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Chapter: Advancing Digital Transformation through Information and Innovation Management

IMPACT OF DIGITAL FINANCIAL INCLUSION ON AGRICULTURAL ENTERPRISE INNOVATION

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Annotation. *Innovation is an inexhaustible motive force for enterprise development, and the arrival of the digital economy era has injected new vitality into enterprise innovation and development. Whether agricultural enterprises can seize the opportunities of digital economy advancements for innovation remains to be further investigated. This study aims to reveal whether agricultural enterprises can enjoy the digital financial inclusion dividend and play a role in promoting innovation. Based on resource dependence theory and financing constraint theory, using the financial data of Chinese A-share listed agricultural enterprises and the digital financial inclusion data of the Institute of Digital Finance Peking University from 2011 to 2022, the impact of digital financial inclusion on agricultural enterprise innovation was empirically examined. The Results indicate that, (1) The development of digital financial inclusion can significantly promote the innovation of agricultural enterprises, among which the usage depth of digital financial inclusion exerts a stronger effect than its coverage breadth and digitalization level. This conclusion still holds after performing the endogeneity and robustness tests. (2) Compared with non-state-owned enterprises, and enterprises in the eastern region and small-sized enterprises, state-owned enterprises, as well as enterprises in the central and western regions, and large-sized enterprises are promoted more substantially in the aspect of innovation by digital financial inclusion. (3) Digital financial inclusion mainly promotes the innovation of agricultural enterprises by alleviating financing constraints and enhances investment guarantee for*

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agricultural enterprises to continuously carry out innovative activities. The conclusions can provide theoretical guidance for agricultural enterprises to use digital financial inclusion to alleviate financing constraints, sustain innovation, and provide a decision-making basis for government to formulate innovation support policies for agricultural enterprises.

Keywords: digital financial inclusion, enterprise innovation, financing constraints, research and development investment.

JEL classification: G20, G32, M11, Q13, Q16.

Introduction

Innovation is widely recognized as a crucial factor for the survival and development of enterprises (Anicic, 2024), particularly for listed enterprises facing increasingly complex market competition and challenges (Brink, 2024), accompanied by the rapid technological upgrading of the current industry (Anguelov, Angelova, 2023). To effectively adapt and respond to the complex and changeable market development environment, enterprises need sustained innovation to survive and develop significantly in the highly competitive global market (Lukyanova *et al*., 2022; Pinkovetskaia *et al*., 2022; Smit *et al*., 2024). This implies that enterprises have to allocate a certain amount of budget annually to research and development (R&D). The scale and financial strength of agricultural enterprises are relatively weaker than those of industrial enterprises, which is closely related to the inherent weakness characteristics of the agricultural industry. Many agricultural enterprises are faced with financial challenges such as financing difficulties and high financing costs, and the funds used for technological innovation are limited, thereby impeding their ability to innovate and develop (Neuberger *et al*., 2023). Nevertheless, agricultural enterprises are closely linked with the primary industry and have substaintial bearing on the future of the national economy's basic industries. Therefore, agricultural enterprise innovation is particularly worthy of attention, and promoting such an innovation is significant to the broad development of the national economy (Ali *et al*., 2021; Tireuov *et al.,* 2023).

As information technology develops rapidly, industrial digitalization has become the main development trend of the entity economy, which has also accelerated the development of digital financial inclusion. Many financial institutions, such as banks, securities companies and insurance companies, have embraced the digital development trend by formulating related development strategies, strengthening the construction of digital infrastructure, facilitating the digital transformation of various businesses, and providing affordable financial services for all social classes and groups. China, after years of development, has welcomed the fastest development of digital financial inclusion in the world (Fan, Chen, 2022). As such, the following question must be answered: Can the rapid development of digital financial inclusion alleviate the financing difficulties and high financing costs faced by agricultural enterprises in innovation and development and promote agricultural enterprise innovation?

For theoretical research, the impact of digital financial inclusion on agricultural enterprise innovation has been investigated independently from the perspectives of resource dependence theory and financing constraint theory. According to resource dependence theory, resource dependence exists between organizations (Casciaro, Piskorski, 2005). In reality, strong resource dependence has been observed between agricultural enterprises and financial institutions, and the innovation and development of agricultural enterprises cannot be separated from financial support. Previous studies have indicated that

traditional finance or green finance can promote the innovation of agricultural enterprises (He *et al*., 2024; Han *et al*., 2022). However, digital financial inclusion is different from the aforementioned financial resources. As an emerging financial product with digital technology as the carrier, its impact on agricultural enterprise innovation needs to be re-examined or retested. The resource dependence faced by agricultural enterprises in innovation and development is also relatively reflected in financing constraints, which needs to be alleviated by fiscal subsidies and financial support. Financing constraint theory reveals that enterprises can adopt internal and external financing, in which the latter reflects dependence on other organizations. Agricultural enterprises are generally faced with financing constraints, and their innovative development is characterized by high and uncertain resource demands, expecting to obtain stable and sustained financial support. In existing research, financing constraints serve as the mechanism variable for the impact of digital financial inclusion on agricultural enterprise innovation. Empirical analysis indicates that digital financial inclusion can promote agricultural enterprise innovation by alleviating financing constraints (Hong *et al*., 2024; Jin, Zhong, 2024). However, agricultural enterprise innovation has been measured mainly using total factor productivity, which is a comprehensive and static reflection of agricultural enterprises' innovation results. Agricultural enterprise innovation is just one of the core contributing factors, and agricultural enterprise innovation is a behavioral process of dynamic development. Moreover, the static result indicator may be biased when measuring dynamic process indicators, which will amplify the role of digital financial inclusion in agricultural enterprise innovation. Unfortunately, resource dependence or financing constraint theory has been independently adopted in the relevant research, providing considerable emphasis on the passive dependence of enterprise innovation on external resources (Cuervo-Cazurra *et al*., 2019; Andrews, Hodgkinson, 2024). This case does not consider that agricultural enterprises can obtain financial support by virtue of resource dependence, thereby breaking through the resource dependence or financing constraints and promoting the innovation and development of enterprises. Moreover, existing research fails to focus on the emerging digital financial inclusion and agricultural enterprises' innovation input reflecting the innovative behavioral process in the selection of financial resources and innovation indicators of agricultural enterprises. This situation results in the lack of direct evidence to conclude that digital financial inclusion can promote agricultural enterprise innovation. Fortunately, an internal relationship exists between resource dependence theory and financing constraint theory. Embedding financing constraint theory into resource dependence theory can provide new ideas for the research on the impact of digital financial inclusion on agricultural enterprise innovation, and can match the macro-level digital financial inclusion data with the micro-level agricultural enterprise innovation data to analyze the impact and underlying mechanism of digital financial inclusion on agricultural enterprise innovation from the perspectives of resource dependence theory and financing constraint theory, respectively. Therefore, the impact of digital financial inclusion on the innovation of agricultural enterprises remains to be further discussed, which is the core problem that this study aims to solve.

