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Digital finance and trade credit financing: Evidence from Chinese private enterprises

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Digital finance and trade credit financing: Evidence from Chinese private enterprises

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Digital finance and trade credit financing: Evidence from Chinese private enterprises

Abstract: Based on the data of Chinese A-share privately listed companies from 2011 to 2020, we explore the impact of digital finance on the trade credit financing of private enterprises. We find that digital finance significantly improves the trade credit financing of private enterprises. This effect occurs by increasing bank credit, enhancing market power, and reducing default risk. Furthermore, we find that this positive impact is greater in private enterprises under strict financial supervision and with high operational uncertainty. Our study extends the literature on the economic consequences of digital finance and provides new insights into how digital finance effectively supports the real economy at the micro-enterprise level.

Keywords: Digital finance; Trade credit financing; Private enterprises; China

JEL: M15; G30; L14

1. Introduction

In recent years, with the widespread application of emerging information technologies such as artificial intelligence, big data, and cloud computing in the financial sector, digital finance (DF) has emerged and experienced rapid development. DF refers to a new generation of financial services that integrate the Internet and information technology with traditional financial service models. The surge in digital finance has not only significantly influenced the macro-environment but also shaped micro-level behaviors within enterprises. Existing studies primarily explore the impacts of digital finance on investment efficiency (Huang et al., 2023), financing constraints (Lu et al., 2021), corporate innovation (Zhang et al., 2023), firm value (Xu et al., 2023), financial risks (Dai and Zhang, 2022), and bankruptcy risk (Ji et al., 2022). These studies have recognized the positive role of digital finance in enterprise development, including enhancements in the financing environment, corporate governance, and risk mitigation. However, there is limited research on addressing how digital finance

influences business and financial transactions between enterprises and suppliers, particularly concerning trade credit financing (TCF). TCF refers to the credit provided by suppliers to enterprises during the process of purchasing goods or services. As a critical capital source for enterprises, trade credit financing helps to expand operations, enhance competitiveness, and stabilize supply chain relationships (Chod et al., 2019; Fabbri and Menichini, 2010; Ferrando and Mulier, 2013). Therefore, exploring the impact of digital finance on trade credit financing can contribute to understanding the effects of digital finance on micro-level enterprise development from a new perspective.

The development of digital finance in China tops the global ranking, providing an ideal research context for exploring the economic consequences of digital finance in this paper Moreover, within China's unique institutional framework, the trade credit financing of private enterprises is worthy of attention. Consequently, we select Chinese privately listed companies as the research sample to explore the impact of digital finance on trade credit financing. Specifically, within China's traditional financial system characterized by credit discrimination, a substantial portion of bank credit resources favors inefficient state-owned enterprises, leaving more efficient private enterprises struggling to access adequate bank credit. This mismatch in financial allocation between different ownership structures drives private enterprises to rely on trade credit for alternative financing (Cull et al., 2009; Ge and Qiu, 2007). However, China's trade credit allocation also suffers from mismatch. As shown in Fig. 1, the trade credit financing level of private enterprises is lower than that of state-owned enterprises. In other words, more trade credit flows to state-owned enterprises, leading to private enterprises that face challenges in acquiring bank credit also have trouble in gaining trade credit financing. This exacerbates financial constraints on private enterprises, increasing their development burden. In particular, private enterprises play a crucial role in driving China's high-quality economic development. Therefore, improving trade credit financing of private enterprises becomes an urgent issue to address. So, can digital finance improve the trade credit financing of private enterprises? If so, through what mechanisms does digital finance operate? Exploring these questions not only has practical significance within the Chinese context; but also enriches theoretical research

of digital finance and trade credit financing.

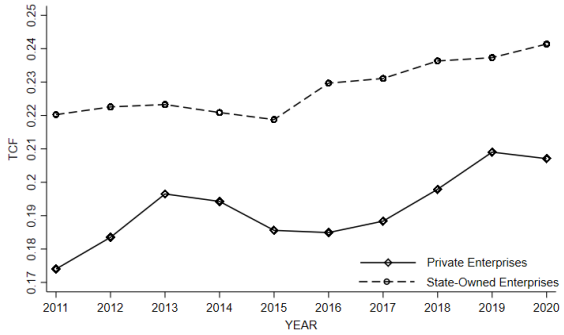

Fig. 1. Trade credit financing of enterprises with different ownership

We select A-share privately listed companies on the Shanghai and Shenzhen stock exchanges in China from 2011 to 2020 as our research sample. The primary findings of our study are summarized as follows. Firstly, the baseline regression results reveal that digital finance significantly improves the trade credit financing of private enterprises. Secondly, the mechanism test results demonstrate that digital finance achieves it by increasing bank credit, enhancing market power, and reducing the default risk of private enterprises. Thirdly, the heterogeneity test results show that for private enterprises under strong financial supervision and with high operational uncertainty, digital finance has a more significant effect on improving trade credit financing.

The potential contributions of our study are as follows. First, we expand the relevant literature on the economic consequences of digital finance from the perspective of trade credit financing, offering empirical evidence that digital finance effectively supports the real economy at the micro-enterprise level. Trade credit financing, stemming from business transactions such as product or service purchases, has both financial and operational attributes. Therefore, by examining the impact of digital finance on trade credit, we extend the studies on the economic consequences of digital finance to the real economy. Second, we enrich the research on the influencing factors of trade credit financing. While prior studies primarily focus on factors of the enterprise feature such as age (Ferrando and Mulier, 2013), scale (Long et al., 1993; Murfin and Njoroge, 2014), financial status (Barrot, 2016; Boisjoly et al., 2020), and corporate governance (Jiang et al., 2021; Sah and More, 2022), digital finance is an important factor that is non-

enterprise feature. Our research provides new evidence for trade credit financing from the new perspective of digital financing in the context of global digital economic development, thus enriching the literature on factors influencing trade credit financing. Third, we provide empirical evidence for the complementary relationship between bank credit and trade credit financing. Our findings indicate that digital finance not only improves the bank credit financing of private enterprises; but also enhances their capacities to obtain trade credit financing. Consequently, bank credit and trade credit financing present a complementary relationship. This enriches understanding of the relationship between bank credit and trade credit financing, holding important implications for improving the efficiency of monetary policy fund allocation.

