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Can Digital Financial Inclusion Drive High-Quality Agricultural Development in China's Border Areas?

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Abstract: *This study uses interprovincial panel data from 2011 to 2021 to examine the effects of digital financial inclusion on the high-quality development of agriculture in China's frontier regions. It builds an assessment system for high-quality agricultural development in these areas from four perspectives: high and stable yield, high efficiency, high income, and high environmental protection. It measures this using entropy weighting. The impact and mechanism of digital inclusive financing on the high-quality development of agriculture in China's border areas are then investigated using the fixed effect model, the mediation effect model, and the panel threshold effect model. The study's findings demonstrate that digital inclusive finance can greatly advance the high-quality development of agriculture in China's border regions, with agricultural science and technology innovation serving as a mediating factor in the transmission channel. Moreover, the double threshold effect of digital inclusive finance will have an impact on agricultural science and technology innovation when it comes to advancing the high-quality development of agriculture in China's border regions. Thus, recommendations like quickening the pace of digital inclusive finance growth and encouraging the advancement of agricultural research and technology innovation may be made to support the superior development of agriculture in China's border areas.*

Keywords: *digital financial inclusion, China's border areas, agricultural high-quality development, agricultural science and technology innovation*

1. Introduction

In addition to helping to mitigate the external risks associated with climate change, rural inclusive finance is critical in reducing the income gap between rural and urban areas, easing credit restrictions for different kinds of businesses, improving human capital in rural areas, advancing agricultural technology, and so on[1]. The conventional inclusive finance is losing its viability and efficiency due to issues with dispersed network institutions, temporal and geographic limitations, single goods, and high application thresholds[2].China developed the first national-level strategy plan for equitable financial development in 2016, outlining the inclusive finance development principles and objectives. The growth and extension of traditional inclusive finance is known as "digital inclusive finance," and it is made possible by digital technologies like big data mining, blockchain, and cloud computing. These innovations greatly increase the efficiency of financial services, streamline the financial service chain, and simplify procedures[3]. Governments and international banking institutions have worked to advance digital inclusive finance in China's border provinces, offering township enterprises and farmers easy access to credit funds and financing channels so that all major rural bodies can effectively assess and return loans and support the superior development of China's border areas' agriculture.

Agricultural science and technology innovation is the engine behind high-quality agricultural development. Since agriculture is the backbone of the national economy, realizing high-quality development requires leveraging scientific and technological innovation to overcome resource and environmental constraints, particularly in China's border provinces. Modern agriculture can be modernized with abundant resources and a wealth of benefits.

Therefore, this paper establishes an evaluation system for the high-quality development of agriculture in the frontier regions by combining the characteristics of the frontier regions and, based on prior research, collects rural data in China's frontier regions from 2011 to 2021. It then empirically verifies the impact of digital inclusive finance and its various dimensions on the high-quality development of agriculture in the frontier regions and investigates the relationship between digital inclusive financial and agricultural

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science and technology innovation.

2. Theoretical Analysis and Research Hypotheses

2.1. A theoretical examination of the direct impact of inclusive digital finance on the development of high-quality agriculture in border regions

With the restriction of funds for the "three rural areas" and the encouragement of the development of online credit and insurance services in rural areas, digital financial inclusion has a positive impact on lowering credit constraints in rural areas, optimizing the structure of the agricultural industry, and improving the efficiency and quality of agricultural production[4].Additionally, digital finance inclusion enhances loan opportunities for farmers, broadens the pool of capital available to them for the purchase of agricultural machinery, boosts their income, encourages them to invest in fixed assets during the agricultural production process, and advances agricultural mechanization[5], all of which contribute to the stability of rural agricultural production in the Six Border Region. Through effective resource allocation, financial innovation, and digital networks, digital inclusive finance can aid in lowering agricultural carbon emissions and achieving environmental friendliness[6]. In light of this, Hypothesis 1 is put out in this work.

Hypothesis 1: In China's border regions, high-quality agricultural development may be encouraged via digitally inclusive finance.

2.2. A theoretical examination of the threshold effect of inclusive digital financing on the growth of high-quality agriculture in China's border regions

The development of digital inclusive finance is uneven, with variations in each province's level of economic development and geographic circumstances in China's border regions. Additionally, as the market economy becomes more open, so does the dynamic development of digital inclusive finance. Consequently, the high-quality development of agriculture in the border regions may be impacted differently by various stages of the development of digital inclusive finance. Different effects are caused by high quality development[7]. Considering this, proposes hypothesis 2:

Hypothesis 2: The influence of digital inclusive finance on the high-quality growth of agriculture in China's border regions has a threshold effect.

