An empirical study on financing constraints of digital inclusive finance development on small and medium-sized technology-based enterprise

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Abstract

Purpose – This paper mainly explores the relationship between digital inclusive finance and financing constraints of technological-based SMEs, and how digital inclusive finance affects the financing constraints of technology-based SMEs. This paper empirically analyzes the relationship between them through the OLS model, and then further verifies the relationship between them through robust regression and heterogeneity analysis. At the same time, it uses the mechanism test to explore how digital inclusive finance affects the financing constraints of technology-based SMEs. This paper aims to address these issues.

Design/methodology/approach – This paper aims to explain the relationship between digital inclusive finance and financing constraints of technological-based SMEs. Technology-based SMEs always face the difficult problem of "financing difficulty" and "financing expensive" in the development process, which hinders the survival and development of enterprises to some extent. Digital inclusive finance development policy vigorously promoted by the state has alleviated the financing constraints of technology-based SMEs and brought opportunities for their development.

Findings – The results show that the role of digital inclusive finance in alleviating the financing constraints of technology-based SMEs, and incremental supplement and alleviating information asymmetry are the main reasons for digital inclusive finance to alleviate the financing constraints of technology-based SMEs. In view of the availability of digital inclusive financial data, this paper only uses the data from 2014 to 2019.

Originality/value – The authors' research clearly found that the development of digital inclusive finance alleviates the financing of technology-based SMEs from the two aspects of "incremental supplement" and alleviating information asymmetry, so as to provide corresponding reference basis for the government to formulate a series of plans to support the development of technology-based SMEs.

Keywords Digital inclusive finance, Technological-based SMEs, Financing constraints

Paper type Research paper

1. Introduction

The report of the 19th Communist Party of China (CPC) National Congress clearly pointed out we should firmly implement innovation driven development, putting scientific and technological innovation in the key position of national development. As the main body of technological innovation, enterprises have made important contributions to China's economic growth. Technology-based SMEs refer to enterprises that rely on a certain number of scientific researchers to engage in scientific and technological research and development activities, obtain independent intellectual property rights and convert them into high-tech products or services, thereby achieving sustainable development. Technological-based SMEs are the new force of national innovation. It has been found that 65% of the total number of patents and 80% of new products in China are created by technological-based SMEs. It can be said that technological-based SMEs are gradually becoming the core of China's economic

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transformation and development. However, due to the defects of small scale and high risk, technological-based SMEs have been unpopular with traditional financial institutions. Lacking financial support has gradually become an important challenge for the survival and development of technological-based SMEs, and insufficient financial support has gradually become an important factor restricting their development. It is a systematic project to solve the financing problem of technological-based SMEs. How to solve financing problem of technological-based SMEs and help development of technological-based SMEs is the key point for the country to insist on becoming a scientific and technological power.

Scholars from various countries have also made great contributions to the causes of financing constraints of technological-based SMEs. Someone believes that information asymmetry leads to financing difficulties for technological-based SMEs (Redmond, 2011). Some scholars also believe that the immature national financial system is the main reason restricting financing constraints of technological-based SMEs (Hong, 2005; Lv, 2015); And the imperfect financial system is the main reason for the financing constraints of technological-based SMEs. Compared with large enterprises, technological-based SMEs are more likely to face financing constraints due to their small scale and weak ability to resist risks (Yu *et al.*, 2014; Deng and Zeng, 2014), which seriously affects the loan efficiency of technological-based SMEs. Some scholars have also reached the same conclusion through empirical studies. For example, Ayyagari *et al.* (2010) took Chinese enterprises as samples and found that the expansion of financing services provided by financial institutions could improve the total factor productivity of technological-based SMEs to a certain extent. Chen and Guariglia (2013) used the data of 130,840 SMEs in China to find that the stronger the financing constraints are, the lower the total factor productivity will be.

In recent years, as strong government supports the development of the digital industry, digital technology widespread use in all professions and trades, development of digital inclusive finance also brought dawn to the financing of SMEs. Through digital technology, digital inclusive finance can effectively capture the information and data of different industries, enterprises and individuals, establish a third-party credit investigation system, rely on big data to achieve rapid matching of information between different entities, implement an accurate risk assessment for enterprise (Huang, 2018) and effectively alleviate the information asymmetry problem, thus providing more help for the financing behavior of SMEs. Some scholars have also proved this through empirical studies. For example, Huang *et al.* (2020) found that digital inclusive finance could directly optimize the financing system of technology-based SMEs and meet their capital needs. Yuan and Zeng (2020a, b) constructed the financing constraint index based on the text analysis method, finding that digital inclusive finance helps to improve the financing environment of enterprises and alleviate the financing difficulties of scientific and technological small and medium-sized enterprises; Liu and Li (2021), and Ren and Liu (2021) also reached the same conclusion, inclusive of finance aims to alleviate financing constraints from three aspects: coverage, using depth and digitization. In view of the financing difficulties of technology-based SMEs, domestic scholars have also put forward many opinions from different angles, but the overall suggestions are scattered and reasonable, but they cannot solve the fundamental problem.