The rest of this paper is arranged as follows. Section 2 presents our theoretical analysis and hypothesis development. Section 3 describes our research design. Section 4 reports our empirical results. Section 5 presents our mechanism test and heterogeneity analysis. Section 6 offers our conclusion and discussion.

2. Theoretical analysis and hypothesis development

We analyze the impact of digital finance on trade credit financing of private enterprises from three perspectives: the complementary effect hypothesis, the buyer's market hypothesis, and the default risk hypothesis.

2.1. Complementary effect hypothesis

Existing literature primarily proposes two hypotheses regarding the relationship between bank credit and trade credit financing: the substitution effect hypothesis and the complementary effect hypothesis. The substitution effect hypothesis suggests that enterprises tend to resort to trade credit financing when facing constraints in obtaining bank credit (Coulibaly et al., 2013; Meltzer, 1960; Petersen and Rajan, 1997), which indicates a substitutional relationship between the two. Conversely, the complementary effect hypothesis argues that on one hand, enterprises using trade credit financing can signal positive quality to banks (Biais and Gollier, 1997; Burkart and Ellingsen, 2004), thereby facilitating their access to bank credit (Eck et al., 2012; Psillaki and Eleftheriou, 2014). On the other hand, enterprises using bank credit can convey favorable signals about their creditworthiness and debt repayment ability, thus encouraging suppliers to

offer trade credit. In other words, a complementary relationship between bank credit and trade credit financing may exist. Under the realistic background of China, we think that the complementary effect hypothesis may be more reasonable. This is because China's credit system is still under development, leading to information asymmetry in both financial and product markets. In the financial market, enterprises can signal their qualifications to banks through trade credit financing, thus enhancing their access to bank credit. In the product market, enterprises with improved access to bank credit demonstrate better debt repayment ability and creditworthiness, making suppliers more willing to provide trade credit. In fact, Chinese private enterprises often struggle to obtain trade credit financing as an alternative when facing constraints in bank credit, which contradicts the substitution effect hypothesis. Therefore, we analyze the impact of digital finance on trade credit financing of private enterprises based on the complementary effect hypothesis.

Digital finance has the potential to improve the availability of bank credit for enterprises, which in turn promote their trade credit financing. Firstly, digital finance can improve the supply of financial resources. With the help of digital technologies such as big data, artificial intelligence, cloud computing, and blockchain, digital finance can efficiently process massive data at low cost (Ding et al., 2022; Ozili, 2019), thereby expanding the reach of financial services to a broader customer base. This helps financial institutions to absorb public funds characterized by "large, small and dispersed", and convert these funds into financial resource supply. Secondly, digital finance can optimize the efficiency of financial resource allocation. In traditional financial systems, financial institutions prefer large enterprises or state-owned enterprises, resulting in a distorted financial allocation structure (Brandt and Li, 2003; Gordon and Li, 2003). Digital finance minimizes reliance on traditional hard information such as fixed assets and financial statements during the credit approval process. Instead, it mainly uses big data, cloud computing, and other digital technologies to dig deeper into enterprises' historical transaction and operation data. This enables financial institutions to more reasonably assess business risks and growth potential of enterprises (Buchak et al., 2018; Fuster et al., 2019), thereby offering high-

quality private enterprises greater opportunity to be known in the financial market and mitigating credit discrimination against private enterprises. In summary, digital finance improves both the supply and allocation efficiency of financial resources, thus enabling private enterprises to obtain increased bank credit. Based on the complementary effect hypothesis, increased access to bank credit sends a positive signal to the product market that private enterprises face fewer financing constraints, making suppliers more willing to relax credit conditions, and thus promoting private enterprises to gain more trade credit financing.

2.2. Buyer's market hypothesis

The buyer's market hypothesis suggests that trade credit serves as a competitive tool for upstream suppliers, closely linked to the market power of downstream customers. According to this hypothesis, suppliers often proactively offer trade credit to stimulate sales and gain market share (Fisman and Raturi, 2004). When customers hold a powerful position and suppliers face intense competition, customers with higher market power can leverage the threat of switching suppliers to obtain more trade credit (Fabbri and Menichini, 2010). Therefore, enterprises with higher market power can access more trade credit financing.

Digital finance has the potential to enhance the market power of private enterprises, thus promoting them to obtain more trade credit financing. Firstly, capital input is crucial in enhancing market power. According to the above analysis, digital finance improves the availability of bank credit, which enables private enterprises to expand operations and innovation, thereby improving their market competition capacities. Secondly, enhancing market power relies on good corporate governance (Baek et al., 2004; Bai et al., 2004; Gompers et al., 2003). However, generally characterized by the structure of family-owned businesses, private enterprises frequently encounter the problem of dominant controlling shareholders. This problem poses significant corporate governance challenges for private enterprises, potentially leading to inefficiencies in strategic direction and resource allocation decisions, thereby hindering their ability to gain market power. In this regard, digital finance plays an external governance role by reducing information asymmetry (Demertzis et al., 2018; Ji et al.,

2022; Zhu, 2019). With the help of various technological tools, digital finance reduces the cost of acquiring information and improves the flow of information, resulting in bettering the information environment. This can supervise the controlling shareholders and restrain them from pursuing private interests at the expense of minority shareholder interests, thereby easing internal agency conflicts and improving the corporate governance of private enterprises. Good corporate governance optimizes strategic decisions and improves resource allocation efficiency, thus promoting the efficient development of private enterprises and making it easier for them to gain market power. In summary, digital finance can enhance the market power of private enterprises by providing financial support and improving corporate governance. From the customer's viewpoint, downstream customers with a dominant market position have stronger bargaining power, allowing them to effectively negotiate and potentially leverage the threat of supplier substitution to obtain more trade credit financing. From the supplier's viewpoint, offering more trade credit to downstream customers with higher market power not only maintains positive customer relationships but also serves as a credit guarantee for the quality of products sold. Therefore, digital finance has the potential to improve trade credit financing of private enterprises through enhancing their market power.