By using A-share listed agricultural enterprises in China's Shanghai Stock Exchange and Shenzhen Stock Exchange in 2011–2022 as research samples, the influencing effect of digital financial inclusion on agricultural enterprise innovation and underlying mechanism were investigated from the perspectives of resource dependence theory and financing constraint theory. This study will deepen the cognition of resource dependence theory and also contribute new knowledge to the research in the field of agricultural enterprise innovation. The contributions of the current study are mainly reflected in two aspects. First, breaking the inherent thinking of resource dependence theory, financing constraint theory was combined to establish the theoretical logic of "dependence–utilization–de-dependence". That is, the

innovative development of enterprises shows strong resource dependence but can also break the resource dependence constraint by using the resource dependence between organizations. This situation expands the cognitive boundary of the application situation of resource dependence theory and likewise provides a scientific decision-making basis for enterprises to apply this theory or strategy to break through the innovative development constraints. Second, this study further enriches the industrial scope in which digital financial inclusion plays an inclusive role in promoting enterprise innovation. Moreover, digital financial inclusion was revealed to not maximize its inclusive role at the levels of ownership, location, and scale attributes of agricultural enterprises, thereby forming a contrast and complementation with existing research from the perspective of research objects. This finding provides demand-side guidance for the development of digital financial inclusion and also renders a new idea for the government to support the innovative development of agricultural enterprises.

The remainder of this study is outlined as follows. Section 1 introduces theoretical analysis and hypothesis development. Section 2 presents the empirical model. Section 3 covers the estimation results, including benchmark regression results, endogeneity test, heterogeneity analysis, robustness test, and mechanism analysis. Section 4 discusses the empirical results in further detail. The final section summarizes the main findings, managerial implications, and limitations and future directions.

1. Theoretical Analysis and Hypothesis Development

1.1 Development of Digital Financial Inclusion and Agricultural Enterprise Innovation

Resource dependence theory states that to survive, enterprises must interact with other subjects and obtain the resources they need for development from the external environment, among which financing resources are the most important resources. In particular, enterprises in the growth phase or active period of innovation have high capital demands for their operations and a long investment cycle, together with a strong dependence on financial institutions. However, the traditional financial system is subjected to resource mismatch (Wang, Ma, 2023; Bu *et al*., 2024), in which large-sized and powerful enterprises are more likely to obtain financial resources, whereas weak enterprises and with urgent needs have more difficulty and less likely to obtain financial support. Digital financial inclusion, as a new financial format, integrates digital technologies, such as the Internet and big data, which can improve the efficiency of financial resource allocation (Ding *et al*., 2024), enhance the availability of financial resources to market entities, such as agricultural enterprises, and ensure sustained and stable innovation activities. Li and Pang (2023) indicated that digital financial inclusion can effectively correct the mismatch of financial resources in the traditional financial model and enhance the technological innovation ability of small and medium-sized enterprises.

From the business operation perspective, digital financial inclusion is an important embodiment of industrial digitalization development. To adapt to and lead the development trend of industrial digitalization development, enterprises will actively invest in supporting digital infrastructure, expand digital business, and even pursue technological innovation with digitalization as the development direction of enterprises. With the rapid development of digital economy, an increasing number of enterprises respond to this trend, realize digital transformation with the help of emerging technologies, and enjoy the dividends brought by digital transformation (Peng, Tao, 2022). From the perspective of funding sources for enterprise innovation, enterprise innovation has a long cycle and considerable uncertainties, needing to continuously introduce technologies, talents, equipment, and other essential resources. Moreover, meeting innovation and development needs is difficult when only relying on internal

funds, and external financial support is an effective support for enterprises to carry out innovative activities (Nguyen *et al*., 2023; Zhang *et al*., 2023). The development of digital financial inclusion can provide timely and effective financial services for enterprises (Dong *et al*., 2022) and provide financial support, such as funds, insurance, and credit services for enterprises to carry out innovative activities. From the perspective of the market environment for enterprise innovation, the development of digital financial inclusion optimizes the financial environment for enterprise innovation. Moreover, it can alleviate bottlenecks in various stages of technological innovation, improve the participation enthusiasm of all stakeholders, and foster a favorable atmosphere for innovation. Accordingly, this study proposes the following hypothesis:

Hypothesis 1: Agricultural enterprise innovation can be promoted by the development of digital financial inclusion.

