbon emission reduction. The more stringent environmental regulations are formulated and implemented within a certain range, the more significant the role of green finance in agricultural carbon emission reduction.*

Keywords: *Green finance; Agricultural carbon reduction; Environmental regulation*

1. Introduction

With the rapid development of economy and the excessive consumption of resources, environmental problems have seriously restricted people's growing demand for a better life, and the issue of carbon emission has become the focus of attention. As a basic and survivable emission, it is challenging to reduce agricultural carbon emissions while maintaining stable grain production. Compared with other industries with rapid returns, it is difficult for agriculture to obtain financial support. With the adjustment of the national strategy, green finance came into being, which will bring new development ways for the agricultural field. Green finance plays a role in agricultural development, promoting the breakthrough of basic agricultural technologies and the upgrading and transformation of productive agricultural industries. Further expand the role of policy support and market incentives in agricultural development, and reduce excessive carbon emissions in agricultural development.

At the earliest, some foreign scholars put forward the impact of financial development on carbon emissions through research, but scholars have different views on whether it is promoting effect, inhibiting effect or showing an inverted U-shaped relationship. Maosheng Y et al. (2023) believed that green finance could promote economic growth and found that economic growth in the eastern and central regions of China was negatively correlated with carbon emissions after crossing the inflection point of the environmental Kuznets curve[1].By establishing the intermediary effect framework, Yalin Mo et al. (2023) concluded that green finance plays a significant role in China's agricultural development and plays a positive role in reducing agricultural carbon emissions[2]. Chenyang R et al. (2023) found that the carbon emission reduction effect of green finance is more significant in developed regions and western regions, and the carbon emission reduction effect of green finance reform and innovation pilot zone is more significant because in other regions, green finance achieves carbon emission reduction through green innovation and upgrading industrial structure[3]. Hui H et al. (2023) concluded through empirical analysis that green finance development will promote carbon neutral performance, and local green finance has an impact on carbon neutral performance both locally and in neighboring areas[4]. Gongliang W et al. (2024) believe that the impact of green finance on carbon emission efficiency has a double threshold effect, which depends on the level of regional economic development[5]. In view of the existing literature, more attention is paid to the impact of technology and industrial structure, while the government's different requirements for environmental regulation are ignored. Based on the existing literature, this paper analyzes the role of green finance in agricultural carbon emission reduction by using the panel data of 30 provincial regions in China from

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2008 to 2022, and analyzes the role of environmental regulation in its impact process, which helps to deepen the understanding of the impact of environmental regulation policies and promote the construction of environmental regulation system.

2. Theoretical analysis and research hypothesis

2.1 Impact of green finance on agricultural carbon emission reduction

The core concept of green finance is to pay more attention to sustainable development and promote green development when providing funds and related financial services, improve farmers' green development thinking, help farmers adopt eco-friendly agricultural production methods, further improve farmers' green production awareness, and promote resource-saving and environment-friendly agricultural production practices. This includes the popularization of more scientific production rotation systems, the implementation of soil and water monitoring and conservation measures; By promoting technological innovation, implementing more energy-saving and water-saving irrigation technologies and more green and efficient organic fertilizers, energy conservation, emission reduction and environmental protection are achieved. In addition, green finance plays a more significant role in achieving technological breakthroughs and industrial structural upgrading, which can effectively alleviate the existing financial problems of rural industries and related core technology bottlenecks, promote the deep integration of agriculture with green manufacturing, ecological tourism and other aspects, and realize the diversified development of rural areas. Bring significant economic benefits to the countryside to achieve a virtuous cycle to further consolidate the sustainable development of rural areas, promote the development of biomass energy to promote agricultural carbon emission reduction. Based on this, the following research hypothesis is proposed:

H1: Green finance plays a significant role in promoting agricultural carbon emission reduction.

