“Impact of digital inclusive finance on agribusiness innovation performance: Evidence from listed agribusinesses in China”

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IMPACT OF DIGITAL INCLUSIVE FINANCE ON AGRIBUSINESS INNOVATION PERFORMANCE: EVIDENCE FROM LISTED AGRIBUSINESSES IN CHINA

Abstract

Agricultural enterprises play a crucial role in China's rural revitalization strategy, but persistent financing constraints hinder their innovation potential. This study examines the impact of digital inclusive finance on agricultural enterprise innovation, with a particular focus on the mediating role of financing constraints. Using panel data from agricultural enterprises listed on the Shanghai and Shenzhen Stock Exchanges (2014–2023), this study employs fixed-effect regression models and mediation analysis to explore these relationships. The empirical findings reveal that digital financial inclusion significantly enhances innovation levels in agricultural enterprises ($\beta = 0.5127$, $p < 0.01$). Additionally, digital financial inclusion reduces financing constraints ($\beta = -0.0385$, $p < 0.01$), confirming that improved access to digital financial services lowers borrowing costs and increases credit availability. Mediation analysis demonstrates a partial mediation effect, as the coefficient of digital financial inclusion on innovation decreases when financing constraints are included in the model ($\beta = 0.5057$). Subgroup analyses show that SMEs, state-owned enterprises, and non-coastal firms benefit the most from digital financial inclusion in China. These findings have important policy and managerial implications. Policymakers should strengthen digital financial infrastructure in rural areas and promote financial inclusion policies to support agribusinesses. Financial institutions should expand digital financial services, such as fintech-driven credit assessments and online lending platforms, to enhance agricultural innovation. Additionally, agricultural enterprises should leverage digital financial tools to overcome financing constraints and boost competitiveness.

Keywords digital inclusive finance, agricultural enterprise, financing constraints, innovation performance

JEL Classification G21, O31, Q13

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INTRODUCTION

Digital inclusive finance has emerged as a crucial tool for agricultural innovation in China's modernization process (Li et al., 2023). It offers an innovative solution to address the financing constraints agricultural enterprises face and is expected to drive agricultural modernization through enhanced innovation capabilities (Yi et al., 2024). In China, agricultural enterprises play a fundamental role in promoting rural revitalization and agricultural transformation. However, their innovation activities are significantly hindered by financing constraints, limiting their potential to contribute to agricultural modernization (Chen & Hui, 2021).

Digital inclusive finance represents a transformative approach, particularly relevant to agricultural enterprises' innovation activities (Xiao et al., 2023). The widespread digitalization in China's rural areas and the urgent need for agricultural modernization provide a unique context for studying the impact of digital inclusive finance. The impor-

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tance of investigating this relationship cannot be overlooked in China's current agricultural transformation phase. With the implementation of rural revitalization strategies and the push for agricultural modernization, agricultural enterprises need more financial support to enhance their innovation capabilities (Li & Sutunyarak, 2023).

Digital inclusive finance enhances production efficiency by facilitating information channels and promoting green technological innovations, and digital financial innovations for green development in agriculture are of great significance (Liu et al., 2023). In addition, this study contributes to the discussion on innovative financing for agriculture, as developing countries face similar challenges in promoting agricultural modernization and sustainable development.

1. LITERATURE REVIEW AND HYPOTHESES

Understanding the relationship between digital inclusive finance and agricultural enterprise innovation requires a theoretical foundation that explains the financial constraints and opportunities influencing innovation activities. Existing literature provides several key theoretical perspectives that help frame this relationship, including information asymmetry theory, resource-based theory, pecking order theory, and financing constraint theory. These perspectives highlight the structural financial challenges faced by agricultural enterprises and the potential role of digital inclusive finance in addressing them.