1.2 Mediating Role of Financing Constraints

Financing constraint theory is derived from information asymmetry. In case of information symmetry, the capital market will be efficient (Kaplan, Zingales, 1997). Information asymmetry in the capital market will lead to a significant difference in the cost of internal and external financing. The higher the degree of information asymmetry, the higher the cost of external financing, thereby posing greater financing constraints on enterprises (Merkoulova, Zivanovic, 2022). From the external representation of financing constraints, enterprise financing constraints are mainly reflected in two aspects, namely, financing availability and financing costs. These aspects also correspond to financing difficulties and high financing costs faced by enterprises, and those in a weak position or in the initial stage particularly encounter prominent financing constraints. The emergence of digital financial inclusion can relatively replace government intervention with the role of market mechanism to alleviate the financing constraints for enterprises. Digitalization and inclusiveness are two basic characteristics of digital financial inclusion, aligning with the two attributes of financing constraints: financing difficulties and high financing costs. Xu *et al*. (2024) found that digital financial inclusion can alleviate financing constraints and improve credit supply via digital technology. In particular, digital financial inclusion based on the digital economy can reduce information asymmetry between the supply and demand sides of financial services (Gomber *et al*., 2018), enhance the availability of financial services to enterprises, and facilitate the effective matching of supply and demand between the two trading parties. In addition, digital financial inclusion is committed to providing affordable financial services for enterprises and other demanders, as well as convenient access to information, funds, and insurance, which can effectively reduce the information search and transaction costs for enterprises to obtain financial services. Wang and Chen (2023) determined that improving the effective supply of resources and reducing information asymmetry are the main reasons that digital financial inclusion can alleviate the financing constraints for technology-based small and medium-sized enterprises.

Financing constraints are the key factor restricting the innovative development of enterprises. Significant financing constraints will hinder the current innovation activities of enterprises and also increase the uncertainty of their future innovation (Wang *et al*., 2022). To achieve innovation, enterprises need to invest in such key factors as information, technology, and capital (Li *et al*., 2022). Moreover, enterprise innovation activities generally have a long cycle and high risks, requiring continuous capital investment, so high requirements are proposed for the operating efficiency or financial strength of enterprises. Even some enterprises will fall into financing difficulties owing to innovation investments (Pang *et al*., 2023). In the sample enterprises of the current study, the proportion of technological innovation expenditure to the

total revenue of enterprises is as high as 14.48%. Financial strength is the key support for the innovative development of enterprises. Being short of funds, enterprises will be encountered with the high external financing cost and serious financing constraints, so they will reduce their expenditure on R&D, which will lead to the decline of its technological innovation level (Zhang *et al*., 2022). For agricultural enterprises, the weakness of agriculture has a profound impact on their development, thereby forming a natural constraint. Therefore, many countries provide various policy support to agricultural enterprises in terms of subsidies, taxes, and insurance, among others, to promote their innovative development by alleviating financing constraints (Ali *et al*., 2021). Therefore, alleviating financing constraints can enhance the guarantee of investment in enterprise innovation and motivate enterprises to make markedly stable and long-term innovation investment decisions. Therefore, this study proposes the following hypothesis:

Hypothesis 2: The development of digital financial inclusion can promote agricultural enterprise innovation by relieving financing constraints.

2. Methodology

2.1 Samples and Data

In this study, A-share listed agricultural enterprises in China's Shanghai Stock Exchange and Shenzhen Stock Exchange were selected as samples. Enterprises' financial data were derived from the Wind and China Stock Market and Accounting Research (CSMAR) databases and the annual reports of listed enterprises. Digital financial inclusion data were obtained from the Digital Financial Inclusion Index released by the Institute of Digital Finance Peking University. This index was co-compiled by the Institute of Digital Finance Peking University, and ANT GROUP to reflect the development status of digital financial inclusion in China. The samples comprised China's 31 provinces, 337 prefecture-level cities, and approximately 2800 counties. The research period spans 2011–2022 because the provincial and municipal digital financial inclusion index began in 2011. The initial samples were screened according to the research needs. First, the ST and *ST enterprise samples were excluded. Second, enterprise samples with missing key variables were excluded. Lastly, 89 enterprise samples and 1068 observations were obtained for the analysis in this study.

2.2 Variable Settings and Descriptions

This study's dependent variable is enterprise innovation. R&D investment is the fundamental material guarantee for enterprise innovation. The higher the R&D investment, the stronger the innovation vitality of enterprises. This study draws on Aarstad and Kvitastein (2020) and utilizes enterprise R&D investment and the proportion of R&D investment to the total operating revenue.

This study's independent variable of interest is digital financial inclusion. This study draws on Guo *et al*. (2020) and introduces the Digital Financial Inclusion Index released by the Institute of Digital Finance Peking University as the measure for digital financial inclusion. A higher index value indicates a more prosperous development of digital financial inclusion. This index specifically includes the digital financial inclusion total index and three first-level indicators: coverage breadth, usage depth, and digitalization level of digital financial inclusion.

The mediating variable in this study is financing constraint. The current study uses Hadlock and Pierce (2010) as basis in utilizing the *SA* index as a measure for financing constraints of enterprises. The specific calculation formula for the *SA* index is as follows:

$$SA = -0.737 * Size + 0.043 * Size^2 - 0.04 * Age \quad (1)$$

In Equation (1), *Size* represents the natural logarithm of an enterprise's total assets and *Age* denotes the establishment period of the enterprise.

This study referred to existing research (Marinakis *et al*., 2024; Farsani *et al*., 2024; Baiyegunhi, 2023; Anyanwu *et al*., 2023) and selected the following control variables to control for the potential impact of other variables on agricultural enterprise innovation: enterprise size, asset–liability ratio, return on assets, Tobin's Q value, shareholding ratio of the largest shareholder, shareholding ratio of institutional investors, board size, ratio of independent directors, duality, cash flow, and nature of ownership. To address potential heteroscedasticity of variables, natural logarithms were taken from such variables as R&D investment, digital financial inclusion index, and enterprise size, with specific variables as defined in *Table 1*.