2.2 Regulatory effects of environmental regulations

The intensity of environmental regulation reflects the government's efforts and determination in environmental governance. The purpose of environmental regulation is to reduce the discharge of environmental pollutants through policy means, reduce the excessive consumption of resources, and finally achieve green development. Environmental regulation plays an important role in the realization of agricultural carbon emission reduction. On the one hand, environmental regulation sets carbon emission standards and directly limits agricultural carbon emission. In order to solve the problem of pollution discharge, enterprises must allocate part of their funds for pollution prevention and payment of pollutant discharge fees, which will increase the cost of pollutant discharge of enterprises and enhance the green awareness of farmers in production activities. For long-term development, agricultural enterprises will improve the production process, increase R&D investment, introduce green technology and equipment, and force agricultural green technology innovation. In the short term, due to limited capital investment, the conflict between environmental governance and technology research and development will be caused, so the environmental regulation may appear bottleneck in a certain period of time. Environmental regulation may inhibit the innovation of green technology due to the sudden increase in cost. In the long run, according to the Porter hypothesis theory, reasonable environmental regulation and resource allocation can promote technological innovation, reduce the cost of pollutant discharge, and then make up for the increased cost due to environmental regulation, thus strengthening the carbon emission reduction effect of green finance. On the other hand, environmental regulations play a guiding role in the flow of green finance funds to low-carbon environmental protection projects in the agricultural field. Through policy incentives and constraints, the allocation mechanism of green finance resources is optimized, financial institutions are encouraged to increase investment in green agricultural projects and reduce capital expenditure on high-carbon and high-pollution projects. In addition, green finance has a financial compensation effect under environmental regulations. Escort the green innovation of enterprises. The greater the intensity of environmental regulations, the more incentive agricultural enterprises have to develop low-carbon and efficient production technologies to further achieve agricultural carbon emission reduction. Based on this, the following research hypothesis is proposed:

H2: Environmental regulations strengthen the role of green finance in promoting agricultural carbon emission reduction.

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3. Research design

3.1 Variable Definition

3.1.1 Explained variable: agricultural carbon emission

Agricultural carbon emission per unit of output value of agriculture, forestry, animal husbandry and fishery was used to measure agricultural carbon emission intensity. With reference to the practice of Li Bo et al[6]., agricultural carbon emissions were calculated from the aspects of agricultural fertilizer application amount, pesticide use amount, plastic film use amount, agricultural diesel use amount, ploughing and irrigation.

3.1.2 Core explanatory variable: green finance

Green credit (GC), green insurance (GI) and green securities (GS) are selected to measure the development level of regional green finance. The balance of agriculture-related loans is used to measure green credit, and the agricultural insurance premium income is used as the proxy variable of green insurance. The market value proportion of A-share listed environmental protection enterprises was selected as the proxy variable of green securities. The above three indexes are measured by entropy method.

3.1.3 Regulatory variables: environmental regulations

Due to different environmental regulations in different provinces, the ratio of investment completed in industrial pollution control to industrial added value was used as a quantitative index, and the cross-fertilization term between environmental regulation and green finance development was introduced to measure the effect of environmental regulation intensity on green finance in agricultural carbon emission reduction.

3.1.4 Control variables

Agricultural technology innovation (ATI), degree of openness to the outside world (Open), level of industrialization (Indust), level of economic development (Eco) and decentralization of fiscal expenditure (FD) were selected as the control variables for the empirical analysis in this paper.

3.2 Model construction

3.2.1 Benchmark regression model

In this paper, Hausman test was conducted on the sample data, and the results are shown in Table 1

Table 1: Results of Hausmann test

Variable	FE	RE	Difference	S.E.
GF	-0.0032	-0.0038	0.0006	0.0004
ATI	-0.0011	-0.0012	0.0001	0.0006
Open	-0.0026	-0.0011	-0.0015	0.0004
Indust	0.0054	0.0051	0.0003	0.0006
Eco	-0.0005	-0.0004	-0.0001	0.0001
FD	-0.0319	-0.0281	-0.0038	0.0024
Chi2(6)=51.15				
Prob>chi2=0.0000				

The test results show that the P-value is 0.0000<0.01, which strongly rejects the null hypothesis of the existence of random effects, indicating that the fixed effects model should be used for analysis more efficiently. Therefore, taking into account the influence of time factors and individual heterogeneity, the bidirectional fixed-effect model is used to estimate the impact of green finance on agricultural carbon emission reduction. This approach allows us to control for time-invariant characteristics of individual regions as well as specific temporal shocks or trends that may affect the outcome variables. The following model (1) can be obtained:

$$ACE_{it} = \alpha + \beta_0 * GF_{it} + \gamma * X_{it} + u_i + v_t + \varepsilon_{it} \quad (1)$$

ACE_{it} is the explained variable, representing the annual agricultural carbon emission level of each province, and GF_{it} is the annual green finance index of each province. X_{it} is the control variable, u_i and $v_t$represent province fixed effect and year fixed effect respectively. ε_{it} is the random error term.