Information asymmetry has long been recognized as a fundamental market imperfection affecting financial transactions and resource allocation. In a perfect capital market, firms should face equal costs for internal and external financing (Modigliani & Miller, 1959). However, real-world financial markets are characterized by substantial information asymmetries, where borrowers possess more knowledge about their financial health and investment projects than lenders. This creates problems such as adverse selection and moral hazard, which particularly affect agricultural enterprises due to their reliance on intangible assets, seasonality of production, and uncertainty in returns. Digital inclusive finance has the potential to mitigate these issues by leveraging technology to enhance information transparency. The integration of big data analytics, artificial intelligence, and blockchain enables financial institutions to assess creditworthiness more accurately, reducing the reliance on traditional collateral-based lending. As a result, agricultural enterprises that previously struggled to secure financing due to high information asymmetry can access tailored financial solutions that support their innovation activities (Joorbonian, 2024).

Resource-Based Theory (RBT), originally proposed by Penrose (2009), emphasizes that a firm's competitive advantage and growth depend on the resources it possesses and how effectively it utilizes them. For agricultural enterprises, innovation capacity is largely determined by access to critical resources such as financial capital, technical expertise, and human capital. However, many agricultural enterprises, particularly small and medium-sized ones, face severe resource constraints that limit their ability to invest in R&D and technological upgrades. Digital inclusive finance plays a critical role in strengthening the resource base of agricultural enterprises. By offering more accessible financial services, it enables firms to invest in advanced agricultural technologies, precision farming, and sustainable practices. Furthermore, platform-based financial services provide additional resources such as technical support, market intelligence, and business networking, which further enhance innovation potential (Yi et al., 2024).

The Pecking Order Theory (POT), developed by Myers and Majluf (1984), suggests that firms follow a specific hierarchy when making financing decisions, prioritizing internal funds, then debt, and finally equity financing. This theory is particularly relevant for agricultural enterprises, which often prefer internal financing due to the high risks and transaction costs associated with external capital. However, given their limited cash flow and asset-backed borrowing capacity, external financing remains a necessary but challenging option for many firms (Li & Sutunyarak, 2023). Digital in-

clusive finance aligns with POT by providing alternative financing channels that reduce reliance on traditional debt and equity markets. Through peer-to-peer lending platforms, microfinance services, and digital payment ecosystems, agricultural enterprises gain access to more flexible financial solutions that better match their investment needs. This financial flexibility enables firms to allocate resources more efficiently and invest in innovation-driven growth strategies (Xiao et al., 2023).

Building on the assumptions of market imperfections, financing constraint theory highlights how financial market frictions create significant barriers to external financing, particularly for innovation-intensive firms (Fazzari et al., 1988). Agricultural enterprises face distinct financing challenges due to their asset structures, long innovation cycles, and exposure to environmental risks (He & Tian, 2018). Several factors exacerbate these constraints. First, agricultural enterprises primarily own assets such as land, equipment, and biological resources, which often have limited collateral value and are subject to high liquidity risks (Myniv & Batyuk, 2023). Second, agricultural innovation projects require long development cycles and are highly susceptible to unpredictable factors such as climate conditions and market fluctuations (Cano et al., 2023). Third, agricultural innovation projects often involve high information sensitivity, particularly in areas such as seed technology and sustainable farming techniques, which makes it difficult for external financiers to accurately assess risk and potential returns (Tang et al., 2023). Digital inclusive finance offers several mechanisms to alleviate these financing constraints. By utilizing advanced risk assessment models, financial institutions can better evaluate the creditworthiness of agricultural enterprises, reducing their dependency on traditional collateral. Additionally, digital lending platforms provide more flexible financing arrangements, allowing enterprises to access funds according to their innovation cycle needs. Furthermore, digital financial tools facilitate greater financial inclusion by connecting agricultural enterprises with a wider range of financial service providers, thereby increasing competition and lowering borrowing costs.

Therefore, this study aims to examine how digital inclusive finance affects agribusiness innovation capacity in the context of China's specific institutional environment and agricultural modernization. Based on the theoretical analysis of information asymmetry, resource-based theory, and financing constraints discussed above, this paper proposes the following hypotheses:

H1: Digital inclusive finance can promote the innovation level of listed agricultural enterprises.

H2: Digital financial inclusion can increase the innovation level in listed agricultural firms by easing financing constraints.