Table 1. Variable definitions and summary statistics

Variable names	Variable definitions	Mean	SD
Dependent variable			
Enterprise innovation	Yearly R&D investment amount of the enterprise	17.571	1.341
	Ratio of yearly R&D investment to total operating revenue	2.078	1.817
Independent variable of interest			
DFI	Digital financial inclusion (DFI) index	5.365	0.622
DFI_coverage	Coverage breadth of digital financial inclusion	5.248	0.719
DFI_depth	Usage depth of digital financial inclusion	5.401	0.575
DFI_digitization	Digitization level of digital financial inclusion	5.536	0.748
Mediating variable			
Financing constraint	*SA* index	4.966	1.277
Control variables			
Enterprise size	Logarithm of total assets	22.371	1.046
Asset-liability ratio	Ration of total liabilities to total assets	0.381	1.671
Return on assets	Ratio of new profit to total assets	0.052	0.065
Tobin's Q	Tobin's Q value	2.097	1.385
Shareholding ratio of shareholders	Number of shares held by the largest shareholder/total number of shares	34.969	14.455
Shareholding ratio of institutions	Number of shares held by institutional investors/total number of shares	49.125	25.944
Board size	Number of directors in the board of directors	2.156	0.213
Ratio of independent directors	Number of independent directors/total number of directors in the board of directors	0.388	0.081
Duality	1 taken when the chairman and chief executive roles are held by the same person and 0 otherwise.	0.288	0.453
Cash flow	Cash flow from operating activities/total assets	0.074	0.073
Nature of ownership	1 representing state-owned enterprises and 0 representing non-state-owned ones.	0.339	0.474

Source: own calculations.

2.3 Model Construction

To analyze the impact of digital financial inclusion on the innovation of agricultural enterprises, this study develops a panel model of company-annual sample according to the sample characteristics. The benchmark model is set as follows:

$$Innovation_{it} = \alpha_0 + \alpha_1 DFI_{it} + \sum \gamma_j Control_{it} + \varepsilon_{it} \quad (2)$$

In equation (2), $Innovation_{it}$ represents the innovative behavior of enterprise *i* in year *t*. DFI_{it} denotes the development of digital financial inclusion faced by enterprise *i* in year *t*. $Control_{it}$ represents a series of control variables affecting agricultural enterprise innovation. α_0 is a constant term. α_1 and γ_j are the parameters to be estimated, and ε_{it} is a residual disturbance term.

On the basis of Equation (2), the fixed effects of year and industry were further controlled for, and the model was expanded into the following form:

$$Innovation_{it} = \alpha_0 + \alpha_1 DFI_{it} + \sum \gamma_j Control_{it} + \sum Year + \sum Ind + \varepsilon_{it} \quad (3)$$

In Equation (3), *Year* represents the fixed effect of the year and *Ind* denotes the fixed effect of the industry. Other variables are kept consistent with those in Equation (2). To investigate the underlying mechanism of digital financial inclusion on agricultural enterprise innovation, the following mediating effect model was constructed by referring to Moqaddamerad and Ali (2024):

$$M_{it} = \delta_0 + \delta_1 DFI_{it} + \sum \beta_j Control_{it} + \sum Year + \sum Ind + \tau_{it} \quad (4)$$

$$Innovation_{it} = \varphi_0 + \varphi_1 DFI_{it} + \varphi_2 M_{it} + \sum \rho_j Control_{it} + \sum Year + \sum Ind + \omega_{it} \quad (5)$$

In Equations (4) and (5), M_{it} is a mediating variable, indicating the financing constraints faced by enterprise *i* in year *t*. δ_0 and φ_0 are constant terms. δ_1, φ_1, φ_2, β_j and ρ_j are the parameters to be estimated, and τ_{it} and ω_{it} are residual disturbance terms.

3. Results Analysis

3.1 Benchmark Regression Analysis

The Hausman test was conducted on the model. The test results show that the fixed effect model was better than the random effect model, so a two-way fixed effects model was adopted. The model estimation results are presented in *Table 2*. Regression (1) presents the estimation results when only the independent variable of interest is introduced. Regression (2) shows the estimation results when the independent variable of interest and control variables are simultaneously introduced. Regressions (3) to (5) show the estimation results when the coverage breadth, usage depth, and digitalization level of digital financial inclusion serve as the independent variables of interest. Overall, digital financial inclusion remains significant at the 1% statistical level whether or not the control variables are introduced. The positive estimation coefficient indicates that agricultural enterprise innovation can be promoted by the development of digital financial inclusion. Thus, hypothesis 1 is verified. For the three dimensions of the development of digital financial inclusion, the coverage breadth, usage depth, and digitalization level of digital financial inclusion are significantly positive at the 1% statistical level. For the estimation coefficients, the usage depth of digital financial inclusion shows a stronger effect on promoting

agricultural enterprise innovation, followed by coverage breadth and digitalization level of digital financial inclusion.

Table 2. Benchmark regression results

Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)
Independent variable of interest					
DFI	0.616*** (0.028)	0.348*** (0.041)			
DFI_coverage			0.304*** (0.035)		
DFI_depth				0.392*** (0.045)	
DFI_digitization					0.168*** (0.029)
Control variables					
Enterprise size		0.615*** (0.058)	0.621*** (0.057)	0.605*** (0.058)	0.779*** (0.052)
Asset–liability ratio		–0.476** (0.200)	–0.471** (0.200)	–0.485** (0.199)	–0.663*** (0.202)
Return on assets		0.887** (0.409)	0.898** (0.408)	0.834** (0.408)	0.631 (0.416)
Tobin's Q		–0.024 (0.017)	–0.025 (0.017)	–0.018 (0.017)	–0.022 (0.018)
Shareholding ratio of shareholders		0.002 (0.004)	0.002 (0.004)	0.002 (0.004)	0.001 (0.004)
Shareholding ratio of institutions		0.0003 (0.002)	0.0003 (0.002)	0.0002 (0.002)	–0.001 (0.002)
Board size		0.335** (0.149)	0.337** (0.149)	0.305** (0.148)	0.263* (0.152)
Ratio of independent directors		–0.541* (0.276)	–0.568** (0.276)	–0.490* (0.276)	–0.524* (0.282)
Duality		–0.187*** (0.057)	–0.193*** (0.057)	–0.181*** (0.057)	–0.174*** (0.058)
Cash flow		–0.014 (0.314)	0.020 (0.313)	0.022 (0.313)	0.056 (0.321)
Nature of ownership		-0.034 (0.155)	-0.071 (0.155)	-0.020 (0.154)	0.021 (0.158)
Constant	14.268*** (0.153)	1.607 (1.233)	1.778 (1.237)	1.581 (1.227)	–0.829 (1.195)
Industry/Year	YES	YES	YES	YES	YES
Pseudo R^2	0.078	0.308	0.316	0.312	0.304
Sample size	1068	1068	1068	1068	1068

Notes: Values in parentheses indicate robust standard errors. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

Source: own calculations.