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3.2.2 Adjustment effect model

On the basis of reference to the relevant literature on regulatory effect, this paper discusses the regulatory role of environmental regulation in green finance affecting rural green development through the following model:

$$ACE_{it} = \alpha + \beta_1 * GF_{it} + \beta_2 * ER_{it} + \beta_3 * GF_{it} * ER_{it} + \gamma * X_{it} + u_i + v_t + \varepsilon_{it} \quad (2)$$

In the above equation (2), except ER_{it}, which is the regulating variable and represents the intensity of environmental regulations, the definitions of other indicators are consistent with equation (1), and $GF_{it} * ER_{it}$is the interaction term between green finance and environmental regulations. $\beta_2$and β_3 are new parameters to be estimated. This paper focuses on the direction of action of the estimated coefficient β_3 of $GF_{it} * ER_{it}$.

4. Empirical analysis

4.1 Descriptive Statistics

In order to ensure the reliability and persuasivity of the measurement results, this paper takes logarithmic processing of some absolute data, and the nature and relationship of the data do not change after processing. As can be seen from Table 2, there are significant differences in the development level of green finance in different regions and at different times. The difference between the highest value and the lowest value is 0.5921, and the scale of green credit, green insurance and green securities has a large internal difference, which fully indicates that the development level of green finance in different regions is increasing day by day and there is a large difference among different regions. In addition, there is also a large gap in the level of agricultural technology and economic development, and there is a large development gap between different regions. Therefore, it is very important to study the impact of green finance on agricultural carbon emission reduction based on reality.

Table 2: Descriptive statistical results of indicators

Variable	Mean	Sd	Min	Max
ACE	0.0108	0.0045	0.0027	0.0306
GF	0.1482	0.1051	0.0088	0.6009
LNGC	8.5214	1.0378	5.2115	11.0908
LNGI	6.6903	0.2932	2.1736	8.9707
GS	0.1036	0.1383	0.0001	1
LNATI	7.1415	1.3344	2.1972	9.7202
Open	0.2840	0.3072	0.0076	1.5973
Indust	0.3619	0.0899	0.0969	0.5358
Eco	5.2571	3.0855	0.9697	19.0313
FD	0.8512	0.0449	0.7065	0.9377
Number of id	30	30	30	30

4.2 Correlation Analysis

Table 3: Results of Pearson correlation test

	ACE	GF	LN-GC	LN-GI	GS	LN-ATI	Open	Indust	Eco	FD
ACE	1									
GF	-.389**	1								
LN-GC	-.438**	.746**	1							
LN-GI	-.365**	.704**	.630**	1						
GS	-.139**	.303**	0.071	-.094*	1					
LN-ATI	-.587**	.710**	.784**	.647**	.226**	1				
Open	-.158**	0.044	-0.09	-.183**	.444**	.239**	1			
Indust	.425**	-.203**	0.04	-.253**	-.166**	-.235**	-0.081	1		
Eco	-.538**	.435**	.302**	.300**	.325**	.591**	.556**	-.367**	1	
FD	-.266**	0.049	-.151**	0.053	.204**	0.08	.335**	-.385**	.519**	1
** At level 0.01 (two-tailed), the correlation was significant. * At level 0.05 (two-tailed), the correlation was significant.										

Through Pearson's correlation analysis, as shown in Table 3, it is observed that the green finance composite index (GF), green credit (GC), green insurance (GI), green securities (GS) and all control variables are correlated with agricultural carbon emission (ACE) at a significance level of 1%. Green

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finance index, green credit, green insurance and green securities were all negatively correlated with agricultural carbon emissions, indicating that the higher the development level of green finance, the better the effect of agricultural carbon emission reduction. Among the control variables, industrialization will increase agricultural carbon emissions, which is not conducive to the realization of carbon emission reduction.