2. METHOD

Digital financial inclusion is often used as an indicator to comprehensively assess the degree of development of digital financial inclusion in a region or country, including multiple dimensions such as breadth of coverage, depth of use, and degree of digitization. This paper uses a relatively well-known digital inclusive finance index in China, the "Peking University Digital Inclusive Finance Index," which is jointly compiled by the Digital Finance Research Centre of Peking University and Ant Group, and this index has been cited many times in journals such as China Economist and China Economics Quarterly, e.g., Xun et al. (2020) and Guo et al. (2020). On this basis, this paper collects annual panel data of agricultural firms listed in China's main board market and secondary market from 2014–2023 through the WIND database and CSMAR database, and compiles a panel dataset. The analysis utilizes 2014–2023 panel data of 135 agricultural enterprises listed on China's Main Board and secondary markets. In sample screening, the paper treats the sample as follows.

1. Excluding data from ST and *ST listed companies: Usually, ST and *ST companies have serious operational difficulties, and their financial data are not suitable for large-sample studies. To ensure the robustness of the empirical results, this paper excludes such enterprises.

2. Eliminating samples with abnormal or missing data: Enterprises with abnormal or missing research data in the sample year are elimi-

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nated to ensure the completeness and reliability of the data.

3. Dealing with extreme values: To avoid the adverse impact of extreme values on the results of the study, this paper carries out the shrinking of the sample data by 1% up and down.

After the above screening process, this paper finally obtained 910 observations. The financial data used in this paper are mainly from the CSMAR database, and the innovation patent data of the enterprises are collected from the CNRDS database.

Through the above sample selection and data processing steps, this paper seeks to construct a reliable research foundation to explore the impact of digital financial inclusion on the innovation level of listed agricultural companies and to provide empirical evidence for relevant policy formulation and enterprise practice.

This paper refers to Hadlock's and Pierce (2010) method of calculating corporate financing constraints using the financing constraint index (SA index) to assess the level of financing constraints in agribusiness firms. The specific calculation formula is as follows:

$$SA_{it} = -0.737 \cdot SIZE_{it} + 0.043 \cdot SIZE_{it}2 - 0.04 \cdot AGE_{it}, \quad (1)$$

where *SIZE* represents the size of an enterprise and *AGE* represents the age of the enterprise. This calculation method, based on the comprehensive consideration of factors such as enterprise size and age, can effectively quantify the degree of difficulty faced by enterprises in the financing process and provides an important analytical tool and indicator for an in-depth understanding of the problem of financing constraints in agricultural enterprises.

The definitions of specific variables are shown in Table 1.

Based on the above theoretical framework, three econometric models are constructed to examine the relationship between digital inclusive finance and agricultural enterprise innovation, with particular attention to the mediating role of financing constraints.

Model (2) investigates the direct effect of digital inclusive finance on agricultural enterprise innovation:

$$Invent1_{ijt} = \alpha_0 + \alpha_1 DF1_{jt} + \sum \alpha_n Controls_{it} + Year_t + IND_u + \varepsilon_{it}, \quad (2)$$

where $Invent1_{i,j,t}$ represents the innovation level (measured by the number of invention patent applications) of firm *i* in city *j* at year *t*, $DF1_{j,t}$ represents the digital inclusive finance index in city *j* at year *t*, $Controls_{it}$ represents a vector of control

Table 1. Variable definitions

Variable Type	Variable Name	Variable Symbol	Definition
Dependent variables	Level of innovation in enterprises	Invent1	Ln (1+Number of enterprise invention patent applications)
Mediating variables	Financing constraints	FC	Financing constraint index calculated by the SA method
Independent variables	Municipal Digital Inclusive Finance Index	DF1	Peking University Municipal Digital Financial Inclusion Index/100
Control variables	Age of the firm	FirmAge	Ln (Number of years the firm has been in existence+1)
	Size of the Board of Directors	Board	Ln (Number of Board of Directors+1)
	Shareholding Concentration	Share	Number of shares held by the largest shareholder/total number of shares
	Nature of the shareholding	SOE	State-owned enterprises take the value 1, other enterprises take the value 0
	Intangible assets ratio	Intangible	Net intangible assets/total assets
	Gearing ratio	Lev	Total liabilities/total assets
	Return on Assets	ROA	Total net profit/total assets
	Industry	IND	Industry fixed effect
	Year	Year	Annual fixed effects

variables, $YEAR_t$, is the year dummy, IND_u is the industry dummy, and ε_{it} is the error term. The coefficient α_1 captures the total effect of digital inclusive finance on innovation.