For the other control variables, enterprise size is significantly positive at the 1% statistical level, manifesting that the larger the enterprise size, the stronger the innovation ability. Owing to abundant resources and mature management, large-sized enterprises tend to undertake exploratory research to achieve industry-leading breakthrough innovation (Anicic, 2024). The asset–liability ratio exerts a significant negative impact on enterprise innovation. By contrast, return on assets plays a significantly positive role in promoting enterprise innovation, which is consistent with the research conclusions of Ahmed *et al*. (2024). The lower the asset–liability ratio and the higher the return on assets, the more sufficient funds the enterprise has to invest in innovative activities. Board size has a significantly positive impact on enterprise innovation. The reason is that more board members are conducive to the implementation of enterprise innovation strategies and coverage expansion of innovation openness,

thereby enabling access to external knowledge and resources, which can promote enterprise innovation (Dwekat *et al*., 2025). The ratio of independent directors has a significantly negative impact on enterprise innovation because independent directors in China fail to effectively play the supervision and advisory roles, which may even exacerbate the agency problem of listed companies (Acero, Alcalde, 2016). The duality of an enterprise has a significantly negative impact on enterprise innovation, indicating that enterprise innovation will be impeded if the enterprise's chairman and chief executive are assumed by the same person. The reason is that the duality will weaken the independence of the board (Gallego-Alvarez, Pucheta-Martinez, 2022) and impede the ability of the enterprise to make sound decisions on innovation (Ramdani, van Witteloostuijin, 2010).

3.2 Endogeneity Test

In causality identification, endogeneity may arise owing to reverse causality, omission of control variables, and sample deviation. In this study, digital financial inclusion is macro-level data, while agricultural enterprise innovation is individual micro-level data. Moreover, macro-level results can hardly be influenced by individual-level factors, thereby reducing the possibility of reverse causality in the model. However, endogeneity may still arise from other sources and should be considered in this study. To address such concerns, this study introduced two methods for endogeneity test. The one-phase lag of digital financial inclusion was taken as a independent variable of interest for estimation. Referring to Chen and Gong (2021), the distance between the provincial city center of the enterprise's place of registration and the Hangzhou City center was chosen as the instrumental variable of digital financial inclusion, followed by the test via 2-stage least squares method (2SLS).

Table 3. Endogeneity test results

Variables	Regression (1)	Regression (2)	
		First stage	Second stage
Independent variable of interest			
DIF			0.699*** (0.301)
DFI one–phase lag	0.171*** (0.038)		
Distance		–0.043*** (0.007)	
Control variables			
Enterprise scale	0.678*** (0.059)	0.305*** (0.023)	0.621*** (0.094)
Asset–liability ratio	–0.456** (0.202)	–0.983*** (0.147)	0.866** (0.370)
Return on assets	0.560 (0.389)	–2.941*** (0.494)	3.906*** (1.128)
Tobin's Q	–0.026 (0.016)	0.082*** (0.014)	–0.152*** (0.029)
Shareholding ratio of shareholders	0.002 (0.004)	–0.005*** (0.002)	–0.006* (0.003)
Shareholding ratio of institutions	–0.0001 (0.002)	–0.004*** (0.001)	–0.001 (0.002)
Board size	0.297** (0.146)	–0.496*** (0.103)	0.085 (0.230)
Ratio of independent directors	–0.389 (0.261)	0.048 (0.243)	0.374 (0.452)

Table 3 (*continuation*). Endogeneity test results

Variables	Regression (1)	Regression (2)	
		First stage	Second stage
Duality	–0.212*** (0.054)	–0.007 (0.041)	0.142* (0.075)
Cash flow	0.013 (0.309)	0.538 (0.328)	0.155 (0.628)
Nature of ownership	0.067 (0.175)	–0.020 (0.042)	–0.527*** (0.084)
Constant	1.227 (1.267)	0.546 (0.537)	–0.226 (1.021)
Industry/Year	YES	YES	YES
Pseudo R^2	0.289	0.264	0.415
Sample size	979	1068	1068

Notes: Values in parentheses indicate robust standard errors. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

Source: own calculations.

The endogeneity test results are presented in *Table 3*. In Regression (1), the one-phase lag variable of digital financial inclusion is significantly positive at the 1% statistical level, which is consistent with the regression result in *Table 2*. In Regression (2), the instrumental variable in the first-stage regression result is significant at the 1% statistical level, indicating the significant correlation between the instrumental variable and digital financial inclusion. In the second-stage regression result, the significant positive effect of digital financial inclusion on enterprise innovation is upheld when considering endogeneity. The two types of endogeneity test results reflect the relatively strong robustness of the model estimation results in this study.

3.3 Heterogeneity Analysis

To further examine the heterogeneity of the impact of digital financial inclusion on agricultural enterprise innovation, the samples were divided into three groups: state-owned and non-state-owned enterprises, enterprises in the eastern region and in the central and western regions, and large- and small-sized enterprises. Referring to Lu *et al*. (2024), the sample enterprises were divided into state-owned enterprises and non-state-owned enterprises by ownership. According to the place of registration, the sample enterprises were divided into enterprises in the eastern region and enterprises in the central and western regions. Enterprise size was bounded by the average asset size of the overall samples. Lastly, those above and below the average were defined as large- and small-sized enterprises, respectively. Regression estimations were conducted for each of the six sub-samples. The results are shown in *Table 4*.