2.3. Default risk hypothesis

The default risk hypothesis suggests that the trade credit provided by upstream suppliers to downstream customers can be seen as a short-term risk investment. These investment characteristics are mainly expressed in two aspects. First, suppliers can earn additional returns when customers exceed payment deadlines (Petersen and Rajan, 1994). Second, suppliers also bear the risk of customers defaulting on payments due to a liquidity crisis or even bankruptcy (Cuñat, 2006). As macroeconomic conditions deteriorate and the operating conditions of customers worsen, the expected returns of providing trade credit to high-risk enterprises gradually decrease, so suppliers may refuse to provide trade credit (Love and Zaidi, 2010; Love et al., 2007). Therefore, suppliers prefer to provide trade credit to enterprises with lower default risk.

Digital finance has the potential to mitigate the default risk of private enterprises,

enabling them to obtain more trade credit financing. Firstly, according to the above analysis, digital finance increases the availability of bank credit for private enterprises. With sufficient capital support, private enterprises can repay debt to suppliers in time and have a lower likelihood of default (Campbell et al., 2008). Secondly, digital finance can improve the risk management of private enterprises. Specifically, the technology spillover theory suggests that technology has external characteristics, mainly manifested in the dissemination of advanced technologies from leading industries to others, thereby promoting technological innovation across various industries. Digital finance brings advanced information technologies to private enterprises through technology spillover effects, optimizing their operational management and enhancing their risk control capabilities (Lähteenmäki et al., 2022; Zhu, 2019). In addition, digital finance promotes banking competition by breaking the monopoly of private information held by banks, making them tighten credit standards, which in turn restricts private enterprises. In particular, to meet the credit standards, private enterprises need to strengthen their risk management and reduce the likelihood of debt default. In conclusion, digital finance reduces the default risk of private enterprises, thus offering suppliers reliable expectations and making them more willing to provide trade credit.

Based on the above analysis, we put forward the following hypothesis:

H1: Digital finance is positively correlated with trade credit financing of private enterprises.

3. Research design

3.1. Data and sample

We initially select A-share listed companies from the Shanghai and Shenzhen stock exchanges in China from 2011 to 2020 as our sample set. Subsequently, we process the samples following the research requirements as follows. (1) We retain only those samples where the controlling shareholders' equity nature is private at the time of listing. (2) We exclude samples originating from the financial industry. (3) We eliminate samples flagged as ST or *ST. (4) We exclude samples with missing data of key variables. (5) To mitigate the influence of outliers, we winsorize continuous variables at the 1st and 99th percentiles. Following this process, we gather 14,951 firm-annual

observations.

3.2. Variables

3.2.1. Trade credit financing

Drawing on the existing studies (Chen et al., 2019; Fisman and Love, 2003; Petersen and Rajan, 1997), we measure trade credit financing (*TCF*) as the sum of accounts payable, notes payable, and accounts collected in advance divided by total assets. In the robustness test, we adopt several other alternative definitions that have also been widely used in prior studies.

3.2.2. Digital finance

The Peking University Digital Inclusive Finance Index, constructed by the Peking University Digital Finance Research Center and Ant Financial Services Group, is widely used in the research of digital finance (Ding et al., 2022; Li et al., 2023; Tong and Zhang, 2022). We use the province-level Digital Inclusive Finance Index to measure the level of digital finance (*DF*). For clarity in presenting our results, we normalize the Digital Inclusive Finance Index by dividing it by 100. In the robustness test, we substitute *DF* with both the city-level Digital Inclusive Finance Index divided by 100 and the natural logarithm of the provincial-level Digital Inclusive Finance Index. Moreover, we disaggregate digital finance into three dimensions for further robustness testing, including the coverage breadth, use depth, and digitization level.

3.2.3. Control variables

Our study includes the following control variables: enterprise size (*SIZE*), enterprise age (*AGE*), interest coverage ratio (*ICR*), profitability (*ROA*), enterprise growth (*GROWTH*), fixed assets ratio (*TANG*), cash flow from operating activities (*CASH*), size of independent directors (*INDR*), ownership concentration (*TOP*). Detailed definitions of the variables are reported in Table 1.

Table 1

Variable definitions.

Variable	Definition
TCF	(Accounts payable+ notes payable+ accounts collected in advance)/ total assets

DF	The province-level Digital Inclusive Finance Index/ 100
SIZE	The natural logarithm of total assets
AGE	The natural logarithm of the enterprise's listing year
ICR	Earnings before interest and tax/ interest expense × 100
ROA	Net profit/ total assets
GROWTH	The growth rate of operating revenues
TANG	Net fixed assets/ total assets
CASH	Net cash flow from operating activities/ total assets
INDR	The number of independent directors/ the total number of directors
TOP	The total shareholding ratio of the top 10 shareholders
Year	Year dummy variables
Industry	Industry dummy variables

3.3. Model specification

To examine the impact of digital finance on the trade credit financing of private enterprises, we construct the following model (1):

$$TCF_{i,t} = \beta_0 + \beta_1 DF_{m,t} + \beta_i \sum Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (1)$$

where *TCF* represents the dependent variable, *DF* represents the independent variable, and $\sum Controls$ represent the group of control variables. If β_1 is significantly positive, then digital finance significantly improves the trade credit financing of private enterprises and H1 is supported.

3.4. Descriptive statistics

Table 2 reports the descriptive statistics of the primary variables. The mean value of trade credit financing (*TCF*) is 0.148, the minimum value is 0.004, and the maximum value is 0.506, indicating that the level of trade credit financing varies greatly among different private enterprises. The mean value of digital finance (*DF*) is 2.724, the minimum value is 0.188, and the maximum value is 4.319, indicating the considerable divergence in the level of digital finance development among provinces. The descriptive statistics of other primary variables align with prior literature.

Table 2

Descriptive statistics.