2.3. A theoretical examination of the indirect effects of digital inclusive financing on the development of high-quality agriculture in border regions

In addition to lowering transaction and information costs and increasing farmer demand for the use of new technologies, digital inclusive finance satisfies farmers' financial demands by fostering new services and financing models. Talents in agricultural science and technology can make appropriate use of the scarce resources for agricultural innovation, foster the integration of science and technology with agriculture, and advance the advancement and promotion of agricultural scientific and technological accomplishments[8]. First and foremost, as contemporary finance, digital inclusive finance can take part in the process of technological innovation, equipment improvement, and human capital transformation in agriculture; it can also expand agricultural socialized services, enhance enterprise technological innovation, improve investment in research and development, and raise the productivity of agriculture as a whole[9][10]. In light of this, the following theories are put forth in this paper:

Hypothesis 3: By encouraging innovations in agricultural science and technology, digital finance inclusion indirectly supports the high-quality growth of agriculture in China's border regions.

3. Research Design

3.1. Econometric model setting

Based on the theoretical analysis and assumptions, digital financial inclusion has both direct and mediating repercussions for the high-quality development of agriculture in China's border areas. First, the fixed effect model and panel threshold regression model are used to explore the direct effect of digital financial inclusion on the high-quality development of agriculture in China's border areas; second, adopt

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the mediation effect model to study the mediation effect of digital inclusive finance to promote the high-quality development of agriculture in China's border areas through agricultural science and technology innovation. The following threshold regression model (Model 3) is established with the logarithm of the total digital financial inclusion index as the threshold variable.

$$agri_{it} = \alpha_0 + \alpha_1 difi_{it} + \alpha_2 \sum_{i=1}^{n} Z_c + \mu_i + \varepsilon_{it} \quad (1)$$

$$innov_{it} = \beta_0 + \beta_1 difi_{it} + \beta_2 \sum_{i=1}^{n} Z_c + \mu_i + \varepsilon_{it} \quad (2)$$

$$agri_{it} = \theta_0 + \theta_1 difi_{it}(p_{it} \le u_1) + \theta_2 difi_{it}(u_1 \le p_{it} \le u_2) + \theta_3 difi_{it}(p_{it} > u_2) + \theta_4 \sum_{i=1}^{n} Z_c + \mu_i + \varepsilon_{it} \quad (3)$$

$$agri_{it} = \eta_0 + \eta_1 difi_{it} + \eta_2 innov_{it} + \eta_3 \sum_{i=1}^{n} Z_c + \mu_i + \varepsilon_{it} \quad (4)$$

In this case,Z_c represents the set of control variables that affect high-quality agricultural development in China's frontier regions; p_{it} indicates the threshold variable, u_i symbolizes the threshold to be estimated, μ_i represents the individual fixed effect, and ε_{it} stands for the random error term; α、β、θ、and η are the coefficients to be estimated. Where agri is the level of high-quality agricultural development, difi is the digital financial inclusion index, innov is the index for agricultural technology and science innovation.

3.2. Characterizing the data and variables

3.2.1. Variables explained

The degree of high-quality agricultural development (agri) in border regions. The majority of the literature creates assessment indices for the high-quality growth of agriculture based on five factors: innovation, greenness, openness, coordination, and sharing[11]. This study develops four first-level indicators of high stable yield, high efficiency, high income, and high environmental protection in border areas based on the features of agricultural production in border areas. This study builds a second-level indicator system from four aspects: farmers' living income level, agricultural production efficiency, agricultural production stability, and agricultural environmental friendliness, based on the features of agricultural production in border areas. Lastly, choose the three indexes by combining the two indexes. The particular index scheme is displayed in Table 1.

This study employs the entropy weight approach to calculate the weight of each indicator in order to quantitatively examine the amount of high-quality growth of agriculture in the border area. The particular procedures involved in this process are as follows:

Standardized processing data comes first.

positive sign:$y_{ij} = (x_{ij} - \min x_j)/(\max x_j - \min x_j)$

negative sign:$y_{ij} = (\max x_j - x_{ij})/(\max x_j - \min x_j)$

where $\min x_j$ and $\max x_j$ are the minimum and maximum observed values of the jth indicator, respectively, and x_{ij} is the observed value of the jth indicator in province i.

