

Article

Can Agricultural Credit Promote the Green Transformation of China's Agriculture?

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Abstract: The key to sustainable agricultural development is the transition to an environmentally friendly economic growth model. The development of agricultural credit (AC) plays an important role in promoting the shift of agricultural economic growth toward a green and low-carbon direction. In this context, a key question that needs to be addressed is the theoretical basis for how AC development affects agricultural green total factor productivity (AGTFP), and whether this relationship can be empirically tested. This article analyzes the impact mechanism of China's AC development on AGTFP and conducts empirical testing using provincial panel data from 2009 to 2019. The results show that AC development significantly contributes to improving AGTFP. In terms of the underlying mechanism, AC development primarily fosters agricultural green technology innovation, thereby enhancing AGTFP.

Keywords: agricultural credit; green technology innovation; agricultural green total factor productivity; large-scale land management



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1. Introduction

Since the United Nations Development Programme (UNDP) introduced the concept of “green development” in 2002, it has increasingly been recognized as a crucial pillar alongside economic growth and environmental conservation. Scholarly research has highlighted the benefits of adopting green production technologies in mitigating soil contamination [1], reducing carbon emissions [2], and promoting sustainable progress [3]. As the world's most populous developing nation, China, with 491 million rural households and 1.914 billion acres of cultivable land (according to the 2022 “China Natural Resources Statistical Bulletin”), has a critical role in advancing the eco-friendly transformation of its agricultural practices, which is key to promoting global green development.

As shown in Figure 1, with the continuous growth of China's agricultural GDP, agricultural carbon emissions and the use of chemical fertilizers increased rapidly before 2015. This trend poses a challenge to achieving the United Nations' green development goals. How can agricultural GDP growth be promoted while simultaneously reducing the negative outputs (such as carbon emissions) associated with this growth? In addressing this issue, scholars have attempted to evaluate agricultural green production by constructing total factor productivity models that incorporate the negative outputs of agricultural production [4,5].

Meanwhile, other scholars have examined the factors influencing agricultural green production, which primarily include the mismatch of agricultural production factors [6], the adoption of agricultural green production technologies (AGPT) [7], climate change [8],

agricultural insurance [9,10], agricultural planting patterns [11–14], government spending and green policy [12,15–18], and the impact of digital technologies [19–22]. Finally, some studies suggest that implementing land market reforms could positively influence agricultural green total factor productivity (AGTFP) [23].

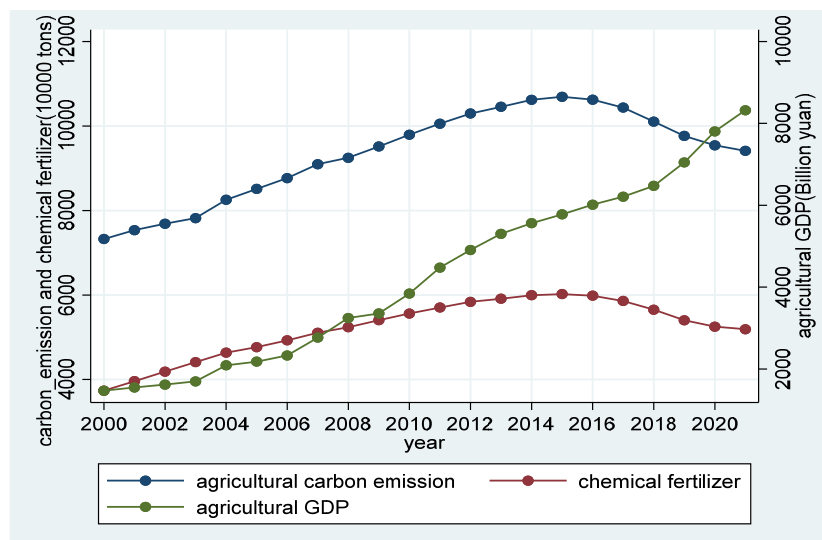


Figure 1. China’s agricultural GDP, agricultural carbon emissions, and chemical fertilizer use from 2000 to 2021.