To investigate whether digital financial inclusion has an effect on the level of innovation in agribusiness through the mediating mechanism of financing constraints, this paper constructs the following mediation effect model:

$$FC_{ijt} = \beta_0 + \beta_1 DF1_{jt} + \sum \beta_n Controls_{it} + Year_t + IND_u + \varepsilon_{it}, \quad (3)$$

$$Invent1_{ijt} = \gamma_0 + \gamma_1 DF1_{jt} + \gamma_2 FC_{ijt} + \sum \beta_n Controls_{it} + Year_t + IND_u + \varepsilon_{it} \quad (4)$$

where FC_{ijt} represents the financing constraints index of firm i in city j at year t. In Model (3), β_1 captures the effect of digital inclusive finance on financing constraints. In Model (4), γ_1 represents the direct effect of digital inclusive finance on innovation after controlling for financing constraints, while γ_2 captures the effect of financing constraints on innovation. The product $\beta_1 \times \gamma_2$ represents the indirect effect through the financing constraints channel.

3. RESULT

Table 2 presents the data structure distribution of all variables used in the basic study. According to the results in the table, it can be found that the mean value of the innovation level of enterprises (Invent1) is 1.543, the standard deviation is 1.362, the maximum value is 4.691, and the minimum value is 0. This indicates that the overall innovation level of the sample agribusinesses is good, but there is a large difference between individuals. In terms of the level of digital financial inclusion development, the average of the digital financial inclusion index (DF1) of the city where each enterprise is located is 2.023, the standard deviation is 0.707, the maximum value is 3.208, and the minimum value is 0.426. This also indicates that the overall level of development is good, but there are large differences in development among regions. In terms of the degree of financing constraints, the mean value of financing constraints (FC) of the sample agribusinesses reaches –3.824, the maximum value is –3.294, and the minimum value is –4.339, with a small difference between the maximum value and the minimum value, which suggests that Chinese agribusinesses are indeed faced with a serious problem of financing constraints.

From the point of view of Firm Age, the sample agribusinesses are mostly mature enterprises; from the point of view of firm equity concentration (Share), the difference in equity concentration between the sample agribusinesses is too large, and some enterprises have too concentrated equity; from the point of view of the nature of equity (SOE), the proportion of non-state-owned enterprises in the sample agribusinesses is relatively high; from the proportion of intangible assets (Intangible), the overall intangible asset investment of the sample agribusinesses is not high, which may be caused by capital constraints; from the return on assets (ROA) of the enterprises, the minimum value of the sample enterprises is –0.243, which indicates that some enterprises have operating losses.

Table 2. Descriptive statistical analysis

Variables	N	Mean	SD	Min	Max	Median
Invent1	910	1.543	1.362	0.000	4.691	1.386
DF1	910	2.023	0.707	0.426	3.208	2.154
FC	910	–3.824	0.222	–4.339	–3.294	–3.838
FirmAge	910	2.897	0.325	1.792	3.434	2.944
Board	910	2.127	0.215	1.609	2.708	2.197
Share	910	36.081	15.180	8.790	70.330	35.019
SOE	910	0.331	0.471	0.000	1.000	0.000
Intangible	910	0.053	0.046	0.000	0.314	0.053
LEV	910	0.384	0.180	0.046	0.938	0.372
ROA	910	0.052	0.077	–0.243	0.260	0.049

Note: Variable definitions are given in Table 1.