Therefore, based on the background of government support for technology-based SMEs, the paper analyzes the influence of digital inclusive finance policy on financing constraints of technology-based SMEs and then finds out whether digital financial development eases the financing of technology-based SMEs evidence of restraint. In addition, due to the large regional differences in the development of digital inclusive finance, digital inclusive finance in different regions may bring different results to enterprise financing. Therefore, after considering the overall quantitative analysis, we also studied the impact of digital inclusive finance on the financing constraints of technology-based SMEs in different regions.

Based on this, this paper uses the data of technology-based SMEs in Hunan Province of China from 2014 to 2019 and matches with the "Peking University Digital Inclusive Finance Index" to establish the relationship between the development of digital inclusion finance and the financing constraints of technology-based SMEs through the OLS model, and tests the robustness of the empirical results through instrumental variables. Finally, the paper examines the potential mechanism of the development of digital inclusive finance to promote financing constraints of technology-based SMEs from the perspective of "incremental supplement" and alleviating information asymmetry.

2. Background

In recent years, the development of digital inclusive finance has received national attention, and various policy documents supporting digital inclusive finance have also been issued one after another, laying a good foundation for digital inclusive finance development. With the support of new information technology represented by the Internet, inclusive finance has gradually included digital features. Digital inclusive financial is leading technology-based SMEs to innovation and upgrading at an amazing speed. According to the data released by Peking University Digital Financial Inclusion Index, Hunan province's digital inclusive financial rose from 45 in 2011 to 347.5 in 2020. In just ten years, the digital inclusive finance in Hunan Province of China increased by nearly eight times, showing a strong growth trend (Figure 1). From 2011 to 2017, the growth trend was steep; the average annual growth rate reached 18.8%, while after 2018, the growth rate became flat, with an average annual growth rate reached at 5.1%. We can know that in the past few years, digital inclusive finance has developed rapidly, and all parts of Hunan Province have achieved a fairly high scale.

From the perspective of distribution, digital inclusive finance has great heterogeneity in all prefectures and cities of Hunan Province. In China's Hunan region, Changsha, Zhuzhou and Xiangtan, the development of digital inclusive finance has reached about 260. The digital inclusive financial index of Shaoyang, Xiangxi Tujia and Miao Autonomous Prefecture, Loudi and other cities has only reached about 240, and the development is relatively slow. Digital inclusive finance index of urban groups of Changsha–Zhuzhou–Xiangtan is in a leading position in the whole Hunan province. Urban groups of Changsha–Zhuzhou–Xiangtan is the economic center of Hunan province; many high-tech industries and scientific research institutions are concentrated in the whole urban agglomeration. Development of digital inclusive finance just provides power for the development of technology-based SMEs. Meanwhile, with the rapid development of digital financial inclusion, the average level of cities in Hunan Province relative

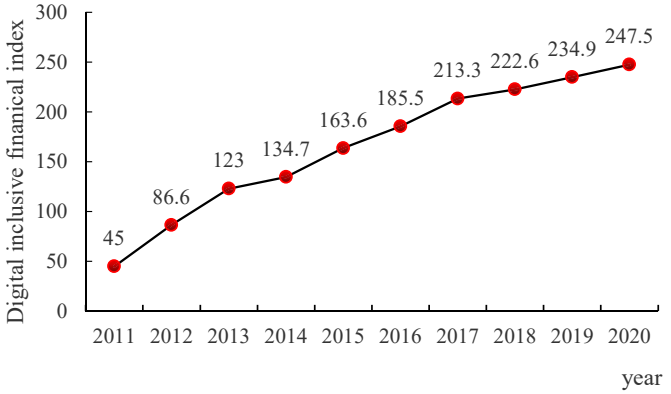

Figure 1.
Development trend of digital inclusive finance in Hunan Province, China

to the national average is gradually shrinking. There are currently four regions in Hunan Province whose digital inclusive finance development level is above the national average, namely Changsha, Zhuzhou, Xiangtan and Yueyang, while other cities and regions are below the national average. However, the gap is not large, which shows digital inclusive finance development in various prefectures and cities in Hunan Province is relatively balanced.

The high-tech industry in Hunan province mainly originated in the late 1980s. After decades of development and reform, technology-based SMEs have gradually become the backbone of enterprise development in Hunan Province and an important pillar of economic development in Hunan province. In Changsha, there were 1,242 technology-based SMEs in 2019, rising 15.3% year on year. However, in the context of severe global financial environment, the credit contraction has caused the output value of the high-tech industry to drop significantly, and the income of the high-tech industry has also declined year by year. The government also gradually withdrew from a train of preferential policies to support the development of SMEs in order to solve the financing difficulties of technology-based SMEs. But China's financial system is not perfect; traditional financial institutions mainly serve large enterprises and listed companies, so technology-based SMEs in the Hunan province are still facing huge financing constraints.