The positive role of agricultural credit (AC) in promoting agricultural development has long been recognized by scholars. Research shows that AC development not only enhances agricultural GDP [24] and productivity [25] but also improves farmers’ welfare [26]. AC is crucial in enhancing green productivity. However, the mechanisms underlying this relationship remain unclear, and existing studies often neglect this critical aspect. While some literature on similar topics emphasizes the importance of digital finance in promoting green agricultural development [27–29], other scholars highlight that digital finance primarily improves farmers’ access to consumer credit without significantly impacting agricultural production credit [30]. Consequently, direct empirical evidence on the impact of financial factors on agricultural green development is still lacking. This article addresses this gap by analyzing AC development’s role in promoting green agricultural transformation.

The purpose of this study is to explore the pathways and marginal effects of AC development on agricultural green total factor productivity (AGTFP) from a sustainable development perspective. The theoretical framework is built on the principles of economies of scale and technological progress. The study employs a non-radial slacks-based measure (SBM) model to calculate the AGTFP index at the provincial level in China, further analyzing development trends and regional differences. Additionally, it uses methodologies such as the two-way fixed effects model to evaluate the marginal impact of AC development on AGTFP and investigate the transmission mechanisms involved.

The remainder of this article is structured as follows: The second section develops hypotheses based on existing literature and theoretical foundations. The third section introduces data sources, methods for calculating variables like agricultural green total factor productivity, and the empirical models used. The fourth section presents quantitative results that assess the impact of AC development on agricultural green productivity and includes a series of robustness tests. It also offers a detailed mechanism analysis. The fifth section concludes with research findings, policy implications, and an outline of potential limitations.

2. Theoretical Analysis and Research Hypotheses

Agricultural green total factor productivity (AGTFP) measures the comprehensive ability to maximize positive agricultural outputs (such as agricultural GDP) while minimizing negative outputs (such as carbon emissions) using minimal inputs. The development of agricultural credit (AC) impacts AGTFP by fostering green technology innovation and large-scale land management.

Green technology innovation undoubtedly has a positive effect on enhancing AGTFP. For instance, new plant breeding technologies can help resolve the trade-off between food security and sustainable agricultural development [31]. Investments in green technology innovation play a decisive role in reducing agricultural carbon emissions [32]. However, the vitality of green technology innovation is closely tied to support from AC. On one hand, research and development in technology carry inherent risks of failure, and AC development can mitigate the adverse effects of such failures on agricultural operators. On the other hand, AC enables farmers to adopt and promote green agricultural technologies. While these technologies often yield higher benefits, they also involve higher risks and hidden costs [33]. Therefore, AC development enhances AGTFP by advancing green technology innovation.

Large-scale farms are pivotal in improving AGTFP. These farms can better absorb the high sunk costs and risks associated with promoting and using green agricultural technologies. Compared to small-scale farmers, large-scale farmers, such as those operating family farms, can more effectively distribute the fixed costs of green technologies through economies of scale and diversified cropping structures. This approach also reduces the financial risks associated with technological innovations. Research shows that a 1% increase in the scale of agricultural production in China results in a 0.5% reduction in pesticide use and a 0.3% reduction in fertilizer use [34]. However, expanding large-scale agricultural operations is closely tied to AC development. In China, the per capita cultivated area of a single farmer is only 0.09 hectares, significantly smaller than the per capita cultivated area of farmers in the United States [35].

First, AC development enables large-scale farmers, such as family farms, to expand their operational scale and achieve economies of scale through land transfer [36]. Second, it supports improvements in agricultural infrastructure, such as irrigation systems, thereby reducing production and operating costs and enabling large-scale agricultural operations [37]. Thus, AC development enhances AGTFP by promoting efficient land management practices.

Based on the theoretical analysis in the previous text, we can derive the following hypothesis.

Hypothesis 1. *The development of AC can improve the productivity of green agricultural factors.*

Hypothesis 2. *Promoting agricultural green technology innovation is the transmission path for AC development to improve agricultural green factor productivity.*

Hypothesis 3. *Promoting the expansion of the land management scale is the transmission path for AC development to improve agricultural green factor productivity.*

3. Materials and Methods

3.1. Data Sources

This article uses balanced panel data from 30 provinces in China from 2008 to 2019. AC data are from the China Rural Financial Services Report, and other data are from the China Rural Statistical Yearbook, the China Statistical Yearbook, and other databases. Some missing values are imputed by linear interpolation.