Next, ascertain the weights of the indicators. Second, determine the index weight. Calculate the contribution degree $p_{ij} = y_{ij}/\sum_i y_{ij}$, calculate the entropy weight $e_j = -\frac{1}{lnn}\sum_i p_{ij}\, lnp_{ij}$, calculate the redundancy $g_j = 1 - e_j$, calculate the weight of each index $w_j = g_j/\sum_j g_j$.

Finally, the comprehensive index of high-quality agricultural development in border areas was calculated $f_i = \sum_j y_{ij}$.

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Table 1: Evaluation index system of high-quality agricultural development

First-class index	Second-class index	Third-class index	Attribute
High stable yield	Stability of agricultural production	Industrial structure adjustment index	+
		Intensity of damage	-
		Agricultural means of production price index	-
High efficiency	Agricultural productivity	Land productivity	+
		Labor productivity	+
		Level of agricultural mechanization	+
High income	The level of farmer's living income	Per capita disposable income of rural residents	+
		Rural living standard	-
High environmental	Agricultural environment friendly	Fertilizer application intensity	-
		Pesticide application intensity	-
		Density of mulch use	-
		Agricultural water consumption	-

3.2.2. Core explanatory variables

The three primary parameters of the development level of digital inclusive finance (difi) are the degree of digitization (degr), depth of usage (usdep), and breadth of coverage (coverage). The Digital Inclusive Finance Index (2011–2021), created by Peking University's Digital Finance Research Center, is used to gauge the state of digital inclusive finance development in the frontier region. Because the index does not correspond to the high-quality development level of agriculture in the frontier region, which was calculated earlier, logarithmic numbers are used to conduct the empirical analysis of digital inclusive finance.

3.2.3. Intermediate variable

Innovation in Agricultural Science and Technology (innov). To create a comprehensive assessment of the state of agricultural science and technology innovation, first create first-level indicators based on the input and output aspects of the field[12]. Next, combine these indicators with second-level indicators derived from the four fields of financial input, human resources input, economic output, and scientific and technological achievements. Lastly, apply the entropy weighting method to complete the assessment. In Table 2, the particular index system is displayed.

Table 2: Evaluation index system of agricultural science and technology innovation

First-class index	Second-class index	Indicator definitions	Attribute
Agricultural science and technology and innovation inputs	Capital investment	Internal expenditure on R%D funding* (gross agricultural output/gross regional product)	+
	Talent inputs	R&D personnel converted to full-time equivalent researchers (person-years)	+
Agricultural science technology and innovation outputs	Economic output	Agricultural value added	+
	Scientific and technological achievements	Agricultural machinery	+
		Technology market turnover	+

3.2.4. Control variables

There are a number of factors influencing the high-quality development of agriculture in China's border areas in addition to digital inclusive finance and agricultural science and technology innovation, so the model uses the degree of Internet penetration, the degree of marketization, and the years of education per capita in rural areas as control variables. Because none of these control variables are on the same order of magnitude as the explanatory variables, this paper divides each control variable by 100. The names and symbols of each variable of the econometric model, as well as a detailed description of the variable, are presented in Table 3.

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Table 3: Interpretation and quantification of economic model parameters

Variables	Variable names and symbols	Description of variables
Explained Variable	Level of high-quality development of agriculture in border areas (agri)	Composite index of high-quality development of agriculture calculated by entropy method
Explanatory variables	Digital financial inclusion development level (difi)	Logarithm of "Peking University Digital Financial Inclusion Index".
	Breadth of coverage (cover)	
	Depth of use (usdep)	
Mediating variable	Agricultural science and technology innovation(innov)	Comprehensive Index of Agricultural Science and Technology Innovation Calculated by Entropy Method
Control variable	Internet penetration(ip)	Rural broadband access users (10,000 households) divided by 100
	Degree of marketization(mar)	Logarithm of the data in the Report on China's Marketization Index by Provinces
	Rural years of education per capita(edu)	Average years of education of rural population (years) divided by 100

3.3. Description of data

The study sample is made up of the provincial panel data structure for nine borderlands provinces in China for the years 2011–2021, including Jilin, Liaoning, Heilongjiang, Inner Mongolia, Gansu, Xinjiang, Tibet, Yunnan, and Guangxi. The data were gathered from China Economy Network (CEWN) databases in all years, as well as the China Rural Statistical Yearbook, China Agricultural Yearbook, China Educational Yearbook, etc. The missing data is filled in using the moving average approach.

