Research on the Impact of the Development of Supply Chain Finance Under the Background of Bank Digitalization on the Credit Constraints of Agricultural-related SMEs

Nianyu Shen[1*]

[1]School of Economics, Minzu University of China, Beijing, China

Abstract. This paper, based on the panel data of agricultural-related small and medium-sized enterprises listed on the New Third Board from 2015 to 2024, employs a fixed-effects model to empirically examine the independent impacts, interaction effects, and non-linear characteristics of digital banking and supply chain finance on credit constraints. The findings reveal that both digital banking and supply chain finance can significantly alleviate the credit constraints of agricultural-related small and medium-sized enterprises. However, the mitigating SCF's role in easing SME funding constraints shows an inverted U-shaped feature as digital banking develops, and excessive digitalization may weaken this effect. Meanwhile, the effect of supply chain finance penetration rate in easing credit constraints for enterprises at all levels of the supply chain varies by industry. Based on this, the research suggests: for regions where the digitalization of banks has not been initiated or is in its early stages, efforts should be accelerated to promote the digitalization of banks and enhance the accessibility of supply chain financial services. It is necessary to be vigilant against the adverse effects of excessive digitalization, and to rationally optimize the application of technology to stabilize the positive mitigating role.

1 Introduction

Agriculture-related small and medium-sized enterprises have the dual attributes of "three rural" and small and medium-sized enterprises, and are important market players in China to promote the implementation of the rural revitalization strategy and the development of the real economy. At the same time, the above characteristics also make such enterprises face a unique financing dilemma for a long time: on the one hand, the inherent natural risks of agricultural production are high and cyclical, and the problems of small scale and insufficient collateral that are common in small and medium-sized enterprises are superimposed on each other; On the other hand, there is a serious information asymmetry between financial institutions and agribusiness, which makes it difficult for traditional credit models to effectively assess their credit risk. Moreover, agricultural producers face a complex risk matrix, including natural risks such as natural disasters and disease risks, as well as market

* Corresponding author:22010754@muc.edu.cn

risks such as price fluctuations.In the past two years, the digital transformation of banks and the innovation of supply chain finance have provided new possibilities for solving the financing problems of agriculture-related SMEs [1,2]. Specifically, in China, the digitalization of banks expands the availability of financial services through the following three paths: first, technologies such as mobile payment and big data risk control reduce service costs, enabling financial institutions to reach long-tail customers in a sustainable way [3-5]. Second, the application of technologies such as blockchain and the Internet of Things (IoT) has enhanced supply chain transparency [6]. Finally, the open banking model facilitates cross-institutional data sharing [7]. At the same time, supply chain finance relies on the real transaction data of the industrial chain and opens new financing channels for agricultural-related enterprises lacking traditional collateral through credit transmission and order financing of core enterprises [1,4].

However, this innovative model gradually exposes new problems in practice. The first and most obvious is the digital divide, where the continuous improvement of digital technology has created a new phenomenon of exclusion while expanding the availability of financial services, which lead to the disadvantage of some agriculture-related SMEs in the digital financial system of banks due to the digital divide, resulting in new credit constraints [8]. The second is the phenomenon of hierarchical exclusion in the supply chain, where core enterprises in the agricultural supply chain often give priority to meeting the financing needs of first-tier suppliers, while traditional agriculture, forestry, animal husbandry and fishery smallholder farmers and micro-processing enterprises in the upstream of the supply chain are difficult to benefit. In addition, from the perspective of credit providers, excessive digitalization may lead to "technology exclusion", and banks' over-reliance on algorithmic models will systematically misestimate the special risks of agricultural production and thus misestimate the amount of loans [9,10]. The existence of these problems makes it of great practical significance to explore the synergy mechanism and boundary conditions between bank digitalization and supply chain finance.

Compared with previous studies, this paper has the following innovations: first, it expands the dimension of financial exclusion theory to the research interpretation in the digital age, and proves the existence of two exclusion effects: "digital divide" and "supply chain hierarchy"; Second, enrich the theoretical framework of supply chain finance, and empirically prove the nonlinear relationship between the digital level of banks and financial efficiency. Third, the impact of digital financial inclusion on alleviating financing constraints in different positions of the agricultural supply chain should be included in the study, to avoid a general description of the mitigation effect of the development of the entire supply chain. This has new enlightenment for our theoretical research.