3.2. Variable Selection

3.2.1. Calculation of AGTFP

The measurement methods for Green Total Factor Productivity primarily include parametric and non-parametric approaches. Based on existing research [38], this paper employs the SBM-GML index to measure AGTFP. In selecting agricultural input indicators, this study refers to relevant literature [39] and includes agricultural labor, fertilizer and pesticide use, land (agricultural sown area), agricultural machinery, and plastic film use, among others. For agricultural output indicators, the “total output value of agriculture, animal husbandry, forestry, and fishery” and “total agricultural carbon emissions” are selected as the desired and undesired outputs, respectively. Additionally, the “total output value of agriculture, forestry, animal husbandry, and fishery” is calculated using 2008 prices. The specific variables are shown in Table 1.

Table 1. Calculation indicators of AGTFP.

Type	Variable	Dimension
Inputs	labor	Number of employees in the primary industry (Ten thousand people)
	land	Agricultural sown area (thousand hectares)
	fertilizer	Amount of agricultural chemical fertilizers applied (10,000 tons)
	machinery	Agricultural mechanization (10,000 kilowatts)
	pesticide	Pesticide usage (10,000 tons)
	plastic film	Plastic film usage (10,000 tons)
Desirable output	Agricultural output	Billion yuan
Undesirable output	Total agricultural carbon emissions	Ten thousand tons

3.2.2. Calculation of AC Development

To measure AC development, most of the measures used in the literature at the regional level are “the ratio of AC to agricultural GDP” [24,40,41]. Drawing on existing research, this article uses the “ratio of agriculture, forestry, animal husbandry and fishery loans to agricultural GDP” as a measure of AC development. The “China Rural Financial Services Report” records loan data for agriculture, forestry, animal husbandry, and fisheries.

3.2.3. Mediating Variable

Agricultural Green Technology Innovation: Existing literature suggests that a greater number of green invention patents indicates a higher level of green technology innovation in a region [39,42]. Following existing research, this article uses the “total number of agricultural green invention patent applications and agricultural utility model patent applications” as an indicator to measure the agricultural green technology innovation level in each province. Data on agricultural green invention patent applications and agricultural utility model patent applications are sourced from the China Scientific Research Data Service Platform (CNRDS).

The Scale of Land Management: Since the China Rural Statistical Yearbook and related databases do not provide direct statistical data on the scale of land management, this article uses “the ratio of the total area of household-contracted farmland transfers to the total area of household-contracted farmland” as a proxy variable. Literature [43] has shown that land transfers in China enhance agricultural productivity by expanding the scale of farm operations. Therefore, it is reasonable to use the “ratio of transferred farmland under household contracts to the total contracted farmland area” to reflect the scale of land management at the provincial level.

3.2.4. Control Variables

Referring to existing research [9,10,39], the control variables selected in this article include the structure of agricultural planting types, the extent of agricultural natural disas-

ters, the degree of agricultural mechanization, as well as the provincial economic structure, agricultural fiscal expenditure, and other factors. The measurement method for the variable representing the structure of agricultural planting types is “the proportion of the sown area of grain crops to the total sown area of crops”. The extent of agricultural natural disasters is measured by “the ratio of the affected area to the total sown area of crops”. The degree of agricultural mechanization is represented by “the total power of agricultural machinery relative to the total sown area of crops”. The provincial economic structure is measured using “the ratio of the province’s agricultural GDP to its total GDP”. Fiscal expenditure on agriculture is calculated as “the logarithm of provincial fiscal expenditure on agriculture, water, and forestry”. The specific variable description is shown in Table 2.

Table 2. Descriptive analysis of variables.

Abbreviation	Variables	Measurements
Dependent Variable		
agtfp	Agricultural green total factor productivity	Frontier-based estimate
Independent Variables		
agrloan_rate	agricultural credit development	The ratio of agricultural loans to primary industry GDP
Mediating Variables		
tech_gre	Regional agricultural green innovation level	“Total number of agricultural green invention patent applications and agricultural utility model patent applications” (100 items)
rate_transfer	Degree of scale of farmland planting	The ratio of the total area of farmland transferred under household contracting to the area of farmland contracted by households
Control variables		
machine	Degree of agricultural mechanization	The ratio of the total power of agricultural machinery to the total sown area of crops (10,000 kilowatts/1000 hectares)
agr_plastr	Structure of agricultural planting types	The proportion of the sowing area of grain crops to the total sowing area of crops
disaster	The degree of natural disasters suffered by agriculture	The ratio of agricultural disaster area to total agricultural sowing area
rate_agrigdp	Provincial economic structure	The ratio of the GDP of the primary industry to the total GDP of the province
lfisexp_agr	Agricultural fiscal expenditure	The logarithm of fiscal expenditure on agricultural, forestry, and water affairs in provinces (billions yuan)

