

A Study on the Impact of Digital Inclusive Finance on Business Innovation- Financing Constraints as a Mediating Variable

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Abstract. SMEs, or Small and Medium-sized Enterprises, are crucial to China's economic growth. However, their small size and limited credit rating often result in significant financing constraints, which hinder their ability to innovate. Fortunately, the advent of digital inclusive finance has opened up new financing channels and methods for SMEs. This paper analyzes data from 2013-2020 for Chinese A-share SMEs listed on the board, and matches it with Peking University's digital inclusive finance municipal data. Through empirical testing, the study confirms that digital inclusive finance can help alleviate SME financing constraints, leading to increased innovation. The research aims to explore how digital inclusive finance can provide better solutions for SME financing, promoting the innovative development of SMEs.

Keywords: Digital Inclusive Finance, Financing Constraints, Firm Innovation.

1. Introduction

China's economy is in a stage of high-quality growth, with SMEs contributing significantly to innovation and employment. However, financing constraints hinder their ability to innovate. Digital inclusive finance is a national strategic direction to solve this problem. This paper examines the impact of digital inclusive finance on SME innovation, explores the transmission mechanism, and suggests ways to promote its development and stimulate SME innovation.

From the existing literature, it is clear that digital inclusion finance can alleviate the problem of corporate financing constraints, especially in the case of SMEs. This facilitative effect is reflected in enhancing the innovation capacity of SMEs by alleviating their financing constraints. At the same time, this impact also exhibits regional and environmental heterogeneity. Therefore, this paper aims to empirically investigate the impact of digital inclusive finance on corporate innovation and provide practical suggestions for SMEs in China to achieve high-quality development by using financing constraints as a mediating variable.

This study investigates the impact of digital inclusive finance on firm innovation and the mediating role of financing constraints. Results show that digital finance positively affects financing constraints and promotes innovation activities, with all three dimensions having a positive effect on innovation. Private, mid-western, and technology-intensive firms benefit more. Digital finance can help SMEs and enhance enterprise innovation. Improving digital finance is expected to enhance innovation capability.

This paper's research on the development of financial inclusion and financing constraints for SMEs provides policy makers with feasible suggestions for enhancing innovation capacity and promoting high-quality SME development in China. It establishes a research model to understand the relationship between digital inclusive finance and innovation capability. The results guide policy makers and enterprises and offer solutions to financing constraints for SMEs in China.

2. Theoretical analysis and hypothesis formulation

2.1. Mechanisms of Digital Inclusive Finance for Corporate R&D Investment

Compared to traditional financial models, digital inclusion is more accessible, provides broader coverage, lower costs, higher efficiency and higher customer satisfaction. These "inclusive" features can better serve SMEs, a large number of long-tail groups with high capital needs, which are often "shut out" by the traditional financial sector, and thus promote and facilitate the innovative activities and technological progress of these SMEs [1].

Digital inclusive finance can contribute to enterprise R&D innovation in the following three ways: expanding SME financing channels and opening up a brand new path for SMEs to finance their innovative activities; effectively alleviating the problem of information asymmetry when financing SMEs, reducing financing costs for them to carry out innovative activities, and to a certain extent reducing financial pressure; and greatly increasing the The probability of successful financing for innovative activities of SMEs is greatly improved [2].

Based on the above analysis, Hypothesis 1 is proposed: digital inclusive finance development has a positive contribution to SME innovation.

2.2. Mechanisms of Digital Inclusive Finance to Ease Financing Constraints

Enterprise R&D innovation inevitably encounters long time, high cost and high risk, so enterprises are prone to face high financing constraints when conducting innovation activities [3]. Enterprise innovation requires a large amount of financial support, so enterprises often obtain funds by means of financial institution financing. However, SMEs often face more difficult financing conditions. The influence of factors such as the lack of financial reports and other related information disclosure, and the relatively small size of SMEs, which makes it difficult to have suitable collateral as a condition for financing, makes a serious information asymmetry problem between SMEs and financial institutions, which increases the cost of financing for SMEs and faces problems such as difficult and expensive financing, which greatly constrains the innovative activities of enterprises.

The emergence of digital inclusive finance can encourage SMEs to supplement their innovation input by alleviating their financing constraints, thereby promoting their innovation activities and innovation level [4]. The reasons are as follows: 1) Digital finance breaks the constraints of the traditional financial service space. It lowers the threshold of financial services and widens financing channels. 2) It reduces financing costs, prevents credit risks and alleviates information asymmetry. 3) It builds a credit collection system, improves financing efficiency and promotes sound operation.