First, it can provide theoretical support for the regulatory authorities to formulate differentiated policies according to the differences in the degree of digitalization of banks in different regions. Second, product adjustments can be implemented for financial institutions, taking the dynamic risk control model with agricultural characteristics as an example, and making appropriate changes according to local conditions; Third, it provides personalized support for agriculture-related SMEs with different digital levels and development stages of banks and supply chain locations to improve the digital adaptability of banks and the adoption of supply chain finance to improve credit availability.

Based on the panel data of agriculture-related small and micro enterprises on the New Third Board in 2015~2024, this paper applies the regression model and DID to study: the role and effect of bank digitalization on supply chain finance alone; the interaction between banking digitalization and supply chain finance; Alleviate the role of credit constraints heterogeneity of agriculture-related small and micro enterprises in different supply chain locations. The results show that the digitalization of banks plays an effective role in improving the supply chain financial credit, alleviating the constraints of agriculture-related credit to a certain extent, and provides a policy basis for establishing and improving the rural digital inclusive finance policy.

2 Empirical design

2.1 Variable selection

Explained variable:DCASH (cash and equivalents/total annual assets) measured credit availability for agricultural SMEs. Explanatory variables: The SCF penetration rate of the enterprise use The ratio of a firm's short-term borrowings and payables to the industry total. To avoid multicollinearity, the logarithm of the total assets of the enterprise at the end of the year is taken to measure the degree of digitalization of the local bank corresponding to the financial activities of the enterprise, as shown in Table 1.

Table 1. Variable Description

Variable Type	Variable Name	Abbre viation	Variable Definition
explaine d variable	Cash holding level	DCAS H	cash and equivalents/total assets at the end of the year
Explanat ory variables	Supply chain finance penetration rate of firms	SCFP	sum of short-term borrowings and accounts payable/sum of total short-term borrowings and accounts payable of the industry
	Digitalization of Corporate Cooperative Banks	DCCB	(Provincial Bank Digitalization Indexpt/National Bank Digitalization Indext)*ln (Total Enterprise Assetsit)
Control Variables	Return on Assets	ROA	Net Profit/Total Assets
	Total Asset Size	LnbAS SET	The logarithm of the total assets of the enterprise
	Leverage	LEV	Total Liabilities at the End of the Year / Total Assets at the End of the Year
	Interest cost	IC	Interest Expense/Total Liability at the End of Period
	Rate of Change in Capital Expenditures	CCE	Capital Expenditures/Operating Cash Flow
	Years of Establishment	AGE	Years of Establishment

The control variables include: (1) return on assets (ROA):Agricultural SMEs often face financial information opacity, and banks rely more on observable profitability to judge repayment ability, as the core financial indicator, ROA directly affects the credit risk assessment of banks (2) total asset size: The scale effect theory points out that larger-scale enterprises usually have stronger risk resilience and more complete financial systems. For agricultural-related enterprises, the asset size not only reflects the stability of operation but also implies the accumulation of social capital, both of which are important considerations for rural financial institutions to lend. (3) Leverage ratio (LEV): high debt ratio may convey historical financing ability, but also predict financial risk, which is an important indicator affecting the availability of corporate credit; (4) Interest cost (IC): IC reflects that financing cost can capture the difference in the pricing of enterprises with different risk levels, and it is necessary to control its endogenous relationship with credit availability; (5) Age of the enterprise: The longer the existence of the enterprise, the stronger the viability and experience accumulation. It is easier for established firms to build reputational capital, which is an important basis for informal finance and rural credit cooperatives to lend; (6) Rate of change of capital expenditure (CCE): reflects the impact of investment demand, and the fluctuation of capital expenditure such as equipment renewal and planting structure adjustment of agricultural enterprises will significantly affect their short-term debt repayment ability. Banks may perceive a sudden increase in capital expenditure as a risk signal, which in turn will affect the availability of credit for agribusiness-related SMEs. (7) In addition, the variable of lnbcash, the logarithmic form of corporate cash and cash equivalents, is also selected for the robustness test.