3.3. Empirical Model

To test whether the development of AC has a positive impact on total factor productivity in agriculture, this paper constructs a panel fixed effects econometric model for empirical testing. According to the Hausman test results [44], using a fixed effects model is the optimal result.

$$\text{agtfp}_{it} = \beta_0 + \beta_1 \text{agrloan_rate}_{it} + \beta_2 \text{control_var}_{it} + \chi_{it} \quad (1)$$

In the above formula, agtfp_{it} represents the AGTFP of province i in year t , agrloan_rate_{it} represents the degree of AC development of province i in year t . control_var_{it} represents a series of control variables. χ_{it} represents the error term. If the coefficient β_1 is significantly positive, it means that Hypothesis 1 is accepted.

To verify whether the development of AC will have a positive impact on AGTFP through green technology innovation and expanding land management scale. This paper constructs the following mediation effect model.

$$\text{media_var}_{it} = \varphi_0 + \varphi_1 \text{agrloan_rate}_{it} + \varphi_2 \text{control_var}_{it} + \varepsilon_{it} \quad (2)$$

$$\text{agtfp}_{it} = \eta_0 + \eta_1 \text{agrloan_rate}_{it} + \eta_2 \text{media_var}_{it} + \eta_3 \text{control_var}_{it} + \gamma_{it} \quad (3)$$

(2) The formula represents two intermediate variables: “agricultural green technology innovation” and “land management scale”. When media_var_i expressing agricultural green technology innovation (tech_gre_{it}), if in Equation (2) φ_1 is positively significant and in Equation (3) η_2 is also positively significant, it means that the mediating effect is established [45]. AC development can have a positive impact on AGTFP by promoting agricultural green technology innovation. Hypothesis 2 has been accepted. In the same way, when media_var_i represents the scale of land management ($\text{rate_transfer}_{it}$), if in Equation (2) φ_1 is positively significant and Equation (3) η_2 is also positively significant, it means that Hypothesis 3 is accepted.

4. Conclusion Analysis

4.1. Descriptive Statistics

The data in Table 3 show that the average value of total factor productivity in agriculture is 0.762, with a standard deviation of 0.155, indicating notable differences between provinces. Similarly, the average value of the AC development level is 0.4, with a standard deviation of 0.25, suggesting the need for further improvement in the overall development of AC.

Table 3. Descriptive analysis.

Variable	Mean	Std. Dev.	Min	Max
agricultural green total factor productivity (agtfp)	0.762	0.155	0.0720	1
agricultural credit development (agrloan rate)	0.400	0.250	0.124	1.737
Regional agricultural green innovation (tech_gre)	2.784	4.133	0.00356	24.68
Degree of scale of farmland planting (rate_transfer)	0.283	0.166	0.0233	0.873
degree of agricultural mechanization (machine)	0.640	0.253	0.239	1.387
agricultural planting structure (agr plastr)	0.663	0.140	0.357	0.971
The degree of natural disasters suffered by agriculture (disaster)	0.175	0.131	0	0.696
Provincial economic structure (rate agrigdp)	10.01	5.251	0.300	28.10
Agricultural fiscal expenditure (lfisexp agr)	5.977	0.633	4.058	7.178

Note: In parentheses are the standard deviations.

Regarding the mediating variables, the average values for the level of agricultural green technology innovation and the farmland transfer ratio are 2.784 and 0.283, respectively. The descriptive analysis of the control variables indicates that the mean value of agricultural mechanization is 0.663, with a standard deviation of 0.14. Additionally, the value added by the primary industry accounts for 13.1% of the provincial production. The mean share of total value added is 10.01, with a standard deviation of 5.241.

Finally, the mean value of agricultural fiscal expenditure is 597.7 million yuan, with a standard deviation of 0.633. As shown in Table 4, the correlation matrix confirms that there is no multicollinearity issue among the variables.

Table 4. Correlation matrix of variables.

	agrloan_rate	machine	agr_plastr	disaster	rate agrigdp	lfisexp agr
agrloan rate	1					
machine	0.0968	1				
agr_plastr	0.0920	0.00390	1			
disaster	0.1293 *	−0.0703	0.100	1		
rate agrigdp	−0.1855 *	−0.3429 *	−0.0933	0.2536 *	1	
lfisexp agr	−0.0178	−0.0673	0.1287 *	−0.2853 *	−0.00230	1

* Represents the significance at 5%.