4.3 Baseline regression analysis

In Table 4, column (1) is the regression result of green finance (GF) on agricultural carbon emission (ACE), column (2) is the regression result after the introduction of control variables, and column (3), column (4) and column (5) are the regression result of single indicators green credit (GC), green insurance (GI) and green securities (GS) on agricultural carbon emission (ACE). According to the results, before the introduction of control variables, the green finance development index has a significant negative correlation with the level of agricultural carbon emissions. Every 1% increase in the level of green finance development, agricultural carbon emissions will decrease by 0.031%. After the introduction of control variables, the significant impact of green finance on agricultural carbon emissions still exists. When the development level of green finance increases by 1%, agricultural carbon emissions decrease by 0.003%, and green credit and green insurance have a significant inhibitory effect on agricultural carbon emissions. Therefore, hypothesis H1 is verified.

4.4 Adjustment effect analysis

As shown in column (6) of Table 4, the impact of environmental regulations on agricultural carbon emissions is significantly negative, and the interaction terms between green finance and environmental regulations are significant (coefficient 2.249 and significant at 1% level), indicating that environmental regulations regulate the impact process of green finance on agricultural carbon emissions and strengthen the impact of green finance on agricultural carbon emission reduction. The combination of a sound environmental regulation system and green finance can maximize the promoting effect of green finance development on agricultural carbon emission reduction. The stricter the environmental regulation, the stronger the promoting effect of green finance on agricultural carbon emission reduction. Hypothesis H2 is established.

Table 4: Regression results

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	ACE	ACE	ACE	ACE	ACE	ACE
GF	-0.031***	-0.003**				-0.001*
	(0.001)	(0.001)				
LNGC			-0.002***			
			(0.001)			
LNGI				-0.001***		
				(0.001)		
GS					0.001	
					(0.001)	
ER*GF						-2.249***
						(0.441)
LNATI		-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Open		-0.003***	-0.002**	-0.002***	-0.002***	-0.002***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Indust		0.005***	0.0018	0.003	0.007***	0.005***
		(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
Eco		-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
FD		-0.032***	-0.013**	-0.034***	-0.037***	-0.031***
		(0.005)	(0.005)	(0.004)	(0.005)	(0.005)
Constant	0.015***	0.048***	0.050***	0.053***	0.051***	0.044***
	(0.000)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
Province	YES	YES	YES	YES	YES	YES
Time	YES	YES	YES	YES	YES	YES
Observations	450	450	450	450	450	450
R-squared	0.528	0.816	0.837	0.841	0.815	0.841
Number of id	30	30	30	30	30	30

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

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5. Conclusions and Suggestions

Based on empirical analysis, this study discusses the correlation between green finance and agricultural carbon emission reduction, and on this basis, further studies the leading role of environmental regulation in agricultural carbon emission reduction and green finance. The main conclusions are as follows: First of all, green finance has a significant role in promoting the realization of agricultural carbon emission reduction and the construction of sustainable agricultural development. By directing financial resources to environmental protection projects and supporting the research and development and promotion of green technologies, green finance effectively reduces carbon emissions in large-scale agricultural production. This shows that green finance, as an important tool for the combination of financial resources allocation and environmental protection, has a strong role. Secondly, environmental regulation has a strong positive guiding effect on green finance to achieve agricultural carbon emission reduction. Strict environmental regulation policies have promoted the emphasis of agricultural producers on environmental costs, and formed a benign interactive mechanism in which the financial market and the policy environment jointly promote agricultural carbon emission reduction.

The government should adapt to local conditions and formulate more reasonable and phased environmental regulation policies by dividing different development regions. It should not be a one-size-fits-all approach and should provide certain practical guarantees for rural development. For example, we will implement carbon emission standards, ecological compensation mechanisms and emission trading systems. At the same time, improve the environmental monitoring and law enforcement system to ensure the implementation of regulatory policies.We will promote innovation and dissemination of green technologies. We should increase the investment in the research and development of green finance in the field of agricultural core technology, encourage scientific research talents to cooperate with agricultural enterprises, and carry out investigation and research in the rural front line to realize the application of technology and related agricultural production. At the same time, through training and publicity, farmers are guided to adopt energy-saving and emission-reduction technologies, such as precision fertilization, water-saving irrigation and clean energy use.The government, financial institutions and agricultural producers should establish a cooperation mechanism to form a policy synergy between green finance and environmental regulation. For example, financial institutions can provide differentiated lending rates based on a company's carbon emissions performance to incentivise agricultural entities to actively reduce carbon emissions. In addition, the government should regularly release assessment reports on green finance and agricultural carbon reduction to enhance the transparency and implementation of policies.

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