4. Examination of the empirical findings

4.1. Fixed effects model regression

Using all of the sample data from nine provinces in China's frontier regions from 2011 to 2021, panel regression is used to investigate the effects of digital inclusive finance and its dimensions on the high-quality development of agriculture in these regions. The explanatory variables include the total index of digital inclusive financial development, breadth of coverage, depth of use, and digitization, and the explanatory variable is the high-quality level of agricultural development in these regions. The cointegration of the data is tested using the Granger causality test. The p-value for the Granger causality test, which examines the causal link between high-quality agricultural growth in border regions and digital financial inclusion, is 0.000, meaning that digital financial inclusion is the major cause. When dealing with face-to-face panel data, the question of whether to employ the fixed effect or random effect model is unavoidable. The Hausmann test yields a p-value of 0.0000, suggesting that the fixed effect model should be used. Table 4 displays the regression results of the fixed-effects model. It is evident from this that the three dimensions of digital financial inclusion—coverage breadth, use depth, and digitization—as well as the total index of digital financial inclusion will encourage the development of high-quality agriculture in border areas. Of these, the use of depth has the greatest impact on the development of high-quality agriculture in China's border areas. Hypothesis 1 is established.

4.2. Panel Threshold Model Regression

4.2.1. Threshold effect test

The objective of this study is to investigate the impact of digital inclusive finance on the development of high-quality agriculture in China's border areas. To ascertain the precise threshold model form, the panel threshold theory is utilized to estimate the single, double, and triple thresholds independently. A simulation of the test of the distribution of statistics and the critical value is conducted 300 times using bootstrap sampling, and the results are displayed in Table 5. The double threshold model ought to be developed since, as Table 5 makes evident, the triple threshold model failed the significance test and the estimate findings for both the double and single thresholds are significant at the 5% level.

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Table 4: Fixed effects model regression results

	(1)	(2)	(3)	(4)
	agri	agri	agri	agri
difi	0.0319***			
	(6.2163)			
cover		0.0247***		
		(4.1297)		
usdep			0.0338***	
			(4.5882)	
degr				0.0279***
				(7.5596)
_cons	-0.3269***	-0.3175***	-0.3039***	-0.3931***
	(-3.7397)	(-3.6184)	(-3.7367)	(-4.0547)
control variable	Yes	Yes	Yes	Yes
province	Yes	Yes	Yes	Yes
R^2	0.8448	0.8372	0.8393	0.8307

t statistics in parentheses
* p < 0.1, ** p < 0.05, *** p < 0.01

Table 5: Threshold effect test

Threshold variables	Threshold nature	F-statistic value	P-value	10% critical value	5% critical value	1% critical value
difi	Single Threshold	42.12	0.0000	22.6515	25.3347	36.6328
	Double Threshold	53.95	0.0333	15.5663	18.5813	32.5482
	Triple threshold	55.8	0.7933	19.8694	24.0594	31.9797

4.2.2. Estimated results of threshold effects

The Table 6 below illustrates how the influence of digital financial inclusion on the high-quality growth of agriculture in China's border areas is split into two intervals based on the threshold value of the level of development of digital financial inclusion. The level of high-quality development of agriculture in border areas will increase by 0.099 units for every unit increase in the level of digital inclusive finance development when it is below the threshold value of 3.3635; when it is between the threshold values of 3.3635 and 5.6797, the level of digital inclusive finance development will increase by 0.099 units for each unit increase in the level of digital inclusive finance development. When the level of digital inclusive finance development is higher than the threshold value of 5.6797, the level of high-quality development of agriculture in the border area will increase by 0.082 units for every 1 unit increase in the level of digital inclusive finance development. The level of high-quality development of agriculture in the border areas will increase by 0.072 units. This indicates that digital inclusive financing has a threshold effect when it comes to encouraging the growth of high-quality agriculture in China's frontier areas. Hypothesis 2 is established.