Figure 2 shows the average development trend of China's AC development and AGTFP from 2009 to 2019. In general, China's AGTFP and AC development show an upward trend. This preliminary indicates that there is a statistically positive correlation between China's AGTFP and AC.

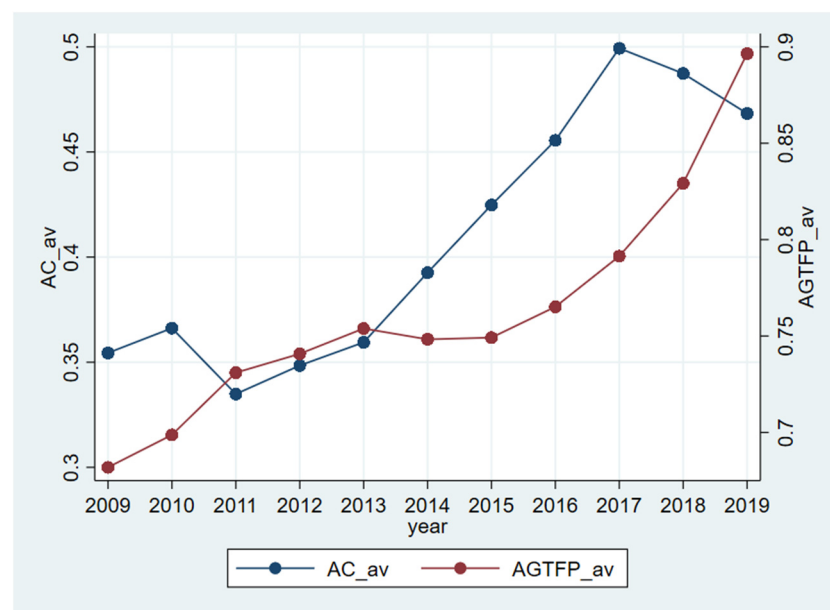


Figure 2. China's agricultural credit (AC) and agricultural green total factor productivity (AGTFP) from 2009 to 2019.

4.2. Regression Analysis

Table 5 shows a series of empirical results on the impact of AC development on AGTFP. Columns (1) control individual fixed effects, Columns (2) control time fixed effects, and Columns (3) add control variables and controls both individual fixed effects and time fixed effects. At the same time, to eliminate the bias caused by heteroscedasticity on the standard errors of the estimated coefficients, the three columns of empirical results all use clustered standard errors at the individual level. The specific empirical results are as follows.

From the empirical results in the first column of Table 5, it can be observed that, under the condition of controlling only individual fixed effects, the marginal coefficient of AC development on agricultural green total factor productivity (AGTFP) is 0.138. Furthermore, this coefficient is significant at the 1% level, indicating that for every 1% increase in the ratio of AC to agricultural GDP, AGTFP increases by 0.138.

Similarly, the second column of the empirical results shows that, when only time-fixed effects are controlled, the marginal coefficient of AC development on AGTFP is 0.101. Finally, the empirical results in the third column of Table 5 reveal that, when individual fixed effects, time-fixed effects, and control variables are accounted for, the impact of AC development on AGTFP remains positively significant at the 5% level. These findings support the hypothesis that AC development enhances agricultural green total factor productivity and demonstrate the robustness of this relationship.

Additionally, according to the empirical results in column 3, the marginal coefficient of agricultural natural disasters on AGTFP is -0.105 , which is significant at the 5% level. This indicates that natural disasters negatively affect the improvement of AGTFP. A possible explanation is that farmers may resort to using more highly polluting production inputs, such as fertilizers and pesticides, to mitigate the production losses caused by natural disasters.

Table 5. Agricultural credit (AC) development and agricultural green total factor productivity (AGTFP).

Variables	Model 1	Model 2	Model 3
	fe	re	Two-Way FE
	agtfp	agtfp	agtfp
agrloan_rate	0.138 *** (0.037)	0.101 *** (0.038)	0.068 ** (0.028)
machine			-0.045 (0.053)
agr_plastr			0.123 (0.167)
disaster			-0.105 ** (0.043)
rate_agrigdp			0.015 ** (0.006)
lfisexp_agr			-0.054 (0.036)
Constant	0.707 *** (0.015)	0.722 *** (0.030)	0.742 *** (0.214)
Time-fixed effect	No	Yes	Yes
Individual fixed effects	Yes	No	Yes
Observations	330	330	330
R-squared	0.060		0.663
Number of code	30	30	30

Note: *** and ** represent significance levels of 1% and 5%, respectively.