Variable	*Obs*	*Mean*	*Std. Dev*	*Min*	*P25*	*Median*	*P75*	*Max*
TCF	14,951	0.148	0.103	0.004	0.069	0.123	0.203	0.506
DF	14,951	2.724	0.968	0.188	2.083	2.864	3.574	4.319
SIZE	14,951	21.699	0.991	19.289	20.961	21.595	22.303	25.105
AGE	14,951	1.570	0.841	0.000	1.099	1.609	2.197	3.296
ICR	14,951	0.159	0.574	-0.948	0.000	0.023	0.100	6.064
ROA	14,951	0.040	0.084	-0.781	0.020	0.046	0.075	0.247
GROWTH	14,951	0.184	0.398	-0.688	-0.007	0.128	0.292	4.453
TANG	14,951	0.185	0.127	0.002	0.085	0.164	0.261	0.579
CASH	14,951	0.046	0.068	-0.199	0.008	0.046	0.086	0.276
INDR	14,951	0.385	0.064	0.250	0.333	0.375	0.429	0.600
TOP	14,951	0.603	0.143	0.221	0.505	0.623	0.717	0.898

4. Empirical results

4.1. Baseline regression results

Table 3 reports the baseline regression results of the relationship between digital finance and trade credit financing of private enterprises. Column (1) shows that the regression coefficient of *DF* is 0.019 without control variables, which is significant at the 1% level. Column (2) shows that the regression coefficient of *DF* is 0.017 when control variables are added, which remains significant at the 1% level. These results indicate that digital finance improves the trade credit financing of private enterprises, thus supporting H1.

Furthermore, we interpret the economic significance of the regression coefficient. A 1-percentage-point increase in the development level of digital finance leads to an increase in trade credit financing by 0.017 units, representing approximately 11.49% (0.017/0.148×100%) relative to the mean value of trade credit financing during the sample period.

Table 3

Baseline regression results.

TCF	(1)	(2)

DF	0.019***	0.017***
	(6.02)	(5.65)
SIZE		0.023***
		(22.93)
AGE		-0.009***
		(-6.27)
ICR		0.004**
		(2.55)
ROA		-0.189***
		(-13.06)
GROWTH		0.018***
		(7.14)
TANG		-0.094***
		(-14.01)
CASH		0.022
		(1.58)
INDR		0.003
		(0.27)
TOP		-0.010
		(-1.37)
Constant	0.077***	-0.377***
	(11.72)	(-16.27)
Year	YES	YES
Industry	YES	YES
N	14,951	14,951
Adj. R^2	0.100	0.165

Note: The numbers in parentheses are the t-statistics; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.2. Endogeneity test

4.2.1. Instrumental variable method

The empirical results of this paper might be influenced by some unobservable factors, potentially leading to an endogeneity problem. We use the instrumental variable method to mitigate the endogeneity problem. We use the internet penetration rate (*INTERNET*) of each province as an instrumental variable for *DF*. The development of regional digital finance is affected by the internet infrastructure, but the development of the regional internet infrastructure is not directly linked to the trade credit financing of private enterprises. Thus, the instrumental variable (*INTERNET)* satisfies the conditions of correlation and exogeneity.

Columns (1) and (2) of Table 4 report the two-stage regression results. As shown in column (1), the regression coefficient of *INTERNET* is significantly positive at the 1% level. This result indicates that the higher internet penetration rate in a region corresponds to the higher development level of digital finance, which confirms the correlation condition of *INTERNET*. As shown in column (2), the regression coefficient of *DF* is significantly positive at the 1% level, which remains consistent with our conclusion. Furthermore, we assess the weak instrumental variable problem. The result shows that the value of F is 760.28, exceeding 10, which suggests that there is no weak instrumental variable problem.

4.2.2. Differences-in-differences method

In order to further solve the potential endogeneity problem, we use the differences-in-differences (DID) method. On December 31, 2015, the State Council issued the "Plan for Promoting Inclusive Financial Development (2016-2020)", aimed at promoting financial institutions' optimization and upgrading through science and technology. The policy encourages financial institutions to use emerging information technologies to improve financial inclusion. As this policy is formulated by the central government, it constitutes a relatively exogenous shock for financial institutions to promote their digital development. Given the digital level among financial institutions varies greatly in regions, those in regions with less advanced digital levels should experience larger shocks. This provides an opportunity for our study to construct a DID model to identify

the causal relationship between digital finance and trade credit financing of private enterprises.

If the digitization index of the prefecture-level city where the enterprise is located by the end of 2015 is below the median of all prefecture-level cities for that year, we define this subset of the sample as the treatment group and assign a value of 1 to *TREAT*. Conversely, if the index exceeds the median, we define this subset of the sample as the control group and assign a value of 0 to *TREAT*. The DID model is as follows:

$$TCF_{i,t} = \beta_0 + \beta_1 TREAT_{i,t} \times POST_{i,t} + \beta_i \sum Controls_{i,t} + Year + Industry + Firm + \varepsilon_{i,t} \quad (2)$$

where *POST* is a time-point variable set to 1 from 2016 onwards and 0 before that. *Firm* represents the firm fixed effect. Other variables remain consistent with previous descriptions. The regression coefficient of *TREAT*×*POST* captures the policy effects. If β_1 is significantly positive, it indicates that the trade credit financing of private enterprises in regions influenced by the policy is improved more significantly, which means that digital finance significantly improves the trade credit financing of private enterprises. As shown in column (3) of Table 4, the regression coefficient of *TREAT*×*POST* is significantly positive at the 1% level, which remains consistent with our conclusion.

The parallel trend assumption is important for ensuring an unbiased estimate in the DID analysis. We examine the assumption by introducing interaction terms of *TREAT* and year dummy variables in the regression model (2). Column (4) of Table 4 reports the results of the parallel trend test, which show that the regression coefficients of *TREAT_YEAR2011, TREAT_YEAR2012, TREAT_YEAR2013, TREAT_YEAR2014,* and *TREAT_YEAR2015* are not significant. These results indicate that the difference in trade credit financing between the treatment group and control group is not significant before the policy intervention. Thus, the parallel trend assumption is satisfied.