For the ownership of enterprises, the impact of digital financial inclusion on state-owned and non-state-owned enterprises' innovation is significantly positive at the 1% statistical level. This result indicates that the innovation of the two types of agricultural enterprises is significantly promoted by the development of digital financial inclusion. For the value of the estimated coefficients, digital financial inclusion exerts a stronger impact on the innovation of state-owned agricultural enterprises than on that of non-state-owned enterprises. This result can be attributed to the fact that state-owned enterprises, compared with non-state-owned enterprises, own more convenient information channels in resource acquisition and allocation (Zhang *et al*., 2022), as well as natural political resource endowments, making them able to gain more financial support for innovation.

Table 4. Heterogeneity analysis results

Variables	Grouped by ownership		Grouped by region		Grouped by size	
	State-owned	Non-state-owned	Eastern region	Central and western regions	Large-sized	Small-sized
Independent variable of interest						
DFI	0.381*** (0.082)	0.321*** (0.048)	0.334*** (0.057)	0.337*** (0.058)	0.469*** (0.075)	0.305*** (0.055)
Control variables	YES	YES	YES	YES	YES	YES
Industry/Year	YES	YES	YES	YES	YES	YES
Constant	1.748 (2.872)	2.593* (1.420)	4.764*** (1.630)	–3.519* (1.991)	1.995 (2.352)	4.560** (2.251)
Pseudo R^2	0.319	0.376	0.261	0.377	0.113	0.115
Sample size	362	706	696	372	442	626

Notes: Values in parentheses indicate robust standard errors. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

Source: own calculations.

For the location of enterprises, the impact of digital financial inclusion on the innovation of enterprises in the eastern region and those in the central and western regions is significantly positive at the 1% statistical level. This result reveals that the innovation of both types of agricultural enterprises is evidently promoted by the development of digital financial inclusion. For the value of estimated coefficients, digital financial inclusion shows a slightly stronger effect on the innovation of agricultural enterprises in the central and western regions than on that of agricultural enterprises in the eastern region. The reason is that China's eastern region, being the central hub of the country's social and economic development, tends to be the primary beneficiary of innovative resources (Ji *et al*., 2020). Meanwhile, economic development in the central and western regions is relatively backward, and financial demand is markedly urgent. As such, the development of digital financial inclusion can significantly meet its needs for innovation and development. In addition, the development of digital financial inclusion in the central and western regions is relatively backward compared with that in the eastern region. According to the law of diminishing marginal returns, digital financial inclusion will play a significant role in promoting the innovation of agricultural enterprises in the central and western regions.

For the size of enterprises, the impact of digital financial inclusion on the innovation of large- and small-sized enterprises is significantly positive at the 1% statistical level. This result indicates that the innovation of both types of agricultural enterprises is significantly promoted by the development of digital financial inclusion. For the value of estimated coefficients, digital financial inclusion exerts a markedly strong impact on the innovation of large-sized agricultural enterprises on that of small-sized agricultural enterprises. The reason is that compared with small-sized agricultural enterprises, large-sized agricultural enterprises tend to own stronger comprehensive capabilities and extensive social networks, enabling them to access more information in the market (Anicic, 2024). Hence, large-sized agricultural enterprises can easily acquire digital financial inclusion to meet their innovation needs, while small-sized agricultural enterprises are usually encountered with financing constraints (Wang *et al*., 2023).

3.4 Robustness Test

To further test the reliability of the preceding findings, two methods were introduced in this study for robustness test. First, the dependent variable was replaced, and enterprise innovation was measured through the ratio of enterprise R&D investment to total operating revenue. Second, the independent variable of interest was replaced, and the digital financial inclusion index at the municipal level was adopted for estimation. The robustness test results are presented in *Table 5*. Digital financial inclusion is significantly positive at the 1% statistical level. Among the three first-level indicators of digital financial inclusion, usage depth of digital financial inclusion exerts the strongest impact on agricultural enterprise innovation, followed by the coverage breadth and digitalization level of digital financial inclusion, completely coinciding with the preceding analysis results. Hence, the robustness of the research results is revealed.

Table 5. Robustness test results

Variables	Replacement of dependent variable	Replacement of independent variable of interest			
	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)
Independent variable of interest					
DFI	0.338*** (0.075)	0.432*** (0.056)			
DFI_coverage			0.417*** (0.054)		
DFI_depth				0.457*** (0.058)	
DFI_digitization					0.222*** (0.037)
Control variables	YES	YES	YES	YES	YES
Industry/Year	YES	YES	YES	YES	YES
Constant	11.586*** (2.270)	0.818 (1.223)	0.357 (1.197)	1.051 (1.230)	–0.142 (1.228)
Pseudo R^2	0.074	0.311	0.317	0.311	0.305
Sample size	1068	1068	1068	1068	1068

Notes: Values in parentheses indicate robust standard errors. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

Source: own calculations.

3.5 Mechanism Analysis

This study further explored the underlying mechanism of digital financial inclusion in promoting agricultural enterprise innovation using a mediating effect model from the perspective of financing constraints. The test results are presented in *Table 6*. In Regression (1), the impact of digital financial inclusion on the financing constraints of agricultural enterprises is significantly positive at the 1% statistical level. This result indicates that the development of digital financial inclusion can effectively alleviate the financing constraints of agricultural enterprises, coinciding with the research conclusion of Zhang *et al*. (2023). After financing constraint and digital financial inclusion were simultaneously introduced into the model, the impact of digital financial inclusion on agricultural enterprise innovation was significantly positive at the 1% statistical level, while the impact of financing constraint was insignificant. Sobel test results of the model reveal a significant Z-statistics of −1.928 at the 10%

statistical level. This finding indicates that financing constraint plays a mediating role between digital financial inclusion and agricultural enterprise innovation. In particular, digital financial inclusion can promote enterprise innovation indirectly by alleviating the financing constraints encountered by agricultural enterprises. Thus, hypothesis 2 is verified.