Moreover, the factors related to agricultural planting structure have a positive and significant impact on AGTFP at the 5% significance level. A potential reason for this is that grain crops, compared to cash crops, are more likely to achieve economies of scale. Consequently, on a per-unit area basis, grain crops require less input of highly polluting production materials such as fertilizers and pesticides.

4.3. Heterogeneity Analysis

Table 6 shows the impact of the development of AC in different regions on total factor productivity in agriculture. All empirical results in Table 6 control for individual fixed effects, time-fixed effects, and control variables.

From the three columns of empirical results in Table 6, we observe that the marginal coefficient of AC on green agricultural productivity is 0.111 in the eastern region, 0.14 in the central region, and 0.111 in the western region. Additionally, the overall marginal productivity coefficient is 0.095. These results indicate that in economically developed regions, the development of AC plays a more significant role in enhancing AGTFP. Therefore, promoting the development of AC is a crucial strategy for advancing the green and sustainable development of agriculture.

Table 6. Agricultural credit (AC) development and agricultural green total factor productivity (AGTFP): different regions.

Variables	Model 4	Model 5	Model 6
	Two-Way FE	Two-Way FE	Two-Way FE
	Eastern Region	Central Region	Western Region
	agtfp	agtfp	agtfp
agrloan_rate	0.111 * (0.051)	0.140 (0.086)	0.095 ** (0.040)
machine	−0.105 (0.094)	0.041 (0.037)	0.167 (0.136)
agr_plastr	0.412 (0.231)	0.251 (0.276)	−0.111 (0.480)
disaster	−0.001 (0.026)	−0.151 ** (0.050)	−0.171 * (0.086)
rate_agrigdp	0.010 (0.011)	0.011 *** (0.003)	0.028 (0.016)
lfisexp_agr	−0.017 (0.054)	−0.021 (0.037)	−0.132 (0.106)
Constant	0.498 (0.289)	0.431 (0.351)	0.962 (0.712)
Time-fixed effect	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes
Observations	132	99	99
R-squared	0.745	0.768	0.695
Number of code	12	9	9

Note: ***, **, and * indicates the significance levels of 1%, 5%, and 10%, respectively.

4.4. Robustness Test

Table 7 presents the results of the quality inspection of agricultural products discussed in this article. Following the methodology outlined by Latief et al. [40], two approaches are employed to assess the quality of agricultural products. The first involves using a one-period lagging indicator of AC growth, while the second replaces the indicators of AC development with the ratio of credit allocated to agricultural product quality inspection.

Table 7. Agricultural credit (AC) development and agricultural green total factor productivity (AGTFP): robustness test.

Variables	Model 7	Model 8	Model 9	Model 10
	fe	Two-Way FE	fe	Two-Way FE
	agtfp	agtfp	agtfp	agtfp
	agtfp	agtfp	agtfp	agtfp
L.agrloan_rate	0.174 *** (0.034)	0.075 ** (0.033)		
agrloan_land			0.072 ** (0.032)	0.026 * (0.014)
machine		−0.061 (0.054)		−0.061 (0.058)
agr_plastr		0.070 (0.176)		0.127 (0.179)
disaster		−0.105 ** (0.050)		−0.103 ** (0.043)
rate_agrigdp		0.015 ** (0.007)		0.015 ** (0.006)
lfisexp_agr		−0.044 (0.037)		−0.048 (0.037)
Constant	0.701 *** (0.014)	0.755 *** (0.247)	0.741 *** (0.010)	0.740 *** (0.223)
Time-fixed effect	No	Yes	No	Yes
Individual fixed effects	Yes	Yes	Yes	Yes
Observations	300	300	330	330
R-squared	0.096	0.641	0.096	0.660
Number of code	30	30	30	30

Note: ***, **, and * indicates the significance levels of 1%, 5%, and 10%, respectively.