With the emergence of mobile payment, Internet lending has gradually become the main way of financing for SMEs. According to statistics, online small-scale loans reached 230 billion yuan in 2019, increasing 11.6% year on year. More and more Internet companies provide lending services on the Internet, such as Alibaba's Alipay, Jingdong Finance, Duxiaoman finance and so on. In terms of the development of SMEs, a series of policies to support SMEs issued by the state have provided impetus for the development of technology-based SMEs, which have played a huge role in promoting the sustainable development of high-tech enterprises, especially SMEs. Up to 2019, there were 1,356 technology-based SMEs enjoying tax incentives in Hunan Province, increasing 16.65% year on year, and the total tax reduction and exemption amounted to 5.233 billion yuan, up 18.35% year on year. Benefiting from digital inclusive finance development, financing constraints of non-state-owned technology-based SMEs, technology-based SMEs in Hunan province have been significantly eased.

3. Mechanism analysis

In recent years, the combination of emerging technologies such as artificial intelligence and other technologies with financial services has brought opportunities for the development of SMEs. Digital inclusive finance has improved the data processing ability in scale, speed and accuracy, and become a research hotspot of scholars at home and abroad (Xie *et al.*, 2018). As an important measure for the state to support technology-based SMEs, digital inclusive finance provides financial services for SMEs; it makes up for the limitations of traditional financial institutions, reducing financing constraints of SMEs.

Digital inclusive finance mainly alleviates financing constraints of SMEs from two aspects of "incremental supplement" and "stock optimization". Incremental supplement means that digital inclusive finance expands financial supply and then eases the financing constraints of technology-based SMEs. The stock optimization means that digital inclusive finance effectively improved the allocation efficiency of financial resources, then alleviating financing constraints of technology-based SMEs. In terms of "incremental supplement", because digital inclusive finance mainly relies on digital technologies such as big data and Internet, it can absorb a large number of small retail funds in the market at a very low cost, effectively expanding the financial supply. Meanwhile, digital inclusive finance, supported by digital technology, can process massive data quickly and cheaply (Gomber *et al.*, 2018), provide a platform for enterprises' lending information, and effectively help technology-based SMEs make reasonable production decisions (Tang *et al.*, 2020). In the aspect of

"stock optimization", digital inclusive finance transforms and upgrades the business of traditional banking institutions, thus improving the information asymmetry between traditional commercial financial institutions and technology-based SMEs. Digital inclusive finance, as a new financial service, drives the remodeling of the traditional financial system to a certain extent (Duarte *et al.*, 2012). Meanwhile, digital inclusive finance forces traditional financial institutions to transform and upgrade by constructing big databases, and improves the allocation efficiency of financial resources (Tang *et al.*, 2019) and risk management ability (Norden *et al.*, 2014). Through digital big data platform, technology-based SMEs can enjoy the required financial services more conveniently and quickly, which improves the allocation efficiency of traditional financial resources to a certain extent and relies on financing constraints of innovative enterprises (Laeven *et al.*, 2015; Zhang *et al.*, 2019).

In addition, digital inclusive finance has reduced systemic risk of traditional financial institutions. Digital inclusive finance can mine a large amount of data, reducing the degree of information asymmetry between enterprises and financial services; then enterprises with financing needs can better match with financial service institutions (Demertzis *et al.*, 2018). In addition, the biggest feature of digital inclusive finance is that it contains digital features. The speed and accuracy of data processing are the advantages of digital inclusive finance.

To sum up, we learn digital inclusive finance mainly alleviates financing constraints of technology-based SMEs through expanding the financial supply and alleviating information asymmetry.

4. Data and empirical research

Due to the lack of timely statistics, few information sources and channels, the existing databases are very limited in collecting information of technology-based SMEs. This paper based on four types of enterprises listed in the National Share Transfer System (New Third Board) of Hunan Province, which mainly includes software and information technology service, technology promotion and application service, computer communication technology and other electronic manufacturing industry. This paper classifies these four types of enterprises as technology-based SMEs and analyzes whether digital inclusive finance policy implemented by the state has effectively improved the financing constraints of technology-based SMEs.

As the situation of enterprises in New Third Board is closer to SMEs, the article takes Hunan province data as the initial sample set. In addition, the New Third Board system was officially established in 2013. To ensure the integrity of enterprise data, the sample interval selected in this paper is the sample data of six years from 2014 to 2019. As for the defining standards of SMEs, the financial information of technology-based SMEs is obtained from the WIND database and China Stock Market and Accounting Research (CSMAR) database.

In addition, considering that some samples are missing or information is not true, many indicators are prone to outliers. Before formal regression, we need to screen the samples of technology-based SMEs. The screening criteria are as follows:

(1) Since there are anomalies in the financial system of special treatment (ST) enterprises, the elimination of these enterprises will easily affect the accuracy of the empirical results, so we will remove the enterprises with ST shares from the final sample.

(2) Eliminating key indicators do not conform to accounting standards and the existence of serious enterprises.

(3) Eliminating enterprises with significant anomalies, such as companies with a debt-to-asset ratio greater than 1.

After filtering according to the above criteria, in the regression process, in order to prevent some outliers from affecting the accuracy of the regression results, we kept the same practice

as the other literature and adopted 1% tail reduction to obtain unbalanced panel data at last. A total of 1,433 enterprises were selected with a total of 6,018 complete samples.