4.2.3. GMM

Trade credit financing at the enterprise level exhibits a certain degree of persistence, that is, there is a serial correlation. To solve this, we further use system GMM regression to control for potential endogeneity. As shown in column (5) of Table 4, the regression coefficient of *DF* is significantly positive at the 5% level, which remains consistent

with our conclusion after considering the serial correlation in trade credit financing. Furthermore, the residual sequence test shows that the P-value of *AR(1)* is less than 0.05, while the P-value of *AR(2)* is greater than 0.05, which suggests that the GMM model satisfies the conditions of first-order sequence correlation and second-order sequence uncorrelation. Additionally, the Hansen test shows that the P-value is greater than 0.05, which indicates that the selection of instrumental variables is effective.

Table 4

Endogeneity test.

Variables	(1)	(2)	(3)	(4)	(5)
	IV		DID		GMM
	DF	*TCF*	*TCF*	*TCF*	*TCF*
L.TCF					0.786***
					(42.98)
DF		0.159***			0.009**
		(10.73)			(2.39)
INTERNET	0.596***				
	(27.57)				
TREAT×POST			0.016***		
			(3.44)		
TREAT_YEAR2011				0.053	
				(1.35)	
TREAT_YEAR2012				0.054	
				(1.44)	
TREAT_YEAR2013				0.063	
				(1.62)	
TREAT_YEAR2014				0.066	
				(1.62)	
TREAT_YEAR2015				0.072	
				(1.73)	

TREAT_YEAR2016				0.074*	
				(1.80)	
TREAT_YEAR2017				0.075*	
				(1.93)	
TREAT_YEAR2018				0.077*	
				(1.89)	
TREAT_YEAR2019				0.080*	
				(1.90)	
TREAT_YEAR2020				0.081*	
				(1.99)	
SIZE	0.005*	0.023***	0.008**	0.008**	0.004***
	(1.85)	(22.87)	(2.62)	(2.67)	(2.85)
AGE	-0.017***	-0.007***	0.005**	0.005**	-0.014***
	(-4.83)	(-4.97)	(2.84)	(2.74)	(-2.88)
ICR	-0.001	0.004***	0.001*	0.001*	0.002
	(-0.19)	(2.67)	(1.95)	(1.94)	(0.71)
ROA	-0.030	-0.186***	-0.094***	-0.095***	-0.109**
	(-1.07)	(-16.08)	(-9.91)	(-9.97)	(-2.55)
GROWTH	-0.006	0.019***	0.016***	0.016***	0.008
	(-1.19)	(8.40)	(6.17)	(5.99)	(1.02)
TANG	-0.151***	-0.070***	0.020	0.021*	-0.023
	(-8.35)	(-8.91)	(1.60)	(1.79)	(-0.59)
CASH	0.184***	-0.007	0.100***	0.100***	0.275***
	(5.50)	(-0.51)	(9.48)	(9.84)	(3.84)
INDR	0.071**	-0.008	-0.003	-0.002	0.126*
	(2.20)	(-0.61)	(-0.30)	(-0.21)	(1.77)
TOP	0.018	-0.014*	-0.042***	-0.041***	-0.090***
	(1.03)	(-1.96)	(-4.57)	(-4.74)	(-2.71)
Constant	0.216***	-0.422***	-0.015	-0.062	-0.072*

	(3.85)	(-18.00)	(-0.22)	(-0.97)	(-1.69)
Year	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES
Firm	NO	NO	YES	YES	NO
F	760.28				
AR (1)					0.000
AR (2)					0.630
Hansen					0.240
N	14,859	14,859	14,878	14,878	12,563
Adj. R²	0.333	0.041	0.081	0.084	

4.3. Robustness test

4.3.1. Change variable measurement method

4.3.1.1. Redefine digital finance. First, we substitute *DF* with the natural logarithm of the provincial-level Digital Inclusive Finance Index (*DF1*). Second, we substitute *DF* with the city-level Digital Inclusive Finance Index divided by 100 (*DF2*). As shown in columns (1) and (2) of Table 5, the regression coefficients of *DF1* and *DF2* are both significantly positive at the 1% level, which remains consistent with our conclusion.

4.3.1.2. Dimension reduction decomposition of digital finance. The Digital Inclusive Finance Index comprises three primary sub-indexes: the coverage breadth (*BREADTH*), the use depth (*DEPTH*), and the digitization level (*DIGLEVEL*). To examine the effects of different dimensions of digital finance on trade credit financing, we substitute *DF* with those three sub-indexes. As shown in columns (3), (4), and (5) of Table 5, the regression coefficients of *BREADTH* and *DEPTH* are both significantly positive at the 1% level, while the regression coefficient of *DIGLEVEL* is not significant. These results indicate that the coverage breadth and depth of digital finance play roles in improving the trade credit financing of private enterprises. However, the degree of digitalization mainly reflects convenience. Therefore, it may not significantly influence the trade credit financing of private enterprises.

4.3.1.3. Redefine trade credit financing. First, we redefine trade credit financing as the net trade credit (*TCF1*), calculated as (accounts payable+ notes payable+ accounts

collected in advance- accounts receivable- notes receivable- prepayments) / total assets. Second, we redefine trade credit financing as the ratio of accounts payable to total assets (*TCF2*). As shown in columns (1) and (2) of Table 6, the regression coefficients of *DF* are both significantly positive at the 1% level, which remains consistent with our conclusion.

4.3.2. Change sample period

To exclude the disruptive influence of the COVID-19 epidemic on our conclusion, we adjust the sample period to 2011-2019 for the robustness test. As shown in column (3) of Table 6, the regression coefficient of *DF* is significantly positive at the 1% level, which remains consistent with our conclusion.

4.3.3. Control firm fixed effect

In order to control the influence of the firm individual effect, this paper uses a model containing firm fixed effect and year fixed effect to re-test. As shown in column (4) of Table (6), the regression coefficient of *DF* is significantly positive, which remains consistent with our conclusion.