3.1. Correlation analysis

Table 3 presents the correlation analysis of the main variables used in the study. From the table, it can be seen that the coefficient between digital financial inclusion (DF1) and the level of agribusiness innovation (Invent1) is 0.130 and significantly positively correlated at the 1% level without considering other variables, which preliminarily verifies that the development of digital financial inclusion can promote the level of agribusiness innovation. Financing constraint (FC) is negatively and significantly correlated with the innovation level of agribusiness, while it is also negatively and

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Table 3. Correlation analysis

Variables	Invent1	DF1	FC	FirmAge	Board	Share	SOE	Intangible	LEV	ROA
Invent1	1.000									
DF1	0.130**	1.000								
FC	−0.075**	−0.421***	1.000							
Firm Age	−0.064*	0.412**	−0.929***	1.000						
Board	0.012**	−0.126***	−0.091***	0.085**	1.000					
Share	−0.077**	−0.025***	0.245***	−0.267***	0.007	1.000				
SOE	0.003*	−0.065–	−0.174***	0.193***	0.298***	0.092***	1.000			
Intangible	−0.063*	−0.083**	−0.099***	0.059*	0.041	−0.103***	−0.013	1.000		
LEV	0.144***	0.020	−0.145***	0.114***	0.021	−0.227***	0.075**	0.237***	1.000	
ROA	0.134***	−0.026	0.084**	−0.041	0.149***	0.260***	−0.053	−0.201***	−0.313***	1.000

Note: *t*-statistics are in parentheses, *** p < 0.01, ** p < 0.05, and * p < 0.1.

significantly correlated with digital inclusive finance, indicating that digital inclusive finance is likely to be a way to help Chinese listed agricultural enterprises get out of the financing dilemma so as to achieve the optimal improvement of the innovation level. In addition, the innovation level of agribusiness firms is correlated with Firm Age, board size, shareholding ratio of the largest shareholder, SOE, intangible asset ratio, LEV, and ROA.

In the empirical analysis, an econometric regression model is established. Since the selected indicators may exhibit multicollinearity problems, which will cause bias in the empirical results, before establishing the model, regression analysis should be used to test whether there is multicollinearity between the indicators. Therefore, this paper chooses to use the variance inflation factor (VIF) test, the results are shown in Table 4. Table 4 shows that the VIF value of each variable is far less than 5, within the range of reasonable values, and the average value of VIF is 1.31, which is also within a reasonable range, so the covariance between the indicators selected in this paper will not affect the empirical results.

Table 4. Variance inflation factor (VIF) test for variables

Variable	VIF	1/VIF
DF1	1.21	0.768
FC	1.45	0.826
FirmAge	1.45	0.689
Board	1.17	0.854
Share	1.23	0.814
SOE	1.22	0.822
Intangible	1.10	0.908
LEV	1.19	0.841
ROA	1.22	0.821
Mean	1.23	

To study the impact of digital financial inclusion on the innovation level of Chinese agricultural listed companies, the sample data are substituted into model (1) for regression, and the regression results are presented in Table 5. As can be seen from the table, without adding control variables, Table 5, column (1), shows that the coefficient of digital financial inclusion (DF1) is 0.2512 and is significant at the 1% level; after adding control variables, Table 5 (2) shows that the coefficient of digital financial inclusion becomes 0.4242, which is still significant at the 1% level, which preliminarily indicates that the development of digital financial inclusion can significantly promote the innovation level (Invent1) of agribusiness. level (Invent1) improvement. To further improve the robustness of the results, this paper also controls the year and industry dummy variables, and the regression results are shown in Table 5 (3). The correlation between digital inclusive finance and the level of innovation of agribusiness is still positive and significant at the 1% level. This indicates that the digital inclusive finance plays a significant role in promoting the level of innovation of agribusiness, and verifies Hypothesis 1 of this paper.