4.1 Data description

Explained variable is the degree of financing constraint of the enterprise. At present, there are many indicators for measuring corporate financing constraints in academia, including SA index, WW index, KZ index and so on. Since the measurement methods of WW index and KZ index depend on a series of endogenous financial indicators, there is a large endogeneity in the actual regression, which may lead to inaccurate empirical results of estimation even in the case of large samples. Therefore, accurately reflecting the financing constraints of enterprises, we refer to the SA index designed by Hadlock and Pierce (2009). The calculation formula is

$$\mathrm{SA} = \left|-0.737 \times \mathrm{Size} + 0.043 \times \mathrm{Size}^2 - 0.04 \times \mathrm{Age}\right| \tag{1}$$

where, symbol SA represents the degree of financing constraint of an enterprise, which is composed of a linear combination of enterprise size and enterprise age. The symbol Size represents the size of the enterprise, measured by the company's total assets. Symbol Age is the age of the enterprise, which indicates the time since the establishment of the enterprise. Since SA index may be negative, it is common to compare absolute value of the SA index.

Core explanatory variable: digital inclusive finance. "Peking University Digital Financial Inclusive Index" compiled by the Peking University Digital Finance Research Center and Ant Research Institute is the most representative one in China to measure the development level of digital inclusive financial (Guo *et al.*, 2020; Guo and Xiong, 2021). The basic data of the index mainly comes from the Alipay ecosystem. The index also reflects development degree of digital inclusive finance amongst regions from three aspects: the breadth of digital financial services coverage and depth of using and degree of digitalization, which is conducive to further clarify the causal relationship between digital inclusive finance and corporate financing constraints.

Other control variables: Because the financing constraints of the company will also be affected by some other variables, we also selected some control variables based on the literature, including company's growth ability (Zhao *et al.*, 2021), company's operating capacity (Su and Miao, 2021), share of fixed assets, proportion of senior management's shareholding, changes in short-term corporate liabilities, etc. In order to exclude some unobservable variables, we added the year fixed effect, individual fixed effect. Variables are defined as seen in Table 1. Table 2 shows the descriptive statistics of the variables.

As shown in Table 2, average value of financing constraints (SA) of technology-based SMEs is 11.582, standard deviation is 0.833, the maximum and minimum values are 9.673 and 11.325, respectively. Taken together, it is found that technology-based SMEs have a big problem of financing constraints, but as technology-based SMEs are easily discriminated against by traditional financial institutions, the overall relative fluctuations are relatively small. Average value of the degree of digital inclusive finance development is 192.478, while the standard deviation is 37.807. The overall fluctuation is large, indicating that there are great differences in digital inclusive finance among different regions in Hunan Province.

4.2 Econometric model

In order to verify that digital inclusive finance development help to ease financing constraints of technology-based SMEs, this paper estimates influence of digital inclusive finance on financing constraints of technology-based SMEs through multiple linear regression model, specific model is established as follows:

Variable type	Variable name	Variable symbol	Variable definitions
Explained variable	Degree of financing constraint	SA	Represents the SA index
Explanatory variable	Digital inclusive finance	Difi	Peking University Digital Inclusive Finance Index
	Breadth of coverage	Cove	Digital Inclusive Finance Index secondary indicator
	Depth of use	Depth	Digital Inclusive Finance Index secondary indicator
	Degree of digitization	Digi	Digital Inclusive Finance Index secondary indicator
Control variables	Enterprise growth capacity	Grow	MBRG
	The operating capacity of the enterprise	Opera	Cash recovery for all assets
	Share of fixed assets	Asset	Ending fixed assets + depreciation/ Total ending assets
	Executive shareholding ratio	Share	The number of senior executive holdings/Nstbout
	Corporate capital spending	Expend	Long-term capital expenditure/Total assets at end

Table 1. Variable name and meaning

Variable	Sample number	Mean	Standard deviation	Min.	Max.
SA	6,018	11.582	0.833	9.673	15.325
Difi	6,018	192.478	37.807	120.83	281.93
Cove	6,018	174.715	34.793	115.65	279.73
Depth	6,018	196.512	47.798	107.52	272.83
Digi	6,018	243.808	45.935	134.65	319.93
Grow	6,018	0.280	0.881	−0.603	3.359
Opera	6,018	2.506	15.502	−88.36	177.98
Asset	6,018	0.173	0.204	0	0.943
Share	6,018	0.035	0.055	0	0.319
Expend	6,018	0.044	0.057	0	0.338

Table 2. Descriptive statistic

$$SA_{it} = \alpha_0 + \beta_1 Difi_{it} + \gamma Z_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Among them, symbol SA is an explained variable, which represents the financing constraints of technology-based SMEs, symbol Difi is an explanatory variable, and represents development level of digital inclusive financial, and symbol Z is a series of variables that affect the financing constraints of technology-based SMEs, mainly including corporate growth capabilities, the company's operating capabilities, fixed asset shares, senior management's shareholding ratio and corporate capital expenditures, etc. The subscript i represents the company, the symbol t represents the year, and the symbol μ_i represents firm fixed effect, which controls the variable at the firm level that does not change with time, and symbol λ_t is year fixed effect, which controls the common annual change factors of all enterprises, that is, macro shocks at the national level. Symbol ε_{it} is the random error term. The coefficient concerned in this article is β_1 if β_1 is negative shows that digital inclusive financial alleviates financing constraints of technology-based SMEs.