Table 5

Redefine digital finance+ Dimension reduction decomposition of digital finance.

TCF	(1)	(2)	(3)	(4)	(5)
DF1	0.025***				
	(4.38)				
DF2		0.010***			
		(6.00)			
BREADTH			0.014***		
			(4.78)		
DEPTH				0.015***	
				(6.83)	
DIGLEVEL					0.001
					(0.23)
SIZE	0.023***	0.023***	0.023***	0.023***	0.023***

	(22.97)	(22.73)	(22.93)	(22.92)	(23.02)
AGE	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***
	(-6.37)	(-6.32)	(-6.29)	(-6.26)	(-6.42)
ICR	0.004**	0.004**	0.004**	0.004**	0.004**
	(2.55)	(2.46)	(2.55)	(2.52)	(2.52)
ROA	-0.189***	-0.186***	-0.189***	-0.189***	-0.189***
	(-13.04)	(-12.80)	(-13.06)	(-13.05)	(-13.04)
GROWTH	0.018***	0.017***	0.018***	0.018***	0.018***
	(7.11)	(6.71)	(7.11)	(7.20)	(7.08)
TANG	-0.095***	-0.093***	-0.094***	-0.094***	-0.097***
	(-14.23)	(-13.49)	(-14.05)	(-14.01)	(-14.48)
CASH	0.023*	0.023	0.023*	0.021	0.026*
	(1.67)	(1.62)	(1.65)	(1.49)	(1.82)
INDR	0.003	0.000	0.003	0.004	0.004
	(0.27)	(0.03)	(0.26)	(0.30)	(0.36)
TOP	-0.010	-0.009	-0.010	-0.011	-0.009
	(-1.40)	(-1.23)	(-1.34)	(-1.45)	(-1.26)
Constant	-0.467***	-0.378***	-0.375***	-0.376***	-0.371***
	(-14.62)	(-16.06)	(-16.18)	(-16.24)	(-16.03)
Year	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES
N	14,951	14,951	14,951	14,951	14,951
Adj. R^2	0.164	0.167	0.164	0.166	0.163

Table 6

Redefine trade credit financing **+** Change sample period + Control firm fixed effect.

Variables	(1)	(2)	(3)	(4)
	TCF1	*TCF2*	*TCF*	*TCF*
DF	0.008**	0.015***	0.018***	0.027*
	(2.24)	(7.25)	(5.29)	(1.92)

SIZE	0.026***	0.012***	0.024***	0.009***
	(22.79)	(16.77)	(21.51)	(2.58)
AGE	0.001	-0.007***	-0.011***	0.005*
	(0.77)	(-7.06)	(-7.07)	(1.74)
ICR	-0.002	0.002**	0.004**	0.001
	(-0.96)	(2.34)	(2.47)	(1.38)
ROA	-0.185***	-0.107***	-0.184***	-0.094***
	(-10.82)	(-10.73)	(-11.46)	(-8.57)
GROWTH	0.004	0.010***	0.015***	0.016***
	(1.35)	(6.32)	(5.76)	(8.40)
TANG	0.064***	-0.019***	-0.089***	0.020
	(8.01)	(-4.36)	(-12.27)	(1.44)
CASH	0.459***	-0.018*	0.016	0.099***
	(25.44)	(-1.96)	(1.09)	(7.90)
INDR	0.024*	-0.014*	-0.007	-0.003
	(1.65)	(-1.83)	(-0.59)	(-0.29)
TOP	0.058***	-0.005	-0.014*	-0.044***
	(6.51)	(-1.04)	(-1.80)	(-2.91)
Constant	-0.620***	-0.190***	-0.379***	-0.038
	(-24.16)	(-11.43)	(-15.00)	(-0.54)
Year	YES	YES	YES	YES
Industry	YES	YES	YES	NO
Firm	NO	NO	NO	YES
N	14,951	14,951	12,588	14,951
Adj. R^2	0.176	0.173	0.170	0.080

5. Mechanism test and heterogeneity test

5.1. Mechanism test

The previous sections prove that digital finance improves trade credit financing of private enterprises. Then, how does it achieve this? In this section, we further explore the mechanisms through which digital finance influences trade credit financing of

private enterprises. In our theoretical analysis, we argue the impact of digital finance on trade credit financing of private enterprises from three perspectives: the complementary effect hypothesis, the buyer's market hypothesis, and the default risk hypothesis. From the complementary effect hypothesis, digital finance increases the availability of bank credit for private enterprises, which sends a positive signal that private enterprises face few financing constraints. This encourages suppliers to relax credit terms, thereby improving trade credit financing of private enterprises. Therefore, increasing the scale of bank credit is the one mechanism by which digital finance improves trade credit financing of private enterprises. From the buyer's market hypothesis, digital finance not only provides adequate capital support for private enterprises but also optimizes their corporate governance. This contributes to the growth of private enterprises, thereby enhancing their market power and making it easier for them to obtain trade credit financing. Therefore, enhancing market power is another mechanism. From the default risk hypothesis, digital finance not only improves the debt repayment capabilities of private enterprises but also enhances their risk management through the technology spillover effect. This reduces the default risk of private enterprises and increases suppliers' trust, thereby increasing suppliers' willingness to provide trade credit. Therefore, reducing default risk is the third mechanism.

To test the potential mechanisms, this paper uses a stepwise regression method, conducting regression tests on models (1), (3), and (4) in turn. In order to ensure the robustness of the conclusion, we also use the Bootstrap test and Sobel test. Models (3) and (4) are constructed as follows:

$$M_{i,t} = \beta_0 + \beta_1 DF_{m,t} + \beta_i \sum Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (3)$$

$$TCF_{i,t} = \beta_0 + \beta_1 DF_{m,t} + \beta_1 M_{m,t} + \beta_i \sum Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (4)$$

where M is the mediating variable, including bank credit (BC), market power (MP), and default risk (DR). BC is measured by the natural logarithm of debt. MP is measured by the ratio of an enterprise's sales revenues to industry-wide sales revenues. The measurement of DR is given in Appendix A. Other variables are consistent with the previous description. Columns (1) and (2) of Table 7 report the results when the

mediating variable is *BC*. As shown in column (1), the regression coefficient of *DF* is significantly positive at the 10% level, which indicates that digital finance increases the bank credit of private enterprises. As shown in column (2), the regression coefficient of *BC* is significantly positive at the 1% level, which indicates that there is a complement between bank credit and trade credit financing of private enterprises. Meanwhile, the regression coefficient of *DF* remains significantly positive at the 1% level. These results suggest that bank credit plays an intermediary role between digital finance and trade credit financing of private enterprises, supporting our expectation.