To test whether financing constraints have a mediating effect between digital financial inclusion and the innovation level of Chinese listed agricultural enterprises, this paper is based on model (2), and then substitutes the sample data into models (3) and (4) for the empirical test of mediating effect, and the specific regression results are shown in Table 6. Table 6, column (1), shows the relationship between digital financial inclusion (DF1) and the innovation level of agricultural enterprises (Invent1), and the results remain consistent with

Table 5. Digital inclusive finance and the innovation level of listed agricultural firms in China

Variable	Invent1		
	(1)	(2)	(3)
DF1	0.2512*** (3.960)	0.4242*** (6.169)	0.5127*** (2.965)
FirmAge		−0.9274*** (−5.877)	−0.9703*** (−6.183)
Board		0.0173 (0.081)	−0.0559 (−0.264)
Share		−0.0138*** (−4.427)	−0.0155*** (−5.094)
SOE		0.1993** (1.998)	0.1999** (2.051)
Intangible		−1.4990 (−1.532)	−2.6540*** (−2.718)
LEV		1.5755*** (6.093)	1.6630*** (6.587)
ROA		4.0644*** (6.576)	3.6590*** (5.894)
Constant	1.0348*** (7.612)	11.028***	2.7144*** (3.748)
Year	No	No	Yes
IND	No	No	Yes
Observations		910	
R-squared	0.0159	0.111	0.155
F	15.68	15.15	16.35

Note: *t*-statistics are in parentheses, *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

the above regression results. Table 6 (2) shows the regression results of model (2), and it can be seen that the coefficient between digital financial inclusion and financing constraints (FC) is at the 1% level, and the results remain consistent with the above regression results. Table 6 (2) presents the regression results of model (2). It can be seen that the coefficient between digital financial inclusion and financing constraints (FC) is negatively significant at the 1% level, with a coefficient of −0.0385. This indicates that digital financial inclusion can alleviate the financing constraints faced by enterprises. Table 6 (3) presents the regression results of model (3), and it can be seen that in the same model, the innovation level of agricultural enterprises is significantly positively correlated with digital financial inclusion and significantly negatively correlated with financing constraints, and the coefficient of digital financial inclusion is reduced to 0.5057. Combining the regression results of columns (1), (2), and (3), the financing constraints play an intermediary role between the innovation level of digital financial inclusion and the listed Chinese agricultural enterprises, which verifies hypothesis 2 of this paper.

Table 6. Digital inclusive finance, financing constraints, and the innovation level of listed agricultural firms in China

Variable	Invent1	FC	Invent1
	(1)	(2)	(3)
DF1	0.5127*** (2.965)	−0.0385*** (−3.477)	0.5057*** (3.168)
FC			−0.9861** (−1.888)
FirmAge	−0.9703*** (−0.110)	−0.6176*** (−61.411(	−0.3612 (−1.007)
Board	−0.0559 (−0.264)	−0.0293** (−2.167)	−0.0269 (−0.127)
Share	−0.0155*** (−5.094)	−0.0002 (−1.242)	−0.0153*** (−5.018)
SOE	0.1999*** (2.051)	0.0061 (0.975)	0.1939** (1.991)
Intangible	−2.6540*** (−2.718)	−0.1788*** (−2.857)	−2.4776** (−2.529)
LEV	1.6630*** (6.587)	−0.0280* (−1.729)	1.6906*** (6.694)
ROA	3.6590*** (5.894)	0.1293*** (3.249)	3.5315*** (5.663)
Constant	2.7144*** (3.748)	−1.8636*** (−40.154)	4.5520*** (3.754)
Year	Yes	Yes	Yes
IND	Yes	Yes	Yes
Observations		910	
R-squared	0.155	0.845	0.159
F	16.35	486.7	15.23

Note: t-statistics are in parentheses, *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

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In the base regression, this paper uses the number of invention patent applications as a proxy variable for the level of innovation. To further ensure the reliability of the regression results, taking into account that different enterprises have different focuses on patent innovation, and their investment in invention patents, utility patents and design patents are inconsistent, this paper takes the total number of the three kinds of patents as a proxy variable for the innovation level of the enterprise to carry out the regression. The specific operation method is to take the logarithm of the total number of invention patents, utility patents, and design patents, and then substitute them into the original model for regression, and the regression results are shown in Table 7. From the table, it can be seen that the innovation level of agricultural enterprises (Invent2) maintains a significant positive correlation with digital financial inclusion (DF1), and is always significantly negatively correlated with financing constraints (FC), indicating that the promotion of digital financial inclusion on the innovation level of Chinese listed agricultural enterprises and the mediating role of financing constraints are robust.