2.2 Model construction

The purpose of this study is to analyze the mitigation effect of supply chain finance on the credit constraints of small and medium-sized agricultural-related enterprises in the context of bank digitalization, and construct the following empirical model based on the fixed-effect panel model (1):

$$DCASH_{i,t} = \alpha_0 + \alpha_1 SCFP_{i,t} + \alpha_2 DCCB_{i,t} + \alpha_3 control_{i,t} + \varepsilon_{i,t}$$

In the above formula, $DCASH_{i,t}$ represents the cash holding level of enterprise i at time t, reflecting the availability of credit, and $SCFP_{i,t}$ represents the supply chain finance penetration rate of $DCCB_{i,t}$captures the digitalization degree of firm i's local cooperative bank at t; $control_{i,t}$ stands for other level control variables.

3 Analysis of empirical results

Table 2 benchmark regression shows that the penetration rate of supply chain finance (STL3) has a significant positive impact on the cash holding ratio (DCASH), with a coefficient of 8.647 that is significant at the 1% level. The results confirm that SCF development significantly relieves credit constraints in agricultural SMEs. Consistent with our model, SCF integrates supply chain actors' creditworthiness, thereby diversifying funding channels, lowering entry requirements, and strengthening cash positions for these enterprises [1,4]. Moreover, the coefficient of the Bank Digitalization Index (SZH) is significantly positive, suggesting that improvements in the level of bank digitalization can independently alleviate corporate credit constraints. Specifically, the digital transformation of banks significantly improves the financing environment for agriculture-related SMEs through multiple mechanisms. First, at the level of information acquisition, the bank uses big data technology to integrate multi-dimensional data such as taxation, water and electricity, and logistics, and combines blockchain technology to ensure the authenticity and traceability of information, which effectively solves the problem of opaque financial information of agricultural business entities. Secondly, in terms of business processes, the intelligent risk control system realizes automatic approval, compresses the loan approval time from several working days to 24 hours, and continuously optimizes the risk assessment model through machine learning to improve the accuracy of approval. In addition, in terms of service scope, technical means such as mobile financial terminals and remote video underwriting break through the limitations of physical outlets, especially for special agricultural product processing enterprises distributed in remote areas, to provide convenient access to financial services [1,4].

Table 2. Benchmark regression results

VARIABLES	(1) E1 DCASH	(2) E2 DCASH
SCFP	8.647***	
	(1.52)	
ROA	0.133***	0.131***
	(0.02)	(0.02)
lnbASSET	-1.718***	-3.872***
	(0.25)	(0.76)
LEV	-0.091***	-0.068***
	(0.01)	(0.01)
AGE	0.259***	0.247***
	(0.04)	(0.04)
IC	-0.471***	-0.432***
	(0.12)	(0.12)
CCE	0.000	0.000
	(0.00)	(0.00)
DCCB		2.984***
		(0.74)
Constant	41.862***	11.843**
	(4.78)	(5.55)
Observations	1,424	1,423
R-squared	0.130	0.120

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Regarding control variables, the financial leverage coefficient is negative and significant, aligning with the theory that highly leveraged firms are more susceptible to credit constraints, while the coefficient of return on assets (ROA) is positive and significant, which aligns with economic intuition that profitable firms are more likely to obtain external financing. The coefficient of enterprise size (lnbASSET) is also significantly positive, indicating that asset capacity is a factor influencing credit constraints; the age coefficient (AGE) is significantly positive, which may be due to the accumulated credit history and social capital of long-established firms, making it easier to alleviate credit constraints. Additionally, the financing cost (IC) coefficient is significantly negative, confirming the significant impact of financing cost on corporate credit constraints.

4 Robustness test

To ensure the robustness of the research conclusions, this paper performs the robustness test by replacing the measure method of the explanatory variables, and regresses the explanatory variables by replacing the original proportion (DCASH) with the natural logarithm of cash holding rate (Inbcash). The regression results in Table 3 show that the coefficient of STL3 is still 1.506 and is significant, which is consistent with the direction of the benchmark regression results, and the coefficient of SZH2 is also significant. Indicates the robustness of the results. In addition, the symbols and significance of the control variables are unchanged, which further improves the reliability of the conclusions.