Columns (3) and (4) of Table 7 report the results when the mediating variable is *MP*. As shown in column (3), the regression coefficient of *DF* is significantly positive at the 1% level, which indicates that digital finance enhances the market power of private enterprises. As shown in column (4), the regression coefficient of *MP* is significantly positive at the 1% level, which indicates that private enterprises with greater market power gain more trade credit financing. Meanwhile, the regression coefficient of *DF* remains significantly positive at the 1% level. These results suggest that market power plays an intermediary role between digital finance and trade credit financing of private enterprises, supporting our expectation.

Columns (5) and (6) of Table 7 report the results when the mediating variable is *DR*. As shown in column (5), the regression coefficient of *DF* is significantly negative at the 1% level, which indicates that digital finance reduces the default risk of private enterprises. As shown in column (6), the regression coefficient of *DR* is significantly negative at the 1% level, which indicates that private enterprises with bigger default risk gain less trade credit financing. Meanwhile, the regression coefficient of *DF* remains significantly positive at the 1% level. These results suggest that default risk plays an intermediary role between digital finance and trade credit financing of private enterprises, supporting our expectation.

In addition, the results of the Sobel test and Bootstrap test also verify the mediating effects of bank credit, market power, and default risk.

Table 7

Mechanism test.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	BC	*TCF*	*MP*	*TCF*	*DR*	*TCF*
DF	0.373*	0.017***	0.003***	0.017***	-0.001***	0.018***
	(1.69)	(5.56)	(2.73)	(5.51)	(-2.59)	(4.93)
BC		0.001***				
		(6.84)				
MP				0.123***		
				(4.07)		
DR						-0.401***
						(-4.03)
SIZE	3.500***	0.020***	0.010***	0.022***	0.001***	0.021***
	(53.01)	(18.58)	(18.94)	(21.28)	(3.31)	(16.58)
AGE	0.231**	-0.009***	-0.002***	-0.009***	-0.000	-0.014***
	(2.28)	(-6.40)	(-2.97)	(-6.06)	(-0.90)	(-5.58)
ICR	0.315**	0.004**	0.001	0.004**	0.000**	0.001
	(2.40)	(2.37)	(1.37)	(2.49)	(2.16)	(0.68)
ROA	-12.742***	-0.179***	0.005	-0.189***	-0.016***	-0.168***
	(-15.39)	(-12.38)	(1.16)	(-13.10)	(-3.30)	(-10.67)
GROWTH	1.691***	0.016***	0.002**	0.018***	0.000	0.014***
	(10.74)	(6.60)	(2.25)	(7.09)	(0.04)	(5.23)
TANG	11.657***	-0.103***	-0.002	-0.094***	-0.001	-0.121***
	(25.06)	(-15.19)	(-1.06)	(-14.00)	(-1.21)	(-15.15)
CASH	-20.665***	0.038***	-0.005	0.023	0.003	0.044**
	(-21.60)	(2.71)	(-0.77)	(1.62)	(1.48)	(2.51)
INDR	-0.144	0.003	0.002	0.003	0.002	-0.022
	(-0.16)	(0.28)	(0.31)	(0.25)	(1.35)	(-1.54)
TOP	-5.096***	-0.006	0.002	-0.010	0.000	-0.020**
	(-10.38)	(-0.83)	(0.43)	(-1.39)	(0.21)	(-2.31)
Constant	-59.587***	-0.330***	-0.170***	-0.356***	-0.010***	-0.262***

	(-39.27)	(-13.52)	(-15.72)	(-15.32)	(-3.37)	(-9.25)
Year	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES
Sobel Z	2.551**		2.591***		1.685*	
Bootstrap 95% confidence interval	[0.0109, 0.0260]		[0.0109, 0.0227]		[0.0116, 0.0223]	
N	14,951	14,951	14,951	14,951	9,822	9,822
Adj. R²	0.302	0.168	0.461	0.167	0.040	0.165

5.2. Heterogeneity test

5.2.1 Financial supervision

The complexity and variability of digital financial technology innovation amplify the speed of financial risk transmission and the severity of consequences. Therefore, the long-term and stable development of digital finance cannot be separated from the strict control of the government. Standardized supervision guides financial institutions to improve their professional financial service capabilities and better provide high-quality financial services for the real economy. Based on this logic, we expect that digital finance may play a more significant role in improving the trade credit financing of private enterprises under strict financial supervision.

We use the ratio of financial supervision expenditure to the added value of the financial industry to measure the level of financial supervision. We divide the samples into groups with strong and weak financial supervision based on the median ratio. As shown in columns (1) and (2) of Table 8, the regression coefficient of *DF* is significantly positive at the 1% level in the group under strong financial supervision, whereas it is not significant in the group under weak financial supervision. Moreover, the differences between the two groups are significant. These results indicate that digital finance has a more significant effect on improving trade credit financing of private enterprises under strict financial supervision, thereby confirming our expectation.

5.2.2 Operational uncertainty

Operational uncertainty means that the profit level and cash flow of enterprises fluctuate greatly in the future. This volatility may increase the default risk of enterprises, which makes suppliers less willing to provide trade credit. Therefore, for private enterprises with high operating uncertainty, raising the quality of development is important to stabilize operations and foster suppliers' willingness to provide trade credit. Digital finance not only increases the bank credit of private enterprises; but also optimizes their corporate governance and risk management capabilities. These benefits help private enterprises to improve the quality of development and reduce operational uncertainty. Based on this logic, we expect that digital finance will play a more significant role in improving trade credit financing of private enterprises with high operational uncertainty.