In order to further explore which specific index of digital Inclusive finance has an impact on the financing constraints of science and technology SMEs in Hunan Province. This article further explores the influence on the financing constraints of technology-based SMEs according to the breadth of the index's digital financial services coverage, depth of using and degree of digitization. Specific regression equations are as follows:

$$SA_{it} = \alpha_0 + \beta_1 Cove_{it} + \gamma Z_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

$$SA_{it} = \alpha_0 + \beta_1 Depth_{it} + \gamma Z_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

$$SA_{it} = \alpha_0 + \beta_1 Digi_{it} + \gamma Z_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

Among them, Equation (3) is to verify the influence of breadth of digital financial services on financing constraints of technology-based SMEs, and Equation (4) is to verify the influence of depth of use of digital financial services on the financing constraints of technology-based SMEs. Equation (5) is to verify the impact of the digitalization of digital financial services on financing constraints of technology-based SMEs. Other indicators are still consistent with Equation (1).

5. Main result

5.1 Benchmark results

In this paper, OLS estimation, random effect and fixed effect models are used to estimate the impact. The fixed effect model is better than the random effect model. Therefore, all the regressions in this paper adopt the fixed effect model. The article first examines the influence of the total index of digital inclusive finance on financing constraints of technology-based SMEs; Results are in Column (1). After the general indicators, this paper respectively examines the impact of the breadth of digital financial services coverage, depth of using, the degree of digitalization on financing constraints of technology-based SMEs and results obtained are the last three columns. It should be noted that in order to exclude the influence of unobservable variables that do not change over time on the regression results, this paper controls both the fixed effect of enterprises and the fixed effect of years. Table 3 shows the results.

Variable	(1)	(2)	(3)	(4)
Difi	−0.435*** (0.089)			
Cove		−0.350** (0.159)		
Depth			−0.408** (0.190)	
Digi				−0.103* (0.056)
Grow	−0.035** (0.017)	−0.033** (0.016)	−0.034** (0.015)	−0.034** (0.015)
Opera	−0.083 (0.062)	−0.080 (0.060)	−0.081 (0.060)	−0.083 (0.060)
Asset	−0.138*** (0.019)	−0.142*** (0.021)	−0.118*** (0.014)	−0.128*** (0.020)
Share	0.104** (0.043)	0.100*** (0.034)	0.106*** (0.035)	0.091** (0.037)
Expend	−0.283*** (0.060)	−0.325*** (0.085)	−0.310*** (0.092)	−0.292*** (0.072)
Constant	3.357*** (1.083)	4.285*** (1.135)	3.904*** (1.330)	5.237*** (1.804)
Firm fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Observed value	6,018	6,018	6,018	6,018
R^2	0.537	0.428	0.582	0.331

Table 3.
Regression results

Note(s): The symbols ***, ** and * indicate significant at confidence level of 1, 5 and 10%. Standard errors are in parentheses

In Table 3, Column (1) shows the regression results. The coefficient is significantly negative at the 1% confidence interval, indicating digital inclusive finance development alleviates financing constraints of technology-based SMEs in Hunan Province. Specifically, the digital inclusive financial index increased by one unit will result in a decrease of 0.435 units in the financing constraints of technology-based SMEs in Hunan Province. Columns (2)–(4) respectively show the empirical results of the three subindicators of the digital inclusive financial index. From the results, no matter which indicator is significant at the confidence interval of 5%, it indicates that the breadth, depth and digitization of digital financial services have alleviated financing constraints of technology-based SMEs. From the coefficient, the absolute value of the breadth and depth of digital inclusive financial services are far greater than the degree of digitalization of digital inclusive financial, which indicates that the breadth and depth of digital inclusive financial services play a greater role in alleviating financing constraints of technology-based SMEs. This also illustrates the need for the government to vigorously promote policies supporting digital inclusive financial in China. Therefore, digital inclusive finance development will help to alleviate the financing constraints of technology-based SMEs in Hunan Province.

From the perspective of control variables, coefficient of enterprises' growth ability is −0.035; this shows that enterprises' growth ability increase by one unit will lead to a reduction of enterprises' financing constraints by 0.035 units. On the one hand, the increase of the main business income of the enterprise will increase the total amount of capital of the enterprise, thus reducing the financing demand of the enterprise, and thus reducing the financing difficulty of the enterprise. On the other hand, the increasing in the main business of an enterprise indicating that the enterprise is in good business condition, which will further eliminate distrust of financial institutions toward SMEs and thus make it easier to obtain loans than before. The coefficient of fixed asset share of the enterprise is −0.138, which is significant at the confidence interval of 1%, indicating that every 1 unit increases in the fixed asset share of the enterprise will reduce the financing constraint of the enterprise by 0.138 units. From the perspective of financial institutions, fixed assets as collateral for loans can increase the loan amount of financial institutions to a certain extent. From the perspective of enterprises, the increasing in the share of fixed assets is a manifestation of their financial strength, which may make financial institutions more confident in the repayment ability of SMEs and thus increase loans to enterprises. The coefficient of executive shareholding ratio is 0.104, indicating that the increase of executive shareholding ratio will increase the financing constraint difficulty of technology-based SMEs. However, the coefficient of enterprise capital expenditure is −0.283, indicating that the increase of enterprise capital expenditure will reduce the difficulty of financing constraints of technology-based SMEs. The control variables of the other three columns are in the same direction as Column (1), so this paper will not explain.