From the first column of Table 7, it is evident that using the lagged first-period AC development variable as a proxy for AC development, the hypothesis that “the development of AGTFP benefits from AC factors” remains positively significant at the 1% level. Furthermore, the empirical results in column 2 of Table 7 indicate that even after including control variables, time-fixed effects, and individual fixed effects, AC development continues to have a positive and significant impact on AGTFP at the 5% significance level. This demonstrates the robustness of Hypothesis 1.

Additionally, the results in columns 3 and 4 of Table 7 show that when the ratio of AC to agricultural area is used as a proxy variable for AC development, AC development still significantly enhances the green total factor productivity of agriculture. This further reinforces the validity of Hypothesis 1.

4.5. Endogeneity Test

In the above, the development level of provincial-level Agricultural Credit (AC) is used as the explanatory variable in this article. However, as green and low-carbon agricultural production and operational methods are increasingly valued by the government, these methods may also attract financial institutions to expand the scale of AC supply. Therefore, using AC development as an explanatory variable may lead to endogeneity problems due to reciprocal causality. To address this issue, this paper uses the concentration of the provincial banking industry (HHI) as an instrumental variable for AC development. Theoretically, a higher concentration in the banking industry indicates a higher degree of banking monopoly, meaning that financial institutions will issue less AC, but it will not have a direct impact on agricultural green total factor productivity. Therefore, it is reasonable to use the concentration of the banking industry in a province as an instrumental variable [46]. On this basis, this article employs the 2SLS model for empirical testing. The specific empirical results are as follows.

From the empirical results in column 1 of Table 8, we can see that the Anderson LM statistic for the non-identifiability test, without considering control variables, is 50.022, which is significant at the 1% significance level. This indicates that there is no issue with weak instrumental variables when using provincial banking industry concentration as an instrumental variable. Based on this, the Cragg-Donald Wald F statistic for weak instrumental variable testing is 50.421 (greater than 10). The *p*-value of the Sargan statistic for the over-identification test is 0.000, suggesting that there are no weak instrumental variables or over-identification issues in the selection of instrumental variables. Furthermore, under the condition of using provincial banking concentration as the instrumental variable, the development of AC still has a positive and significant impact on AGTFP at the 1% significance level, indicating that Hypothesis 1 is robust. In addition, from the empirical results in columns 2 and 3 of Table 8, it can be seen that after adding control variables, individual fixed effects, and time fixed effects, using the provincial banking concentration index (HHI) as the instrumental variable, the empirical results remain robust. This further suggests that, when considering endogeneity issues, the development of AC can still improve the green total factor productivity of agriculture.

Table 8. Agricultural credit (AC) development and agricultural green total factor productivity (AGTFP): endogeneity test.

Variables	Model 11	Model 12	Model 13
	2SLS	2SLS	2SLS
	agtfp	agtfp	agtfp
hhi_bank	−3.206 *** (0.607)	−3.204 *** (0.765)	−5.385 *** (2.064)
machine		−0.073 * (0.038)	−0.033 (0.037)

Table 8. Cont.

Variables	Model 11	Model 12	Model 13
	2SLS	2SLS	2SLS
	agtfp	agtfp	agtfp
agr_plastr		0.019 (0.155)	0.329 * (0.178)
disaster		−0.111 ** (0.051)	−0.074 ** (0.033)
rate_agrigdp			0.014 *** (0.003)
lfisexp_agr			−0.045 (0.033)
Constant	1.144 *** (0.060)	1.218 *** (0.104)	1.425 *** (0.273)
Time-fixed effect	No	No	Yes
Individual fixed effects	Yes	Yes	Yes
Anderson LM statistic	50.022 (0.000)	35.670 (0.000)	17.159 (0.000)
Cragg-Donald Wald F	53.421	35.872	15.577
Sargan statistic	0.000	0.000	0.000
Observations	330	330	330
Number of code	30	30	30

Note: ***, **, and * indicates the significance levels of 1%, 5%, and 10%, respectively.

4.6. Mechanism Test

In the previous text, this article empirically tested that AC is beneficial for improving AGTFP. However, further empirical testing is needed to determine whether the development of AC promotes the improvement of AGTFP through agricultural green technology innovation and the expansion of land management scale. Therefore, this article attempts to test the transmission mechanism by constructing a mediation effect model. The specific empirical results are presented in Table 9.

Table 9. Agricultural credit (AC) and agricultural green total factor productivity (AGTFP): mechanism analysis.