We use the standard deviation rate of EBIT for the current year and the next two years to measure operational uncertainty and divide the samples into groups with high and low operational uncertainty based on the median ratio. As shown in columns (3) and (4) of Table 8, although the regression coefficients of *DF* are both significantly positive in the two groups, the coefficient in the group with high operational uncertainty is significantly larger than the coefficient in the group with low operational uncertainty. This result indicates that digital finance has a more significant effect on improving trade credit financing of private enterprises with high operational uncertainty, thereby confirming our expectation.

Table 8
Heterogeneity test.

TCF	(1)	(2)	(3)	(4)
	Strong financial supervision	*Weak financial supervision*	*High operational uncertainty*	*Low operational uncertainty*
DF	0.033***	-0.001	0.025***	0.012***
	(7.41)	(-0.21)	(5.88)	(2.90)
SIZE	0.021***	0.026***	0.015***	0.030***
	(14.24)	(18.40)	(11.21)	(20.98)

AGE	-0.008***	-0.010***	-0.002	-0.018***
	(-4.02)	(-5.08)	(-1.11)	(-8.71)
ICR	0.002	0.005***	0.002	0.007***
	(0.79)	(2.71)	(0.94)	(3.04)
ROA	-0.160***	-0.218***	-0.154***	-0.617***
	(-8.13)	(-10.75)	(-10.31)	(-15.51)
GROWTH	0.016***	0.020***	0.015***	0.029***
	(4.76)	(5.53)	(5.22)	(6.54)
TANG	-0.093***	-0.094***	-0.054***	-0.168***
	(-9.60)	(-10.11)	(-5.90)	(-17.01)
CASH	0.000	0.046**	-0.014	0.182***
	(0.02)	(2.41)	(-0.81)	(7.93)
INDR	-0.026	0.029*	0.015	-0.004
	(-1.48)	(1.78)	(0.92)	(-0.26)
TOP	0.001	-0.024**	0.004	-0.021*
	(0.06)	(-2.31)	(0.40)	(-1.96)
Constant	-0.319***	-0.426***	-0.247***	-0.464***
	(-9.69)	(-13.24)	(-7.82)	(-14.36)
Year	YES	YES	YES	YES
Industry	YES	YES	YES	YES
N	6,853	8,098	7,597	7,354
Adj. R^2	0.173	0.169	0.140	0.229
Diff		0.000		0.016
P-Value				

6. Conclusion

Based on the data of A-share privately listed companies on the Shanghai and Shenzhen stock exchanges in China from 2011 to 2020, we examine the impact of digital finance on the trade credit financing of private enterprises. Firstly, we find that digital finance significantly improves the trade credit financing of private enterprises. This conclusion still holds after a series of robustness and endogeneity tests. Secondly,

we further explore the mechanisms of the positive relationship between digital finance and trade credit financing. The mechanism test reveals that digital finance improves trade credit financing by increasing bank credit, enhancing market power, and reducing default risk. Thirdly, in the heterogeneity test, we examine the influence of financial supervision and operational uncertainty on the relationship between digital finance and trade credit financing of private enterprises. The relationship is more significant among enterprises under strict financial supervision and with high operational uncertainty.

There are two limitations in our study. First, more mechanisms of the relationship between digital finance and trade credit financing need to be further explored. Based on the perspectives of the complementary effect hypothesis, the buyer's market hypothesis, and the default risk hypothesis, we find that digital finance improves trade credit financing by increasing bank credit, enhancing market power, and reducing default risk. However, the impact of digital finance is not limited to these aspects. Future research could explore other potential mechanisms. Second, the measurement of digital finance might be biased. The Peking University Digital Inclusive Finance Index, primarily derived from data from Alipay users, mainly represents individual users rather than enterprises. For this reason, using the index to examine the impact of digital finance might be indirect. Moreover, the index mainly aims at addressing issues related to inclusive development and might not fully capture the contribution of digital technology to the field of digital finance. Future research could use text mining and Python-based methodologies to construct indicators from both financial and technological perspectives.

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Appendix A The measurement of default risk (*DR*)

We use the expected default frequency (*EDF*) computed following Bharath and Shumway (2008) as a substitute variable for default risk (*DR*). The calculation procedures are as follows:

$$DD_{i,t} = \frac{\log\left(\frac{Equity_{i,t}+Debt_{i,t}}{Debt_{i,t}}\right)+(r_{i,t-1}-\frac{\sigma_{Vi,t}^2}{2})\times T_{i,t}}{\sigma_{Vi,t}\times\sqrt{T_{i,t}}} \quad \text{(A1)}$$

where $DD_{i,t}$ is the distance-to-default; $Equity_{i,t}$ is the market value of equity computed by the number of shares outstanding × share price at the end of year; $Debt_{i,t}$ is the face value of debt; $r_{i,t-1}$ is firm i's past annual return computed from monthly stock returns over the previous year; $T_{i,t}$ is set to one year; $\sigma_{Vi,t}$ is an approximation of the volatility of firm assets. $\sigma_{Vi,t}$ is calculated as below:

$$\sigma_{Vi,t} = \frac{Equity_{i,t}}{Equity_{i,t}+Debt_{i,t}} \times \sigma_{Ei,t} + \frac{Debt_{i,t}}{Equity_{i,t}+Debt_{i,t}} \times (0.05 + 0.25 \times \sigma_{Ei,t}) \quad \text{(A2)}$$

Where $\sigma_{Ei,t}$ is the stock volatility calculated by the monthly stock returns over the previous year. Based on the equations (A1) and (A2), we can calculate the distance-to-default ($DD_{i,t}$). Then, we calculate the expected default frequency (*EDF*) through the standard cumulative normal distribution function $Normal\,(.)$, as shown in equation (A3):

$$EDF_{i,t} = Normal\,(-DD_{i,t}) \quad \text{(A3)}$$

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