5.2 Robust regression

5.2.1 Instrumental regression. Although in the benchmark regression part of this paper, it is concluded that digital inclusive finance alleviates degree of financing constraints of technology-based SMEs in Hunan Province, there are still two aspects of endogeneity that may affect the results of this paper. The first is that there is a reverse causal relationship between the development of digital inclusive finance and corporate financing constraints. Second, considering the numerous constraints that affect the financing of technology-based SMEs, endogeneity may exist in the empirical model of this paper due to omit variables or measurement errors. In the modern econometric theory, the best way to solve endogeneity is to look for instrumental variables. This paper selects two instrumental variables according to the practice of the other literature, namely, the distance from Hangzhou (Guo *et al.*, 2017; Zhang *et al.*, 2020) and the development level of the Internet (Xie *et al.*, 2018; Huang *et al.*, 2019).

In order to obtain more robust results, we estimate the regression results by two stage least squares (2SLS) method. We first tested the effectiveness of the two instrumental variables in the first stage. From estimated results of the first stage in Table 4, whether it is the distance from Hangzhou or Internet development level, coefficient is significant. It shows that two instrumental variables and digital financial inclusion have strong relativity. In addition, the statistics of Kleibergen–Paap rk Wald *F* statistic are far greater than the confidence interval of 10%, which further indicates that the choice of these two instrumental variables is very reasonable. Meanwhile, the statistic of Cragg–Donald Wald *F* statistic is far greater than 10, which indicates that neither of the two instrumental variables selected in this paper has the problem of weak instrumental variables. And Hansen J statistic shows that the instrumental variables selected in this article do not have the problem of overidentification. All in all, the distance from Hangzhou and the development level of the Internet selected in this article meet the relevance and exclusivity of instrumental variables, which can solve the endogenous problem generated in this article to a certain extent. The regression results of instrumental variables show in Table 4.

As you can see from Table 4, the two tool variables chosen for this article make perfect sense. The two coefficients of regression in the first stage are 0.455 and 0.181, indicating instrumental variables have a positive influence on development level of digital inclusive finance. From the second stage, the coefficient of distance from Hangzhou is −0.176. The coefficient of Internet development level is −0.183. This indicates that the significance and coefficient size of variables do not change much when endogeneity is considered. So far, this paper believes digital inclusive finance development level can ease financing constraints of technology-based SMEs.

5.2.2 Replace the dependent variable. To increase the authenticity of the empirical results, we replaced the dependent variables. This paper adopts cash – the cash flow sensitivity model, investment – the cash flow sensitivity model. The cash-flow sensitivity model was proposed by Almeida *et al.* (2004). Its internal logic is that when an enterprise has financing constraints, the company will reserve a part of the capital for emergency needs, that is, it can effectively measure the degree of financing constraints by using the cash holdings and cash flow kinetic energy of the enterprise. Generally speaking, the higher the coefficient sensitivity of cash flow is, the stronger the financing constraint is.

Table 5 shows the results of robust regression after changing dependent variables. From the regression results, the coefficient of digital inclusive financial is always significant in the confidence interval of 5% regardless of whether control variables are added. This indicates digital inclusive finance development alleviates the financing constraints of technology-based SMEs. The coefficients and significance of other control variables did not change much. Therefore, the results of this paper show strong robustness.

Variable	(1)	(2)
First stage		
Distance	0.455*** (0.062)	
Internet		0.181*** (0.034)
Kleibergen–Paap rk Wald *F* statistic	54.791	52.868
Stock–Yogo weak ID test critical values: 10% maximal IV size	16.38	19.93
Second stage		
IV	−0.176*** (0.033)	−0.183*** (0.051)
Control variables	YES	YES
Cragg–Donald Wald *F* statistic	1,411.949	859.458
Hansen J statistic	0.000	0.000
Observations	6,018	6,018

Table 4.
Regression of instrumental variables

Variable	(1)	(2)
Difi	−0.711** (0.305)	−0.627*** (0.291)
Grow		−0.049** (0.024)
Opera		−0.061* (0.038)
Asset		−0.133*** (0.020)
Share		0.207* (0.118)
Expend		−0.235** (0.103)
Constant		4.007*** (1.108)
Firm fixed effects	YES	YES
Year fixed effects	YES	YES
Observed value	6,018	6,018
R^2	0.133	0.428

Note(s): The symbols ***, ** and * indicate significant at confidence level of 1, 5 and 10%, respectively. Standard errors are in parentheses. The whole result is three decimal places

Table 5. Robustness test

5.3 Heterogeneity analysis

According to previous studies, there is heterogeneity in the economic activities of digital inclusive finance and technology-based SMEs, mainly including the heterogeneity between regions and different industries. Therefore, in order to further explore such differences, the article makes a heterogeneity test based on the sample of SMEs.