Variables	Model 14	Model 15	Model 16	Model 17
	Two-Way FE	Two-Way FE	Two-Way FE	Two-Way FE
	agtfp	tech_gre	rate_transfer	agtfp
tech_gre				0.003 * (0.002)
rate_transfer				0.017 (0.076)
agrloan_rate	0.068 *** (0.023)	2.691 *** (0.891)	0.080 *** (0.018)	0.059 ** (0.024)
machine	−0.045 (0.032)	3.395 *** (1.257)	0.033 (0.025)	−0.055 * (0.032)
agr_plastr	0.123 (0.120)	−2.395 (4.711)	0.976 *** (0.093)	0.113 (0.141)
disaster	−0.105 *** (0.028)	1.717 (1.088)	0.016 (0.022)	−0.110 *** (0.028)
rate_agrigdp	0.015 *** (0.002)	0.077 (0.096)	0.003 (0.002)	0.015 *** (0.002)
lfisexp_agr	−0.054 * (0.029)	−2.412 ** (1.137)	−0.005 (0.022)	−0.047 (0.029)
Constant	0.742 *** (0.192)	10.736 (7.571)	−0.568 *** (0.150)	0.722 *** (0.197)
Observations	330	330	330	330
R-squared	0.663	0.448	0.867	0.667
Number of code	30	30	30	30

Note: ***, **, and * indicates the significance levels of 1%, 5%, and 10%, respectively.

From the empirical results in column 2 of Table 9, we can see that the development of AC has a significant positive impact on promoting agricultural green technology innovation at the 1% significance level. This indicates that the development of AC can significantly promote agricultural green technology innovation. Meanwhile, based on the empirical results in column 3 of Table 9, we find that improving the level of AC development has a positive and significant effect on farmers expanding their land management scale at the 1% significance level. This suggests that the development of AC is beneficial for farmers in expanding their land management scale. Finally, from the empirical results in column 4 of Table 9, it can be seen that, controlling for AC variables, the factor of agricultural green technology innovation is positively significant at the 5% significance level. This indicates that improving the level of AC development can positively impact AGTFP by promoting agricultural green technology innovation [47]. Hypothesis 2 has been verified. However, from the empirical results in column 4 of Table 9, it can be seen that, after adding AC development variables, the impact of agricultural land management scale variables on AGTFP is not significant. This suggests that Hypothesis 3 is not robust. It cannot be proven that the development of AC improves AGTFP by optimizing agricultural land management. A possible reason is that, although the development of AC has promoted an increase in the proportion of cultivated land transfer, this rise in the proportion of land transfer has also increased competition in the cultivated land market, leading to higher rental costs for cultivated land [48]. Therefore, the development of AC makes it difficult to improve AGTFP by promoting land management.

5. Conclusions and Policy Implications

This article uses a panel bidirectional fixed effects model to empirically analyze the impact of AC development on AGTFP. The empirical results indicate that the development of AC has a significant positive effect on agricultural green factor productivity. These results are further confirmed by a series of robustness tests. Promoting green technology innovation is the main pathway through which AC development improves AGTFP.

Based on the empirical results, the following policy implications can be derived. Firstly, in enhancing the green and sustainable development of agriculture, policymakers should focus on improving the level of AC services. For example, promoting the digital transformation of AC institutions. By incentivizing AC institutions to use digital technologies such as mobile payments and digital credit evaluation, the cost of AC issuance can be reduced, and the inclusiveness of AC services can be improved. Secondly, agricultural green technology innovation is an important means to improve the sustainable development of agriculture, and policymakers should optimize the environment for agricultural green technology innovation. For example, establishing an information communication platform between agricultural research institutions and farmers to reduce the degree of information asymmetry between the supply and demand sides of agricultural green technology. Finally, policymakers should address the widening gap in agricultural green and sustainable development between regions through the expansion of AC. For instance, while formulating policies to improve AC service levels, policymakers should also enhance agricultural green technology promotion services in economically underdeveloped areas. At the level of green and sustainable agricultural development, policymakers should promote the synergy between AC policies and agricultural green technology promotion policies.

It should be noted that the relevant research results of this article primarily target emerging markets such as China. Due to the agricultural property rights and agricultural land contracting systems, these factors will inevitably affect AGTFP. Therefore, whether the conclusions drawn from this study can also be applied to other countries, such as the United Kingdom and the United States, requires further testing. Finally, when measuring sustainability, it would be meaningful to consider factors such as biodiversity, soil health, and water use efficiency. Further research is needed on this matter.

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