Table 7. Robustness test – replacement of dependent variables

Variable	Invent2	FC	Invent2
	(1)	(2)	(3)
DF1	0.5199*** (3.658)	–0.0385*** (–3.477)	0.5019*** (4.010)
FC			–0.9861** (–1.888)
FirmAge	–0.6816** (–5.284)	–0.6176*** (–61.411)	0.1394 (0.475)
Board	0.0716 (0.412)	–0.0293** (–2.167)	0.1106 (0.638)
Share	–0.0101*** (–4.020)	–0.0002 (–1.242)	–0.0097*** (–3.907)
SOE	0.1612** (2.012)	0.0061 (0.975)	0.1531* (1.991)
Intangible	–1.6380** (–2.041)	–0.1788*** (–2.857)	–1.4002** (–1.745)
LEV	1.1580*** (5.580)	–0.0280* (–1.729)	1.1952*** (5.777)
ROA	3.0242*** (5.927)	0.1293*** (3.249)	2.8523*** (5.584)
Constant	1.1108* (1.866)	–1.8636*** (–40.154)	3.5879*** (3.612)
Year	Yes	Yes	Yes
IND	Yes	Yes	Yes
Observations		910	
R-squared	0.137	0.845	0.146
F	14.13	486.7	13.85

Note: t-statistics are in parentheses, *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

In the basic regression, this paper uses the financial index at the municipal level to conduct empirical analyses and verify the research hypotheses. To ensure the reliability of the conclusions, this paper further uses the financial index at the provincial level to conduct empirical research. The specific operation method is to divide the provincial digital inclusive financial index by 100, and substitute it into the original model for regression after matching with the sample enterprises; the regression results are shown in Table 8. From the table, it can be seen that provincial digital financial inclusion (DF2) is still significantly positively correlated with the innovation level of agricultural enterprises (Invent1), and also significantly negatively correlated with financing constraints (FC). This indicates that the mediating role of digital financial inclusion in promoting the innovation level of listed Chinese agricultural enterprises and financing constraints is robust after changing the dimension of digital financial inclusion measurement.

Table 8. Robustness test – replacement of independent variables

Variable	Invent1	FC	Invent1
	(1)	(2)	(3)
DF2	0.4433*** (2.903)	–0.0455*** (–3.031)	0.4336*** (3.161)
FC			–0.8854** (–2.608)
FirmAge	–0.9383** (–5.995)	–0.6004*** (–38.981)	–0.4067 (–1.584)
Board	–0.0759 (–0.360)	–0.0406** (–1.958)	–0.0399 (–0.190)
Share	–0.0153*** (–5.028)	–0.0008*** (–2.703)	–0.0146*** (–4.788)
SOE	0.1515** (1.523)	0.0280*** (2.863)	0.1267 (1.272)
Intangible	–2.8788*** (–2.977)	0.0807 (0.848)	–2.9503*** (–3.060)
LEV	1.4264*** (6.786)	0.0073 (0.293)	1.7200*** (6.783)
ROA	3.6582*** (5.890)	0.1189* (1.945)	3.5529*** (5.727)
Constant	2.6261*** (3.532)	–1.8731*** (–25.606)	4.2846*** (4.388)
Year	Yes	Yes	Yes
IND	Yes	Yes	Yes
Observations		910	
R-squared	0.155	0.670	0.161
F	16.31	180.6	15.54

Note: t-statistics are in parentheses, *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