5.3.1 Technology-based SMEs in different regions. We found that digital inclusive finance showed very big differences in Hunan Province. For example, development level of digital inclusive finance in Changsha, Zhuzhou and Xiangtan has always been above the national average, while other cities of Hunan province is below the national average. This gap between regions may produce heterogeneity for technology-based SMEs in Hunan Province. Therefore, in order to explore the differences brought by such heterogeneity, this paper divides the Hunan province into two categories according to whether the level of digital inclusive finance development is above national average. One category includes Changsha, Zhuzhou, Xiangtan and Yueyang, which are prefecture-level cities, and their level of digital inclusive finance development is above the national average. The second category includes Hengyang, Shaoyang, Changde, Zhangjiajie, Yiyang, Chenzhou, Yongzhou, Huaihua, Loudi and Xiangxi, whose development level of digital inclusive finance is below national average. Regressions are shown in the Table 6 below.

As can be seen from Table 6, no matter whether the level of digital inclusive finance development is higher than national average, digital inclusive finance development has eased financing constraints of technology-based SMEs in Hunan Province. From the results, Column (1) shows the impact of regional digital inclusive financial development on the financing constraints of technology-based SMEs, which is higher than national average, with a coefficient of −0.661. This shows that development level of digital inclusive finance in four prefecture-level cities of Changsha, Zhuzhou, Xiangtan and Yueyang will reduce the financing constraints of technology-based SMEs in these four prefecture-level cities by 0.661 units. At the same time, Column (2) with a coefficient of −0.303 is lower than national average. It shows that the level of digital inclusive finance development in the remaining ten prefecture-level cities will reduce the financing constraints of technology-based SMEs in these four prefecture-level cities by 0.303 units. By comparing the coefficient of convergence between the two regions, we find that if the development level of digital inclusive finance is higher than the national average level, their digital inclusive finance development will ease financing constraints of technology-based SMEs in this region to a greater extent. This shows that the better the development of digital inclusion financial is, the more effective it is to alleviate financing constraints of technology-based SMEs.

Variable	Above the national average (1)	Below the national average (2)
Difi	−0.661*** (0.115)	−0.303** (0.129)
Grow	−0.083*** (0.022)	−0.011* (0.006)
Opera	−0.071* (0.040)	−0.088 (0.091)
Asset	−0.235** (0.104)	−0.098** (0.045)
Share	0.089** (0.038)	0.119 (0.074)
Expend	−0.407*** (0.101)	−0.198*** (0.051)
Constant	5.220*** (1.200)	4.295*** (1.229)
Firm fixed effects	YES	YES
Year fixed effects	YES	YES
Observed value	4,183	1,835
R^2	0.493	0.505

Table 6.
Heterogeneity results of different regions

5.3.2 Technology-based SMEs in different industries. The samples selected in this paper are based on the four types of enterprises listed in the National Share Transfer System (New Third Board) of Hunan Province, which mainly include the software and information technology service industry, technology promotion and application service, computer communication, other electronic manufacturing, Internet and related services. Due to the development of different industries and the degree of demand for funds, there may be greater heterogeneity. According to the classification of these four different industries, we obtained the heterogeneity of financing constraints of digital inclusive finance on the four different industries through OLS regression. It should be noted that there may be unobservable factors affecting different industries. Regressions are shown in the Table 7 below.

From Table 7, financing constraints of technology-based SMEs between different industries show great differences, which shows that it is reasonable for us to distinguish the industry to examine. In terms of coefficients, no matter what industry it is, the development level of digital inclusive finance effectively alleviates financing constraints of technology-based SMEs. From the significance of the coefficients, the digital inclusive financial

Variable	Software and information technology services (1)	Technology promotion and application services (2)	Computer communications and other electronics manufacturing (3)	Internet and related services (4)
Difi	−0.452*** (0.141)	−0.351** (0.162)	−0.381 (0.261)	−0.413** (0.200)
Grow	−0.101** (0.048)	−0.077*** (0.025)	−0.061** (0.030)	−0.058** (0.027)
Opera	−0.067 (0.078)	−0.016 (0.053)	−0.061* (0.038)	−0.052* (0.032)
Asset	−0.221*** (0.071)	−0.105* (0.064)	−0.307*** (0.088)	−0.420** (0.201)
Share	0.066 (0.050)	0.114 (0.075)	0.104 (0.071)	0.034** (0.015)
Expend	−0.309* (0.173)	−0.294*** (0.078)	−0.431** (0.211)	−0.291** (0.143)
Constant	5.083*** (1.227)	4.891*** (1.204)	4.901*** (1.103)	5.462*** (1.417)
Firm fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Observed value	1,630	1,353	1,789	1,246
R^2	0.382	0.461	0.458	0.440

Table 7.
Heterogeneity results of different regions

coefficients of software and information technology service, technology promotion, application service business, Internet and related services are significant at the level of 5%, while the digital inclusive financial coefficients of computer communication and other electronic manufacturing industries are not significant. Although technology-based enterprises in computer communication and other electronic manufacturing industries are classified as part of small and medium-sized enterprises, the development of digital inclusive finance will not have a great impact on the financing constraints of these enterprises because of their large scale, sound financial systems and good reputation.