Based on the above analysis, hypothesis 2 is proposed: Digital inclusive finance promotes innovation in SMEs by alleviating corporate financing constraints

3. Study Design

3.1. Data source

This paper collects and organizes data mainly from: 1) Peking University Digital Inclusive Finance Index, published by Peking University Digital Finance Research Center; 2) information related to financing constraints, innovation activities and other control variables of Chinese A-share listed enterprises from 2013-2020, which are obtained from Guotaian database (CSMAR), Wind database and Flush Information Financial Terminal System. For the reliability of data validation this paper treats the data as follows: 1) exclude listed companies in financial industry and public utilities; 2) exclude the sample of ST, *ST or PT listed companies without tail reduction; 3) exclude companies with incomplete financial information and data.

3.2. Variable Definition

3.2.1. Explained variables

In this paper, corporate innovation is chosen as the explanatory variable and will be measured mainly from the cost of corporate innovation inputs, and the natural logarithm of total corporate R&D expenditures, denoted as R&D, is chosen.

3.2.2. Explanatory variables

This paper selects the "Peking University Digital Inclusive Finance Index" (hereafter referred to as "Digital Inclusive Finance Index") as the explanatory variable. Based on the traditional financial inclusion indicators, 33 specific indicators are selected from three dimensions, namely, the breadth of digital financial coverage, the depth of digital financial usage and the degree of digitalization of financial inclusion, to build a "financial inclusion index" reflecting the essence of China.

To further investigate how digital inclusive finance (DFI) can substantially affect business innovation by alleviating the financing constraints of SMEs, this paper mainly selects the digital inclusive finance composite index (Index) for measurement. For further testing, three dimensions are chosen for robustness testing, namely breadth of coverage (DIFinConB), depth of use (DIFUD) and degree of digital support services (DIFDL).

3.2.3. Control variables

This paper formulates $Control_{ecy}$ as a series of control variables that may have an impact on firm innovation, with reference to the existing literature, the following variables are selected as firm-level control variables in this paper: (1) Government subsidies (Sub), measured by the natural logarithm of the total government subsidies received by the enterprise in the year; (2) Total return on assets (ROA), measured by the ratio of the enterprise's total profit to total assets (3) Gearing ratio (Lev), measured by the ratio of total liabilities to total assets at the end of the period; (4) Enterprise size (Size), measured by the natural logarithm of the enterprise's total assets; (5) Enterprise operating year (Age), measured by the difference between the year of observation and the year of establishment of the enterprise; (6) Management duality (Dual), assigned a value of 1 if the chairman and general manager are the same person, and 0 otherwise.

Referring to the existing literature, in order to minimize the impact of other factors such as the industry in which the firm is located on the firm's innovation, and to avoid changes in the firm's financing constraints and its innovation trend due to other factors during the observation period, this paper therefore chooses to use a two-way fixed effects model as the baseline regression model, with fixed year effects (Year) and industry effects (Ind). All the variable definitions are shown in Table.1.

Table 1. Variable definitions

Variable Type	Variable Name	Variable Symbols	Calculation formula
Explained variables	Corporate Innovation	RD	Natural logarithm of total corporate R&D expenditures
Explanatory variables	Digital Inclusive Finance Index	Index	
Intermediate variables	Financing Constraints Index	SA	$SA = -0.737 \times Size + 0.043 \times Size^2 - 0.04 \times Age$
Control variables	Government Grants	Sub	Natural logarithm of government subsidies received by enterprises in the year
	Total Return on Assets	ROA	Ratio of total enterprise profit to total assets
	Gearing ratio	Lev	Natural logarithm of ending liabilities and assets
	Enterprise size	Size	Natural logarithm of business assets
	Enterprise establishment time	Age	Difference between the year of observation and the year of business establishment
	Two management positions in one	Dual	For the same person, take 1, otherwise 0
	City economic development level	City	Natural logarithm of (GDP per capita in each province/100000+1)
	Year Effect	Year	
	Industry Benefits	Ind	

3.3. Model design

In this paper, we first analyze the impact of digital inclusive finance on corporate innovation activities in the empirical analysis phase, and we intend to select the logarithm of annual R&D investment of enterprises, i.e., the corporate innovation index, as the explanatory variable, and the regression model is shown in equation (1).

$$RD_{eiy} = \alpha_0 + \alpha_1 Index_{iy} + \alpha_2 Control_{eiy} + \epsilon_{eiy} \tag{1}$$

(1) In equation: the subscripts e, i, and y of RD denote firm, industry, and year, respectively. The explanatory variable RD_{eiy} is the firm innovation variable, and the explanatory variable $Index_{iy}$ is the digital financial inclusion index.