The results of the robustness test show that the research conclusions of this paper are not sensitive to the choice of model setting and variable measurement, demonstrating the credit constraint mitigation effects of SCF and bank digitalization of agriculture-related SMEs does exist, rather than being caused by model setting or measurement errors.

Table 3. Robustness test results

VARIABLES	(1) E1 lnbcash	(2) E2 lnbcash
SCFP	1.506***	
	(0.24)	
ROA	0.031***	0.031***
	(0.00)	(0.00)
lnbASSET	0.767***	0.583***
	(0.04)	(0.12)
LEV	-0.012***	-0.009***
	(0.00)	(0.00)
AGE	0.042***	0.040***
	(0.01)	(0.01)
IC	-0.069***	-0.064***
	(0.02)	(0.02)
CCE	0.000	0.000
	(0.00)	(0.00)
DCCB		0.325***
		(0.12)
Constant	5.866***	1.619*
	(0.74)	(0.87)
Observations	1,423	1,422
R-squared	0.443	0.430

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5 Heterogeneity analysis

The heterogeneity analysis reveals the differentiated impact of supply chain finance and banking digitalization on different types of enterprises. The grouping regression results in Table 4 show that the mitigation effect of supply chain finance is characterized by heterogeneity between industries or different locations in the supply chain.

In the case of wholesale and retail trade (GROUPF), the coefficient is 152.392, which is significant at the level of 5%, while for the traditional agriculture, forestry, animal husbandry and fishery group (GROUPA), the coefficient is -0.428, which does not reach the significant level. This is since the wholesale and retail groups, as the core enterprises of the downstream, have clearer transaction chains and capital flows, and more symmetrical information, which are more likely to have a positive interaction effect with the supply chain finance model. Specifically, this special location advantage gives it a natural transparency advantage in terms of transaction chain and capital flow. On the one hand, wholesale and retail enterprises are directly connected to the terminal market and can obtain accurate market demand information promptly. On the other hand, as a key node of fund settlement, its capital flow and flow are relatively clear and traceable. This transparency advantage greatly reduces the information asymmetry, thereby reducing the information acquisition cost of financial institutions, so that such downstream enterprises can produce a more positive credit availability enhancement effect in the supply chain finance model [11].While the traditional agriculture, forestry, animal husbandry and fishery groups have the original characteristics of long production cycles, dedicated assets, and large risk fluctuations, which makes the financial institutions under the supply chain finance model more stringent than the credit conditions provided by them, and the policy effect is inhibited [12].

Table 4. Heterogeneity regression results

	(1)	(2)	(3)	(4)
	GROUPA	GROUPC	GROUPF	GROUPG
SCFP	-0.356	9.032	152.392**	122.643*
	(-0.09)	(0.98)	(2.17)	(1.76)
ROA	0.078***	0.140***	0.479	-0.016
	(2.63)	(3.56)	(1.63)	(-0.17)
ASSET	0.000	-0.000	-0.000	-0.000
	(0.12)	(-0.97)	(-1.04)	(-1.69)
LEV	-0.105***	-0.094***	-0.586***	-0.503***
	(-3.68)	(-3.72)	(-3.56)	(-6.05)
lnbAGE	-0.160	-0.105	1.214	-0.104
	(-1.07)	(-0.78)	(1.00)	(-0.14)
IC	-0.100	0.031	-5.967***	-1.898***
	(-0.46)	(0.19)	(-4.17)	(-3.59)
CCE	-0.000	0.000	0.000	0.000
	(-0.79)	(0.01)	(0.10)	(0.37)
_cons	15.537***	14.864***	37.989**	41.216***
	(6.64)	(5.56)	(2.70)	(4.28)
N	572.000	747.000	39.000	57.000
r2_w	0.106	0.079	0.711	0.588
F	3.926	3.726	3.513	3.333

Secondly, this difference in industry characteristics may be caused by the characteristics of the supply chain of the wholesale and retail industry itself, that is, the downstream enterprises of the wholesale and retail industry have the characteristics of high supply chain concentration, and the wholesale and retail industry is at the hub of agricultural product circulation and is at the tail end of the entire agricultural supply chain finance [13]. However, agricultural producers basically do not have a standardized financial system and collateral, and the risk sharing system such as agricultural insurance is not perfect, which makes supply chain finance inherently insurmountable in traditionally agricultural industry, therefore, policy planning should incorporate industry-specific characteristics to enhance both the accessibility and effectiveness of supply chain finance [14].