4. DISCUSSION

Empirical results show that digital inclusive finance significantly improves the innovative capacity of agribusinesses. The findings suggest that by reducing financing constraints, digital financial services improve access to capital, which facilitates investment in R&D and technological advancement. This is consistent with the theoretical expectation that financial accessibility is a key determinant of innovation performance (Aghion et al., 2004). Unlike traditional financial services, digital financial inclusion operates through multiple channels and not only improves access to capital but also creates an ecosystem that supports innovation. Digital financial inclusion is associated with playing a transformative role in the level of innovation in agribusiness. This finding aligns with Bergh et al. (2019), Li and Pang (2023), Lee et al. (2023), Wang et al. (2023), and Zhang et al. (2024). In addition, this study builds on the information asymmetry theory and demonstrates that digital technology effectively bridges the information gap in agricultural financing and facilitates a more efficient allocation of financial resources to innovative activities. The positive impact of digital financial inclusion on innovation supports previous research showing that digital financial services improve credit accessibility, especially for the development of SMEs (Demirguc-Kunt et al., 2018). This study extends this perspective by focusing on agribusiness, an area often overlooked in digital finance research.

This study finds that digital financial inclusion significantly reduces financing constraints, which in turn increases the level of innovation in agribusiness. The negative correlation between digital financial inclusion and financing constraints suggests that digital finance mitigates financing difficulties by reducing information asymmetry and increasing credit availability. Digital financial inclusion not only provides direct financial support to firms but also indirectly promotes innovation by alleviating financial bottlenecks. These findings support previous studies that emphasize the importance of financial development in fostering firm innovation (Brown et al., 2009; Ding et al., 2013). The findings corroborate the argument that financing constraints hinder the ability of firms to engage in innovative activities (Hall & Lerner, 2010). It is also found that digital inclusive finance mitigates these constraints, echoing research that financial liberalization and alternative credit channels enhance firm-level innovation (Chava et al., 2013). Furthermore, the empirical results confirm that financing constraints negatively affect firm innovation, as firms with limited access to finance tend to invest less in R&D, leading to lower innovation output. On the contrary, relaxing financing constraints can lead firms to invest more in innovation and enhance their technological capabilities. These findings are consistent with Xiong et al. (2023), Li and Pang (2023), Lee et al. (2023), Wang et al. (2023), and Zhang et al. (2024).

The study also reveals heterogeneous effects across firms of different sizes, providing important insights into the distributional implications of digital inclusive finance. The results suggest that the heterogeneous distribution of financial resources across firm size, ownership structure, and geographic location is consistent with previous research (Xiao & Zhao, 2012). Previous studies have similarly emphasized that financial constraints disproportionately affect SMEs and businesses in rural areas, where access to traditional banking services is limited (Beck et al., 2008). By improving financial accessibility, digital inclusive finance reduces the innovation gap between large and small firms and helps SMEs overcome resource constraints, supporting resource-based theory. These findings are consistent with Quartey et al. (2017), Gao et al. (2022), Xiao et al. (2023), and Li et al. (2023), who argue that digital financial services enhance SMEs' ability to compete with larger firms by improving access to critical financial and technological resources.

This study contributes to the literature by integrating financial constraint theory with digital finance perspectives, providing empirical support for the argument that digital financial inclusion can serve as a mechanism to reduce capital constraints and stimulate innovation. This expands the scope of research beyond traditional financial institutions, highlighting the transformative role of fintech in agricultural development.

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CONCLUSION

This study provides empirical evidence that digital inclusive finance enhances agricultural enterprise innovation, with financing constraints playing a partial mediating role in this relationship. By reducing credit barriers and improving financial accessibility, digital financial services facilitate greater investment in R&D and technological advancements. Notably, SMEs, state-owned enterprises, and non-coastal firms benefit the most, highlighting the equalizing effect of digital financial inclusion in addressing regional and firm-level disparities.

These findings underscore the need for policymakers to strengthen rural digital financial infrastructure and promote financial inclusion strategies tailored to agribusinesses. Financial institutions should expand fintech-driven solutions to support agricultural innovation, while enterprises should actively leverage digital finance to overcome capital constraints.

While this study advances the understanding of digital finance and agricultural innovation, it is limited by its focus on listed enterprises and patent-based innovation measures. Future research should explore non-listed agribusinesses, alternative innovation indicators, and long-term impacts of digital finance. Additionally, comparative studies across different economies could provide further insights into the global applicability of digital financial inclusion in agricultural development.

AUTHOR CONTRIBUTIONS

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Visualization: Yi Wei.
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