4.3. Mediated effects model regression

Table 6: Results of threshold effect estimation

Variables	agri
difi≤3.3635	0.099***
	(8.60)
3.3635≤difi≤5.6797	0.072***
	(11.12)
difi>5.6797	0.082***
	(13.92)
Constant	-0.025
	(-0.73)
control variable	Yes
province	Yes
R-squared	0.834

t statistics in parentheses
* *p* < 0.1, ** *p* < 0.05, *** *p* < 0.01

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How might agricultural science and technology innovation in conjunction with digital financial inclusion support the growth of high-quality agriculture in frontier regions? To investigate the validity of this approach, stepwise regression is utilized. Table 7 displays the specific outcomes. A major contribution of digital financial inclusion to the advancement of agricultural science and technology innovation is shown by the positive and substantial coefficient of digital financial inclusion in Model 2. Model 3's agricultural science and technology innovation coefficient is positive and substantial, suggesting that these factors play a major role in fostering the high-quality growth of agriculture in border regions. Table 7 shows that the path of digital inclusive finance to support high-quality agricultural development in border areas through technological and scientific innovation in agricultural science is established. The direct effect of digital inclusive finance to support high-quality agricultural development in border areas is 0.0253, accounting for 79.31% of the total effect, and the indirect effect is 0.0065, accounting for 20.38% of the total effect, establishing hypothesis 3.

Table 7: Results of the intermediate effect model's regression

	(1)	(2)	(3)
	agri	innov	agri
difi	0.0319***	0.0418*	0.0253***
	(6.2163)	(2.2878)	(4.4193)
innov			0.1557***
			(4.7657)
_cons	-0.3269***	-0.5060	-0.2481**
	(-3.7397)	(-1.2151)	(-3.0048)
control variable	Yes	Yes	Yes
province	Yes	Yes	Yes
R^2	0.8448	0.4819	0.8701

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Robustness testing

5.1. Adding control variables

As an additional control variable for the robust type test, the degree of urbanization (city) is included in this work. In accordance with the benchmark regression, the coefficient of digital financial inclusion, as indicated in Table 8 column (1), is 0.0122 and significant at the 5% level of significance.

5.2. Lagging one period behind

Table 8: Robustness testing regression results

	(1)	(2)
	agri	agri
difi	0.0122**	
	(2.3982)	
city	0.6693**	
	(2.7732)	
L_difi		0.0273***
		(5.1446)
_cons	-0.3963***	-0.3139**
	(-3.9826)	(-2.7050)
control variable	Yes	Yes
province	Yes	Yes
R^2	0.8691	0.8058

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The overall digital financial inclusion index is delayed by one order (L_difi)and utilized as a new explanatory variable to regress the model once again in order to assess the model's robustness,and the outcomes are displayed in the Table 8. The results in Table 8 column (2) demonstrate that, at the 1% level, digital financial inclusion substantially fosters high-quality agricultural growth in China's border regions,

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proving that the benchmark regression satisfies the endogeneity test.

6. Conclusions and recommendations

From the perspective of agricultural science and technology innovation, this paper analyzes the impact of digital inclusive finance on the high-quality development of agriculture in China's border areas and puts forward research hypotheses. After analyzing the econometric model, it is found that: (1) in general, digital inclusive finance can significantly promote the high-quality development of agriculture in China's border areas; (2) in terms of the path, digital inclusive finance can indirectly affect the high-quality development of agriculture in China's border areas from the agricultural scientific and technological innovation, the agricultural scientific and technological innovation plays a mediating and the intermediary effect accounts for 20.38% of the total effect; (3) the promotion effect of agricultural science and technology innovation on the high-quality development of agriculture in China's border areas is affected by the threshold effect of digital inclusive finance. As a result, this paper puts forward three policy recommendations:

First and foremost, there should be a faster pace to the development of digital financial inclusion. The government ought to enhance the development of digital financial inclusion in border regions and broaden financial services available to farmers in rural areas. In accordance with their unique circumstances, development features, and geographic advantages, nine bordering provinces can use finance to steer the development of environmentally friendly agriculture, create distinctive rural industries, fully utilize the Internet and finance, grow and fortify local industries, and encourage the development of high-quality agriculture.

Second, quicken the rate of innovation in agricultural science and technology. In addition to increasing financial, land, and tax support for initiatives like experimental bases and research and development agglomerations, the government can establish a special fund for the study and development of the agricultural and seed industries. It can also actively encourage all stakeholders to invest in agricultural production, R&D, experimentation, logistics, and other scientific and technological industries.

Third, aggressively develop talent in agricultural science and technology innovation. The government should keep enhancing the agricultural science and technology innovation institutional mechanism, the policy for income distribution, the agricultural science and technology innovation talent cultivation mechanism, the enhancement of a healthy ecological environment for the talents, the promotion of the high-quality farmer cultivation program, and the enhancement of the radiation-driven role of agricultural science and technology service talents.

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