The differences in the effect of credit constraint relief in different industries provide the following suggestions for the current credit policy adjustment. In the traditional agriculture industries, the first is to increase the application of data, such as enhancing the transparency of information flow in the industrial chain based on blockchain technology; The second is to establish a superposition mechanism of "policy-based guarantee and supply chain finance" to reduce the concerns of policy-based financial institutions about the use of funds [13]. Encourage upstream and downstream "core" suppliers to provide financial services downward, integrate small and medium-sized traditional agriculture, forestry, animal husbandry and fishery objects into the core chain of the digital supply chain, and finally achieve a full-chain policy benefit mechanism.

6 Inverted U-shaped relationship

Table 5. Nonlinear trend display.

	(1)
	E2
VARIABLES	DCASH
STL3	-8,396.563***
	(1,218.17)
SZH3	-16.055
	(11.24)
c.STL3#c.SZH3	633.290***
	(93.04)
o.STL3	-
SZH3_sq	0.319
	(0.24)
c.STL3#c.SZH3_sq	-11.937***
	(1.77)
Constant	211.541
	(133.40)
Observations	1,523
R-squared	0.075

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The regression results in Table 5 shows that the quadratic coefficient of the interaction between bank digitalization and supply chain finance penetration = -11.937 is significant at the 1% level, and it can be seen that the impact of digitalization (SZH3) on supply chain finance (STL3) presents an "inverted U-shaped" relationship, and when the level of digitalization is low, improving digitalization will enhance the role of supply chain finance, that is, the marginal effect is incremental. After exceeding the inflection point of the quadratic function, continuing to improve digitalization will weaken the role of supply chain finance, that is, the marginal effect will decrease. The coefficient of the first interaction term = 633.290, which is significantly positive, indicating that the interaction effect is positive in the initial stage of digitization.

Table 6. Segmented regression results.

	(1)	(2)
	E1	E2
VARIABLES	DCASH	DCASH
STL3	-11.533**	18.272***
	(4.76)	(2.70)
ROA	0.700*	0.136***
	(0.36)	(0.04)
lnbASSET	1.866	-2.164***
	(2.11)	(0.33)
LEV	0.273*	-0.101***
	(0.14)	(0.02)
AGE	0.962*	0.263***
	(0.54)	(0.04)
IC	2.713	-0.509***
	(1.84)	(0.19)
CCC	-0.000	0.000
	(0.00)	(0.00)
Constant	-57.843	50.476***
	(50.84)	(6.53)
Observations	25	1,399
R-squared	0.346	0.144

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The regression results in Table 6 clearly reveal that there is a typical inverted U-shaped relationship between bank digitalization and the development of supply chain finance. This non-linear feature indicates that the impact of digitalization on supply chain finance is not simply a linear promotion, but a change trajectory that first rises and then declines. The results show that with the gradual improvement of the digital level of banks, their enabling effect on supply chain finance first strengthens and then weakens, and when the digital level exceeds the critical value, continuing to improve digitalization will weaken the mitigation effect of supply chain finance.

The formation mechanism of this inverted U-shaped relationship can be explained from the following two key dimensions: in the stage of moderate improvement of digitalization, banks improves the transparency and reliability of transaction data through big data analysis and blockchain and other technical means, effectively reducing the information asymmetry between enterprises and commercial banks in the entire supply network, and the improvement of this phenomenon makes the credit assessment and loan pricing of financial services such as loans for agriculture-related SMEs more accurate, thereby reducing the credit constraints of such enterprises. Specifically, big data analysis technology can deeply mine the historical transaction records, production and operation data and market supply and demand information of agricultural-related enterprises and build a multi-dimensional credit evaluation model. The immutability of blockchain technology effectively guarantees the authenticity and traceability of data in the supply chain of agricultural products, from production, processing, to sales [6].