To further test whether digital inclusive finance promotes innovation in SME firms by alleviating financing constraints, the mediation effect test procedure proposed by Zhonglin Wen and Baojuan Ye (2014) [5] is referred to.

$$RD_{eiy} = \alpha_0 + \alpha_1 Index_{iy} + \alpha_2 Control_{eiy} + \epsilon_{eiy} \tag{2}$$

$$SA_{ijt} = \beta_0 + \beta_1 Index_{jt} + \beta_2 Control_{ijt} + \theta_{ijt} \tag{3}$$

$$RD_{ijt} = \gamma_0 + \gamma_1 Index_{ijt} + \gamma_2 SA_{ijt} + \gamma_3 Control_{ijt} + \delta_{ijt} \tag{4}$$

Among them, the mediating variables are used as indicators of corporate financing constraints, which are measured by SA, and the variables and measures of the remaining variables remain the same as above. Model (2) captures the total effect of digital inclusion finance on firm innovation,

with coefficient α_1 measures the total effect. The coefficient in model (3) β_1 reflects the effect of digital inclusive finance development on financing constraints. The coefficients in model (4) γ_1 reflects the direct effect of digital inclusive finance on enterprise innovation. Coefficients γ_2 and the coefficient in model (3) β_1 of model (3) $\beta_1\gamma_2$ reflects the mediating effect of financing constraint, i.e., the effect of digital inclusive finance in promoting corporate innovation by alleviating corporate financing constraint.

4. Empirical Analysis

4.1. Descriptive Statistics

Descriptive statistical characteristics are reported in Table 2. According to the statistical results, the maximum value of RD is 22.868 and the minimum value is 12.356, i.e., the highest level of innovation among the sample companies has more than 10 points of R&D investment than the lowest level of innovation. It indicates that there is a large difference in innovation levels among the same SMEs, and it is necessary to further study the reasons for the difference. The mean value of the total index of digital inclusive finance development (Index) is 208.809, the maximum value is 321.646, and the minimum value is 47.030, with a large standard deviation, indicating that there are large differences in the level of digital inclusive finance development in different regions, as shown in Table.2.

Table 2. Descriptive statistics

Variables	Observations	Minimum value	Maximum value	Average value	Standard deviation
RD	4208	12.356	22.868	17.951	1.215
Index	4208	47.030	321.646	208.809	56.821
SA	4208	-5.237	-3.098	-3.707	.227
Sub	4208	-978875725.920	1673251852.260	9223.372	61687272.395
ROA	4208	-9223.372	9223.372	20.347	922.730
LEV	4208	-4.832	1.525	-1.128	.604
SIZE	4208	5.708	12.375	8.160	.926
AGE	4208	3	52	14.820	5.452
DUAL	4208	0	1	.330	.471
CITY	4208	1.063	2.844	2.031	.332

4.2. Baseline return

As shown in Table.3, the results of the benchmark regression of digital inclusive finance affecting innovation of SMEs. From the regression results, the overall fit of the model is good, and the main variables all pass the significance test at the 5% level, which indicates that the development of digital inclusive finance has a significant positive impact on enterprise innovation, which is consistent with the main hypothesis. It can also be seen that there is no significant difference between the digital inclusive finance indices of different dimensions, all of which have a positive effect on SME innovation, and also provide evidence that the development of digital inclusive finance has a robust relationship with SME innovation.

Specifically, as shown in Table.3, the results in column (1) indicate that the total digital inclusion index is positively correlated with RD at the 1% significance level, i.e., each unit of development advance in the regional level of digital inclusion promotes an increase of 0.0041 units in RD. The above findings remain unchanged after adding the enterprise control variable. It indicates that SMEs' innovation capacity is strengthened under the influence of the rapid development of digital inclusion finance, which is conducive to high-quality development. Hypothesis 1 is proved.

Table 3. Baseline regression results

Variables	(1)	(2)	(3)
	RD	RD	RD
Index	0.0041*** (11.7353)	0.0038*** (9.5469)	-0.0016 (-1.5766)
Control	Control	Control	Control
_cons	13.6784*** (70.4136)	14.0918*** (80.6542)	13.4310*** (62.0921)
N	4208	4208	4208
adj. R ²	0.168		0.318
Year	Control	Control	Control
Ind	Control	Control	Control

Note: ***, **, * denote 1%, 5%, and 10% significance levels, respectively, and robust standard errors are in parentheses.