5.4 Mechanism test

In the benchmark regression, we find digital inclusive finance alleviates financing constraints of technology-based SMEs. In this part, we will further verify how digital inclusive finance alleviates financing constraints of technology-based SMEs, namely the mechanism test. According to the previous analysis, we will verify from two aspects: expanding the financial supply and alleviating information asymmetry. In this paper, the bank loan scale and financial expense ratio of enterprises are used as proxy variables reflecting expanding the financial supply and alleviating information asymmetry. This is mainly because if the development of digital inclusive finance increases bank loan scale of enterprises and reduces financial expense ratio of enterprises, we believe that digital inclusive finance can relieve financing constraints of technology-based SMEs by replenishment of stock and easing information asymmetry. In the empirical analysis, OLS regression was also used to verify the two mechanisms of expanding the financial supply and alleviating information asymmetry. Regressions are shown in Table 8 below.

As can be seen from Table 8, when the explained variable is the scale of corporate bank loans, the coefficient is positive and significant, indicating that development of digital inclusive finance has increased bank loan scale of enterprises. Digital inclusive finance helps expand loan amount of commercial banks to a certain extent. This is because my country's financial institutions are mainly banks, and about 70% of corporate loans come from commercial bank loans. Digital inclusive finance development has effectively absorbed scattered resources of small customer groups in society as bank deposits. As a result, the scale of loans to technology-based SMEs has been expanded. If the dependent variable is the company's financial expense rate, the coefficient is negative, which means that every increase of 1 unit of digital financial inclusion will reduce the financial expense of technology-based SMEs by 0.159 unit. Mainly, digital inclusive finance development has forced the transformation and upgrading of the traditional financial sector. The development digital inclusive finance has brought support of effective digital technology to the payment and

Variable	Incremental supplement (1)	Enterprise information asymmetry (2)
Difi	0.271** (0.117)	−0.159*** (0.036)
Grow	0.083* (0.050)	−0.026** (0.011)
Opera	0.106 (0.073)	−0.175* (0.098)
Asset	−0.041** (0.018)	−0.020* (0.011)
Share	0.055 (0.044)	0.138 (0.114)
Expend	0.306*** (0.093)	0.391** (0.180)
Constant	1.305*** (0.042)	3.391*** (0.096)
Firm fixed effects	YES	YES
Year fixed effects	YES	YES
Observed value	6,018	6,018
R^2	0.682	0.461

Table 8.
Mechanism analysis

credit management of commercial banks, reducing the size of corporate and financial institutions. The information asymmetry between institutions has gradually improved the efficiency of financial resource allocation.

6. Conclusion and suggestion

This paper selects 1,433 enterprises in Hunan Province from 2014 to 2019 as the sample data, constructing an empirical model for the analysis of financing of technology-based SMEs by digital inclusive finance. Using benchmark regression and robustness regression, it is confirmed digital inclusive finance development can help ease financing constraints of technology-based SMEs in Hunan Province. At the same time, in order to get more detailed conclusions, the samples are further divided to further investigate heterogeneity of technology-based SMEs in different regions and different industries according to whether the level of digital inclusive finance is higher than the national average level. As a result, we found that areas where the level of digital inclusive financial is higher than national average have a greater effect on alleviating the financing constraints of technology-based SMEs. The effect of financing constraints on technology-based SMEs serving the three industries is even more obvious. Finally, it further explored the mechanism of digital inclusive financial in alleviating the financing constraints of technology-based SMEs, and found that expanding the financial supply and alleviating information asymmetry are the main reasons for digital inclusive financial to ease the financing constraints of technology-based SMEs.

Combined with the above research conclusions, the article puts forward some countermeasures and suggestions. First, government should vigorously support digital inclusive finance development and formulate long-term development plans. Seizing the opportunity of history, cultivate outstanding financial technology talents, increase the level of technology research and development and further promote the integration of financial transactions and technology products. Second, improving the construction of the data management platform, building data sharing platform. The development of digital inclusive finance has greatly alleviated the problem of information asymmetry between enterprises and financial institutions, which plays a very important role in both corporate financing and the performance of commercial banks. The government should promote the establishment of an information contribution platform and formulate corresponding regulations, so as to form a credit platform that can expand the sharing of institutions. Third, further improve the regulatory system construction of digital financial platforms to balance the stability of digital inclusive finance. Although the development of digital inclusive finance has provided impetus for the development of technology-based SMEs, fundamentally, the development of digital inclusive finance has also increased the systemic financial risks of commercial banks. The government should pay attention to the design of the supervision mechanism for this new type of financial business, and ensure that it finds an appropriate balance between serving the real economy and balancing financial risks.

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