However, when the level of digitalization of banks exceeds the optimal threshold, excessive digitalization will lead to three negative effects: on the one hand, banks rely too much on standardized algorithm models, which makes non-standard transactions with agricultural characteristics (such as seasonal agricultural products and traditional farmer business) systematically misestimated in the risk control system; On the other hand, the improvement of technological capabilities makes banks more sensitive to the identification of "pseudo-transactions" in the supply chain, reducing the supply of credit to such enterprises. On top of that, digital development changes the competitive landscape in financial services. When banks establish a complete customer portrait system, they are more inclined to directly serve high-quality node enterprises in the supply chain, rather than relying on the credit transmission of core enterprises, which ultimately leads to a decline in the efficiency of supply chain finance [9]. Compared with the first two negative effects, the reasons for the formation of the last negative effect are more complex, and the specific logical chain lies in the following two aspects: first, the digital risk control system can accurately identify and "siphon" high-quality enterprises in the supply chain, which may not be core enterprises and the credit chain of agriculture-related small and medium-sized enterprises in need of loans is more complicated, but banks still rely on credit calculation technologies such as credit scoring to make credit allocation. As a result, banks are gradually tilting their credit resources towards these digitally verified high-quality enterprises, rather than relying entirely on the traditional supply chain finance model. However, this does not mean that the credit transmission role of core enterprises completely disappears, but its importance is relatively reduced. Secondly, the business substitution effect is also gradually emerging, and the new credit products spawned by digitalization forms comparative advantages in terms of approval efficiency, financing costs and mortgage flexibility, and these innovative methods can directly analyze the real business conditions of enterprises through big data to gradually replace part of the supply chain finance needs.

7 DID test

To alleviate the problem of benchmark regression, a DID test was constructed to alleviate the policy effect of the significant positive relationship in benchmark regression, which may be mixed with the influence of time trend or the inherent characteristics of firms.

As shown in Table 7, the benchmark DID regression results showed that the coefficient of DID of the policy interaction item was 3.037 and was significant at the 10% level, indicating that the credit constraints of agriculture-related SMEs were alleviated to a certain extent after the implementation of the policy. This positive effect is consistent with the policy objectives, indicating that the supply chain finance policy has effectively improved the financing environment of small and medium-sized enterprises by integrating the credit resources of the agricultural industry chain. It is worth noting that the coefficient of the time variable -2.459 (significant at the 5% level) reflects the deterioration trend of credit constraints before the implementation of the policy, while the coefficient of the treated variable in the treatment group is -3.821 (significant at the 1% level) reveals that the enterprises in the treatment group were originally facing more serious credit constraints, which highlights the necessity of the policy to accurately help the weak market entities.

Table 7. In 2018, the first central document on the development of the supply chain of agriculture, agriculture and agriculture

VARIABLES	(1) DCASH
time	-2.459**
	(1.18)
treated	-3.821***
	(1.33)
did	3.037*
	(1.57)
Constant	11.285***
	(1.02)
Observations	664
R-squared	0.017

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

8 Conclusion

It is found that both bank digitalization and supply chain finance can significantly alleviate the credit constraints of agriculture-related SMEs, but the credit mitigation effect of supply chain finance development on agriculture-related SMEs shows a nonlinear characteristic with the level of bank digitalization. Secondly, the heterogeneity analysis further found that there is industry heterogeneity in the mitigation effect of supply chain finance, and the effect of supply chain finance on the mitigation of credit constraints in industries with a high degree of application to wholesale and retail digitalization is prominent, but the effect on the credit constraints in traditional agriculture industries is not obvious.

The above also gives suggestions for multiple entities such as the supply side and the demand side of credit, in order to achieve a more effective alleviation of the constraints on agriculture-related credit.