Regression results show that digital inclusive finance (DIF) significantly reduces financing constraints and costs for local SMEs. Adding the mediating variable financing constraint SA confirms that DIF and SME innovation have significantly positive regression coefficients, but these are reduced, indicating the significant mediating effect of financing constraints on the relationship between DIF and SME innovation. This is mainly because most SMEs rely entirely on limited internal funds can hardly afford the financing gap of R&D activities need external financing to ensure the sustainability of R&D projects [6], as shown in Table.4. Hypothesis 2 is proved

Table 4. Mediation effect test

Variables	1	2	3
	RD	SA	RD
Index	0.00414*** -0.000498	-0.0000595*** -0.0000167	0.00387*** -0.000493
DIFinConB	0.00415*** -0.000502	-0.0000415** -0.0000169	0.00395*** -0.000496
DIFUD	0.00394*** -0.000457	-0.0000566*** -0.0000154	0.00368*** -0.000452
DIFDL	0.00220*** -0.000403	-0.0000696*** -0.0000135	0.00188*** -0.0004
N	4208	4208	4208
R2	0.176	0.943	0.196
Year	Control	Control	Control
Ind	Control	Control	Control

4.3. Robustness tests

The above findings have initially controlled for the potential impact of industry and year changes on firm innovation by introducing industry and year dummy variables. To further validate the findings, improve the credibility of the conclusions, and address possible endogeneity issues, this paper further employs multiple methods for robustness testing.

Substitution of variables method

To avoid the conclusions being influenced by the way digital inclusion indicators are measured, three further sub-indicators of the digital inclusion index are used for measurement, namely breadth of coverage (DIFinConB), depth of use (DIFUD), and degree of digital support services (DIFDL). Replacing the original measures separately and regressing them again, it can be found that after replacing the variables, the sub-indicators are significantly and positively correlated with business innovation, in line with the results of the model above.

Controlling individual corporate fixed effects

To further control for possible endogeneity problems, a panel data fixed-effects model is used to add firm-level individual effects and re-test the hypotheses of this paper on the basis of consistent original indicators, and the results are presented in column (2). After controlling for individual firm effects, digital inclusive finance on firm innovation is significant at the 5% level, which supports the hypothesis of this paper and indicates that the above findings are robust, as shown in Table.5.

Shortened sample years

In order to avoid the influence of the objective time measure, the sample years are further shortened from "2013-2020" to "2016-2020" in the baseline sample for the regression, and the test results are shown in column (3) of Table 5. After shortening the sample years, the digital inclusive finance index is significantly and positively correlated with enterprise innovation at the 1% level, indicating that digital inclusive finance has a significant promotion effect on SME innovation, which is consistent with the results of the previous regression analysis.

Table 5. Robustness tests

	Substitution of explanatory variables			Individual fixed effects model	Shortened sample years		
	(1)			(2)	(3)		
Index				-0.0040** (-2.0514)	0.0066*** (10.0164)	0.0066*** (10.0164)	0.0007 (0.4921)
DIFinCOnB	0.0032*** (7.1243)						
DIFUD		0.0034*** (8.3623)					
DIFDL			0.0024*** (7.8306)				
Control	Control	Control	Control	Control	Control	Control	Control
_cons	13.3865*** (62.8593)	13.5363*** (62.8899)	13.3890*** (63.2518)	12.7652*** (26.4601)	16.5675*** (101.6877)	16.5675*** (101.6877)	- 1.7e+02*** (-2.8709)
adj. R2	0.165	0.169	0.167	0.179	0.036	0.036	0.131
Year	Control			Control	Control		
Ind	Control			Control	Control		

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively, and robust standard errors are in parentheses.

4.4. Heterogeneity analysis

The results of the above benchmark regressions and robustness tests show that the development of digital inclusive finance expands financial coverage, facilitates financial services and enriches financial products, which greatly alleviates the financing constraints of SMEs, thus helping to promote the innovative output of enterprises. However, the relationship between digital inclusive finance and firm innovation is also affected by other factors, such as the nature of firm's equity and geographical location. To further explore the role of the above factors in digital inclusive finance and enterprise innovation, the regressions are further grouped by whether the sample is state-controlled and the geographic location of the enterprise to explore the moderating effects of the nature of equity and geographic location.

4.5.1. Nature of ownership

The innovation incentive effects of digital inclusive finance differ across firms of different sizes. State-owned and private enterprises differ in their strategic goals, management systems, and ownership. State-owned enterprises receive more government subsidies, bank policy tilts, and financial institution loans, while private enterprises face higher financing costs due to information asymmetry [7].

In order to test whether the nature of enterprise equity has an impact on the study, group tests were conducted on the state-owned and private enterprise samples, respectively. Because of the small number of state-owned enterprises in the SME board, after screening a total of 592 valid data, the same number of private enterprises from the SME board were screened for analysis, in an attempt to more carefully portray the ownership heterogeneity of the impact of digital finance on corporate innovation.