Table 6. Test results of mechanism analysis

Variables	Regression (1)	Regression (2)
	Financing constraint	Enterprise innovation
Independent variable of interest		
DFI	–0.027*** (0.003)	0.361*** (0.042)
Financing constraint		0.491 (0.444)
Control variables	YES	YES
Industry/Year	YES	YES
Constant	–22.139*** (0.094)	12.473 (9.900)
Pseudo R^2	0.998	0.312
Sample size	1068	1068

Notes: Values in parentheses indicate robust standard errors. *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

Source: own calculations.

4. Discussions

The development of digital financial inclusion is rising, thereby providing diversified and convenient financial services for enterprise development and serving as a booster for the innovation and development of enterprises. Can digital financial inclusion promote the innovation of agricultural enterprises? Existing research mainly focuses on strategic emerging industrial enterprises, manufacturing enterprises, high-tech enterprises, and enterprises listed on the Growth Enterprise Market (Chen *et al*., 2024a; Yao, Yang, 2022). For the agricultural industry, which has inherent weakness characteristics, related enterprises need additional policy support, especially financial support. Meanwhile, the weakness of agricultural industry will also restrict agricultural enterprises from fairly obtaining various financial resources. The current study finds that digital financial inclusion can significantly promote the innovation of agricultural enterprises, break through the constraints of its own industrial characteristics, and enjoy the dividends brought by the development of digital financial inclusion, consistent with the research conclusion of He *et al*. (2024). The most essential reason is that enterprise innovation requires a large amount of capital investment, and digital financial inclusion provides convenient and efficient financial services or support, such as credit, insurance, and other financial services or support for enterprise innovation (Huang, Azman, 2023). Combined with the existing research on other types of enterprises, digital financial inclusion is also inclusive in promoting enterprise innovation and improving the efficiency of financial resource allocation, thereby not only promoting the innovation of industrial enterprises and high-tech enterprises that are economically strong (Han, Gu, 2021; Lin, Xu, 2024), but also promoting innovation of agricultural enterprises with a relatively weak development foundations.

From the perspective of different dimensions of digital financial inclusion, the coverage breadth, usage depth, and digitalization level of digital financial inclusion can promote the innovation of agricultural enterprises, further confirming the inclusiveness of digital financial inclusion in promoting enterprise innovation (Huang *et al*., 2023). In particular, the usage depth of digital financial inclusion plays a strong role in promoting the innovation of agricultural enterprises, followed by coverage breadth and digitization level of digital financial inclusion. The reason is that the expansion of usage depth reflects that enterprises can easily obtain effective financial services (Chen *et al*., 2024b). This conclusion is also consistent with the overall development trend of digital financial inclusion. Between 2011 and 2022, the average value of digital financial inclusion index in China's 31 provinces increases from 40.0 in 2011 to 379.4 in 2022, in which the growth in the usage depth of digital financial inclusion is an important driving force for the growth of the digital financial inclusion index. With the narrowing of development space for the coverage breadth and digitalization level of digital financial inclusion, the future development of digital financial inclusion will mainly rely on the usage depth of digital financial inclusion (Dong *et al*., 2022). This aspect is also markedly conducive to promoting agricultural enterprise innovation.

Does digital financial inclusion have inclusiveness within the same type of enterprises? Is there any effect difference within the industry? This study reveals that digital financial inclusion shows no inclusiveness in terms of enterprise ownership and enterprise size, and its promoting effect on the innovation of state-owned agricultural enterprises and large-sized agricultural enterprises is stronger than on the innovation of non-state-owned agricultural enterprises and small-sized agricultural enterprises. The reason is that state-owned and large-sized enterprises possess considerably broad channels to obtain information, funds, and other resources, and have strong guarantees for innovation (Zhang *et al*., 2022; Anicic, 2024). At the regional level, the inclusiveness of digital financial inclusion is gradually emerging. The impact on the innovation of agricultural enterprises in the eastern and central–western regions does not show a significant difference, which is closely related to the underlying mechanism by which digital financial inclusion promotes agricultural enterprise innovation. This study finds that digital financial inclusion mainly promotes agricultural enterprise innovation by alleviating financing constraints, which is consistent with the research conclusion drawn by Wang, Chen (2023) and Xu *et al*. (2024). China has been committed to addressing unbalanced regional development and pursuing common prosperity. In recent years, the economic development gap between the eastern and central–western regions has gradually narrowed, and many policy resources are also turning toward the central–western region. To promote the development of digital financial inclusion, government should focus on the differences of its impact on different industries and also to the effect differences among enterprises within the industry, with focus on supporting the innovative development of disadvantaged industries and enterprises.

Conclusions and Implications

Main Findings

This study used the A-share listed agricultural enterprises in China's Shanghai Stock Exchange and Shenzhen Stock Exchange as bases to empirically test the impact of digital financial inclusion on the innovation of agricultural enterprises, mainly by constructing a panel model. The conclusions are as follows. (1) The development of digital financial inclusion can significantly promote the innovation of agricultural enterprises. Among the three first-level indicators of digital financial inclusion, the usage depth of digital financial inclusion exerts a stronger promoting effect on the innovation of agricultural enterprises than coverage breadth and digitalization level. This conclusion still holds after performing

endogeneity and robustness tests. (2) The heterogeneity analysis results indicate that compared with non-state-owned, eastern, and small-sized enterprises, the development of digital financial inclusion has a greater effect on promoting the innovation of state-owned enterprises, enterprises in the central and western regions, and large-sized enterprises. In addition, the inclusiveness of digital financial inclusion has not been fully reflected, especially in terms of ownership and enterprise size. (3) The mechanism test results show that digital financial inclusion mainly promotes the innovation of agricultural enterprises by alleviating financing constraints, which also responds to the financing difficulties and high financing costs generally faced by agricultural enterprises. Lastly, the development of digital financial inclusion provides a feasible way to solve these difficulties.

Managerial Implications

The following policy enlightenments are obtained on the bases of this study's conclusions.