At the same time, banks should combine the advantages of digital finance and supply chain finance to change their lending ideas in stages: in the first stage of digital finance for banks, the direction of efforts is to rely on big data, blockchain, etc. to achieve the "seeing" of supply chain finance, and solve the problem of financing availability and financing cost of agriculture-related small and medium-sized enterprises; In areas where digital finance is relatively mature, on the basis of being vigilant against the negative effects dominated by algorithm models in digital finance, the risk control ideas should be dynamically adjusted, and the consideration of agricultural production should be increased in the process of reviewing and approving letters, so as to prevent the risk control work under digital finance from being rejected due to the use of standard risk control, resulting in the rejection of non-standardized agricultural transactions.

Agriculture-related small and medium-sized enterprises should take the initiative to adapt to the trend of digitalization and strengthen financial standardization and data management capabilities. Traditional agricultural enterprises should strengthen cooperation with core enterprises and high-quality enterprises and financial institutions outside the core enterprises, and improve their credit level through contract agriculture and guarantee alliances.

First, for regions with low levels of digitalization, the government should introduce guidelines and policies to increase fiscal investment in infrastructure, especially financial inclusion. At the same time, the government can enhance the digital capabilities of agriculture-related entities in the region through targeted training. Second, for regions with a high level of digitalization, it is necessary to strengthen the monitoring of bank digitalization to avoid technological exclusion due to excessive digitalization, and if necessary, adjust the imbalance in the development of digital technology and supply chain finance through policy adjustment mechanisms. Third, regulators should actively encourage banks to innovate financial service models and standardize the development of the industry, such as standardizing algorithms to ensure the fairness of algorithms and avoiding systematic undervaluation of the agricultural sector.

References

1. B.Q. Fu, S.Z. Bai, The alleviating effect of supply chain finance on financing constraints of small and medium-sized agricultural enterprises. J. Northwest A&F Univ. (Soc. Sci. Ed.) **21**, 140 (2021)
2. M.-J. Gallego-Losada, A. Montero-Navarro, E. García-Abajo, R. Gallego-Losada, Digital financial inclusion: Visualizing the academic literature. Res. Int. Bus. Financ. **64**, 101862 (2023)
3. L.Y. Fu, The role and strategy of commercial banks in the innovation of digital supply chain finance. Foreign Econ. Relat. Trade **8**, 80 (2024)
4. X. Luo, Z.H. Yang, Q.L. He, Digital transformation of SMEs, supply chain finance development and financing constraint alleviation. Wuhan Financ. **11**, 54 (2023)
5. Y.L. Dai, X.D. Wu, Research on the impact of digital inclusive finance on rural revitalization: Analysis based on the moderating effect of industrial diversity. Financ. Regul. Res. **4**, 76 (2024)
6. Y. Wang, Blockchain empowering high-quality development of digital inclusive finance: Practical considerations. Changbai J. **5**, 113 (2022)
7. Y.N. Guo, B.Q. Xiao, Digital economy era open banking development models and paths: A comparative study of China and the UK. J. Hohai Univ. **23**, 51-59 (2021)
8. W. Gao, D. Lin, Research on the dilemmas and countermeasures of digital transformation of supply chain finance in commercial banks. Tianjin Econ. **6**, 35 (2023)
9. M. Bazarbash, Fintech in financial inclusion: Machine learning applications in credit scoring. IMF Work. Pap. (2019)
10. N. Selwyn, Reconsidering political and popular understandings of the digital divide. New Media Soc. **6**, 341-362 (2004)
11. L.M. Gelsomino et al, Supply chain finance: A literature review. Int. J. Phys. Distrib. Logist. Manag. **46**, 348 (2016)
12. H. Ge, B. Li, D. Tang, H. Xu, V. Boamah, Research on digital inclusive finance promoting the integration of rural three-industry. J. Environ. Res. Public Health. **19**, 63363 (2022)
13. J.Y. Jin, The impact of supply chain concentration on retail enterprise value creation: Empirical analysis based on data from listed wholesale and retail enterprises. J. Commer. Econ. **43**, 54 (2023)
14. Q.H. Lu, T.T. Xu, S. Li, D. Xiao, Research on subsidy and guarantee mechanisms in agricultural supply chain finance under government leadership. Oper. Res. Manag. Sci. **3**, 198 (2023)