The estimated coefficients of Index as shown in Table.6, the columns (1) and (4) show that the promotion effect of digital finance development on innovation is stronger among SOEs. Comparing the estimated coefficients in column (2) and column (5) Index, it is clear that the mitigation effect of digital finance on corporate financing constraints is more significant among private firms.

Table 6. Regression results of firm ownership heterogeneity

Variables	State-owned enterprises			Private enterprises		
	RD (1)	SA (2)	RD (3)	RD (4)	SA (5)	RD (6)
Index	0.00414*** (0.000993)	-0.0000616* (0.0000445)	0.00393*** (0.000983)	0.00273*** (0.000374)	-0.000107** (0.0000369)	0.00286*** (0.000373)
Control	Control	Control	Control	Control	Control	Control
N	592	592	592	592	592	592
R-sq	0.347	0.953	0.362	0.615	0.940	0.620
Year	Yes	Yes	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes	Yes	Yes

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively, and robust standard errors are in parentheses.

4.5.2. Geographical location

The financing needs and innovative behaviors of SMEs are affected by the macroeconomic environment and financing constraints. The distribution of financial resources among regions in China is unbalanced, with high levels of development in the east having intensive financial resources, while the less developed provinces in the central and western regions have relatively poor financial resources [8]. The difficulty of financing is the main reason that restricts many SMEs in China to invest in innovation research, and the financial resources in the central and western regions are difficult to effectively meet the financing needs of enterprises in the region, which to a certain extent restricts the innovative development of enterprises [9].

As shown in Table.7, columns (1)-(3) and (4)-(6) show the regression results of digital inclusion finance by affecting financing constraints for SMEs innovation in the East and the Midwest, respectively. By comparing columns (2) and (5), it can be seen that digital inclusion finance helps to alleviate SME financing constraints for both eastern and mid-western SMEs, but has a greater effect on alleviating financing constraints for mid-western SMEs.

Table 7. Regression results of heterogeneity in the regional distribution of enterprises

	Eastern Region			Midwest Region		
	(1)	(2)	(3)	(4)	(5)	(6)
	RD	SA	RD	RD	SA	RD
Index	0.00354*** (0.000385)	-0.0000528** (0.0000209)	0.00346*** (0.000384)	0.00702*** (0.000867)	-0.000111*** (0.0000341)	0.00680*** (0.000870)
Control	Control	Control	Control	Control	Control	Control
_cons	13.75*** (0.207)	-3.025*** (0.0112)	9.379*** (0.992)	13.18*** (0.512)	-3.143*** (0.0202)	6.901** (2.700)
N	3298	3298	3298	910	910	910
R-sq	0.188	0.940	0.193	0.186	0.941	0.191
Year	Control	Control	Control	Control	Control	Control
Ind	Control	Control	Control	Control	Control	Control

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively, and robust standard errors are in parentheses.

By comparing the regression results in columns (1) and (4), it is found that the regression coefficient of digital inclusive finance is more significant in the central and western regions. This indicates that the innovation-driving effect of SMEs brought by digital inclusive finance is more obvious in the central and western regions.

5. Conclusion and Insights

This study examines the impact of digital inclusive finance on SMEs' R&D investment, using Chinese A-share SMEs listed from 2013 to 2020. Results indicate that digital inclusive finance improves financing efficiency, promotes SME innovation, and has a positive effect on SMEs' R&D investment. The study constructs three dimensions of digital inclusive finance, which all positively affect SME innovation. Financing constraints play a mediating role in promoting innovation.

The findings of this paper have the following policy implications. 1) Promote the development of "inclusiveness" of financial services. Many SMEs encounter unfair treatment in accessing financial services and face "ownership discrimination" and "size discrimination". The government should build an open and transparent digital-driven financing platform to reduce the information asymmetry between banks and enterprises and thus narrow the gap between companies of different ownership. 2) Digital inclusive finance drives SME innovation more in central and western regions, but development is uneven across regions. The east leads, creating regional imbalance. Therefore, increase digital infrastructure in central/western regions, coordinate financial resource allocation, and deepen digital inclusive finance in lower-developed regions. Gov't can narrow regional SME differences by improving financial infrastructure in remote areas and building digital financing platforms.

The government should continue to promote the development of digital inclusive finance, continue to promote the construction of digital infrastructure, further enhance the breadth of digital inclusive finance coverage, try to use digital technology to build a digital financial ecosystem for SME financing, effectively broaden SME financing channels and improve financing efficiency, which is of great significance to stimulate the innovative vitality of SMEs and enhance social innovation capacity.

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