First, promote the expansion and quality improvement of digital financial inclusion. This study reveals that agricultural enterprise innovation can be promoted by the three dimensions of digital financial inclusion, especially its coverage breadth, providing a new idea for government to formulate policies supporting the agricultural enterprise innovation. Effort should be exerted to master the new development opportunity of digital economy, carry out digitalization transformation of traditional financial institutions, elevate the digitalization level of financial inclusion, reduce the information asymmetry in the resource acquisition of agricultural enterprises, and improve financial resource mismatching; continuously improve digital financial inclusion infrastructure, such as broadband networks, communication base stations, and mobile devices; establish agricultural enterprises-oriented digitalized and inclusive financial service platforms, innovate digital financial inclusion products, and marketing channels; continuously improve the coverage breadth and usage depth of digital financial inclusion, especially the expansion of the usage depth; reduce the threshold and cost for agricultural enterprises to obtain financial support; and better serve the innovative development of entity economy, such as agricultural enterprises.

Second, formulate differentiated digital financial inclusion development strategies. This study finds that digital financial inclusion exerts a stronger promoting effect on the innovation of state-owned enterprises, enterprises in the central and western regions, and large-sized enterprises than that of non-state-owned enterprises, enterprises in the eastern region, and small-sized enterprises. Therefore, when formulating the development policies of digital financial inclusion, such factors as the attributes of enterprise ownership, enterprise size, and region should be fully considered. Appropriate policies should be formulated for specific enterprises, with emphasis on the digital financial inclusive needs of small-sized and non-state-owned enterprises, developing pertinent digital financial inclusion products, providing personalized financial services, rendering more precise digital financial inclusive services, achieving real inclusiveness, and digging the innovation potential of disadvantaged agricultural enterprises.

Third, guide agricultural enterprises to effectively dock with and use digital financial inclusion. Alleviating financing constraints is an important way for digital financial inclusion to promote the innovation of agricultural enterprises, which is conducive to solving the long-standing problems of financing difficulties and high financing costs faced by agricultural enterprises. Therefore, local governments should transform the traditional non-market-oriented problem-solving approach guided by financial support, and alleviate the financing constraints of agricultural enterprises by vigorously developing market-oriented digital financial inclusion, breaking the resources dependence of enterprises, and consolidating

financial guarantee for the sustainable innovation of agricultural enterprises. Agricultural enterprises should also actively engage in digital transformation and equip themselves with digital infrastructure to better obtain and use digital financial inclusion products or services.

Limitations and Future Directions

This study, although revealing the impact and underlying mechanism of digital financial inclusion on agricultural enterprise innovation, still has some limitations. (1) Owing to the difficulty of data collection, attention was concentrated on the agricultural industry, without considering the heterogenous effect of digital financial inclusion at different industrial levels within the agricultural industry. In the future, the impact of digital financial inclusion on the innovation of enterprises must also be focused on such industries as the planting, forestry, animal husbandry, and fishery industries. (2) In addition to financing constraints, there are other underlying mechanisms that digital financial inclusion affects agricultural enterprise innovation, which remain to be further explored. (3) Agricultural enterprises are generally faced with financing difficulties and high financing costs. How to quantify the two issues separately and explore the impact of digital financial inclusion on them will be beneficial for the profound understanding of the positive effects of digital financial inclusion, which is the focus of future research.

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SKAITMENINĖS FINANSINĖS ĮTRAUKTIES POVEIKIS ŽEMĖS ŪKIO ĮMONIŲ NAUJOVĖMS

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Santrauka. *Naujovės yra nuolatinė varomoji įmonių plėtros jėga, o skaitmeninės ekonomikos eros pradžia suteikė tam gyvybingumo. Todėl labai svarbu nagrinėti, ar žemės ūkio įmonės gali pasinaudoti skaitmeninės ekonomikos pažangos teikiamomis galimybėmis inovacijų srityje. Šiuo tyrimu siekiama atskleisti, ar žemės ūkio įmonės gali naudotis skaitmeninės finansinės įtraukties dividendais ir atlikti tam tikrą vaidmenį skatindamos inovacijas. Remiantis išteklių priklausomybės teorija ir finansavimo apribojimų teorija, pasitelkus Kinijos A akcijomis kotiruojamų žemės ūkio įmonių finansinius duomenis ir Pekino universiteto Skaitmeninių finansų instituto skaitmeninės finansinės įtraukties duomenis 2011–2022 m., empiriškai išnagrinėtas skaitmeninės finansinės įtraukties poveikis žemės ūkio įmonių naujovėms. Rezultatai atskleidė, kad skaitmeninės finansinės įtraukties plėtra gali labai paskatinti žemės ūkio įmonių naujoves, tarp kurių skaitmeninės finansinės įtraukties naudojimo gylis veikia labiau nei jos aprėpties plotis ir skaitmeninimo lygis. Ši išvada vis dar galioja atlikus endogeniškumo ir atsparumo bandymus. Be to, palyginti su nevalstybinėmis įmonėmis, rytų regiono įmonėmis ir mažosiomis įmonėmis, valstybės valdomos įmonės, taip pat vidurio ir vakarų regionų įmonės ir didelės įmonės yra labiau skatinamos inovacijų aspektu, jos pasitelkia ir skaitmeninę finansinę įtrauktį. Skaitmeninė finansinė įtrauktis labiausiai skatina žemės ūkio įmonių naujoves mažindama finansavimo suvaržymus ir didindama investicijų garantijas žemės ūkio įmonėms, kad jos galėtų nuolat vykdyti novatorišką veiklą. Išvadose pateiktos teorinės gairės žemės ūkio įmonėms, kaip naudoti skaitmeninę finansinę įtrauktį, kad būtų sumažinti finansavimo apribojimai, išlaikytos inovacijos. Taip pat siekiama vyriausybei suteikti sprendimų priėmimo pagrindą formuoti inovacijų paramos politiką žemės ūkio įmonėms*.

Reikšminiai žodžiai: skaitmeninė finansinė įtrauktis; įmonių inovacijos; finansavimo apribojimai; investicijos į mokslinius tyrimus ir technologinę plėtrą.