



## Research article

# Digital inclusive finance, financial mismatch and the innovation capacity of small and medium-sized enterprises: Evidence from Chinese listed companies

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## ABSTRACT

As the main driver of innovation, enterprises can effectively promote the level of social innovation. This paper incorporates digital inclusive finance into the research framework of innovation in Small and Medium-sized enterprises, and investigates the impact of digital inclusive finance on the innovation ability of Small and Medium-sized enterprises through theoretical and empirical analyses. The theoretical analysis finds that digital inclusive finance can compensate for the “long-tail effect” in the financing process and help enterprises obtain financing loans. In terms of empirical analysis, this paper has conducted empirical tests by selecting the innovation data of Chinese A-share listed companies from 2010 to 2021, and the results show that: (1) Digital inclusive finance still has a facilitating effect on the technological innovation capability of Small and Medium-sized enterprises after the robustness test. (2) The mechanism evaluation finds that the digital inclusive finance segmentation indicators, i.e., the depth of use, the breadth of coverage and the degree of digitalization, are also important ways to enhance the technological innovation capability of Small and Medium-sized enterprises. (3) The innovative introduction of financial mismatch variables reveals that the financial mismatch problem in the financial market has a suppressive effect on the technological innovation capability of Small and Medium-sized enterprises. (4) Further analysis of the mediation effect of digital inclusive finance reveals that digital inclusive finance can effectively correct the financial mismatch problem in the traditional financial model and promote the technological innovation capability of Small and Medium-sized enterprises. This paper enriches the analysis of the economic effects of digital inclusive finance, while providing Chinese empirical support for digital inclusive finance to promote the innovation ability of Small and Medium-sized enterprises.

## 1. Introduction

Endogenous economic growth theory points out that technological innovation, as the main driver of economic development and the result of long-term knowledge accumulation, is the fundamental cause of driving economic growth [1]. Among them, Small and Medium-sized enterprises (the following are abbreviated as SMSEs), as a key force of innovation, are considered to be an important tool to drive the country's economic development and enhance the overall innovation capacity [2]. Innovation in business usually means

*Abbreviations:* SMSEs, Small and Medium-sized enterprises; ADB, Asian Development Bank; R&D, Research and Development.

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generating new production ideas or updating production processes [3]. From the enterprise level, innovation can bring lucrative market revenue, improve the competitiveness of SMSEs in the market, and enhance the market value of enterprises [4]. From the national level, innovative high-quality innovation output can stimulate the market's innovative vitality and shape new development advantages [5]. Taking China, a fast-growing developing country, as an example, SMSEs have always been an important subject of market innovation, an indispensable force in enhancing national economic development, and play a pivotal role in enhancing the overall innovation capacity of society [6].

Among the many factors that influence business innovation, the funding provided by financial financing services is particularly important [7]. Enterprises need to invest a lot of capital and time costs to carry out science and technology innovation activities. However, it is difficult for SMSEs to obtain sufficient financial support through internal financing due to size constraints [8,9]. Therefore, the science and technology innovation activities of SMSEs are inseparable from long-term financial support from external markets. However, according to data released by the Asian Development Bank (ADB), micro, small and medium-sized enterprises in developing Asia face the world's largest financing gap. Asia Pacific accounts for 52% of the global SMSEs financing gap (\$2.7 trillion).<sup>1</sup> Existing studies, both from theoretical and empirical perspectives, have analyzed the structural contradictions and ownership discrimination in the traditional financial system [8,10,11] that exacerbate financial resource mismatch. Financial mismatch is derived from the theory of resource allocation efficiency, which refers to the fact that capital, as a scarce "resource", is not allocated in a Pareto-optimal process [12]. In the long-term development of financial markets, financial mismatch remains an unavoidable problem in the development of the world economy. Financial mismatch makes enterprises lack financial support when engaging in scientific research activities, which seriously affects enterprises engaging in scientific research and development [13]. The financial mismatch in the financial market makes it impossible to allocate lending funds efficiently as a "resource" [14]. In the absence of financial support, SMSEs are more likely to choose activities that can bring short-term revenue (rent-seeking activities) and thus "squeeze out" funds for innovation and research and development (R&D) [10,11], which is a key factor inhibiting the progress of innovation in SMSEs [8,15,16].

It is worth noting that the digitalization and informatization of digital inclusive finance corrects the problem of financial mismatch in the traditional financial system [17], providing a good opportunity to boost enterprises' access to financial services and promote corporate innovation [18]. Digital inclusive finance means changing the traditional financial development model by reducing costs and alleviating information asymmetry through the digital economy and upgrading information technology [19]. In the context of the "Fourth Industrial Revolution", the development of digital inclusive finance is based on the organic combination of traditional financial services and new IT technologies through the physical information system (CPS), using an integrated network of computer hardware, software, production equipment and interactive interfaces to communicate the reality of new financial developments [20]. During the global spread of COVID-19, digital inclusive finance has driven the development of "non-contact" financial models and accelerated the digitalization of the world economy [21].

This leads to the question that needs to be addressed in this paper: can the rapid development of digital inclusive finance alleviate the financial mismatch problem under the traditional financial model? Faced with the problem of difficult and expensive financing for the development of SMSEs, can digital inclusive finance alleviate their financing problems and promote the innovation ability of SMSEs?

Existing literature on digital inclusive finance has focused on two perspectives. (1) Studying the impact of digital inclusive finance on traditional financial development models. Meoli and Vismara (2021) argue through a combination of theoretical and empirical analysis that digital inclusive finance strengthens the link between consumption and traditional financial development [22]. Muganyi et al. (2021) and Bollaert et al. (2021) argue that digital inclusive finance provides diversity in the choice of financial investments for households and promotes the growth of social wealth [23]. YuFeng et al. (2020) point out in their article that digital inclusive finance has promoted the transformation of the traditional financial development model, and financial institutions do not need to set up special business branches in each region, and the whole service can be completed through the information exchange between network platforms, which promotes the sinking of financial services to remote areas that are out of reach of traditional financial institutions [24]. (2) To study the impact of digital inclusive finance on firms' ability to raise finance. During COVID-19, the development of digital inclusive finance has enhanced the availability of corporate financing [25,26], effectively alleviated the financing constraints faced by enterprises [27–29], and helped them innovate in science and technology [30,31]. Fintech companies that launched new forms of finance, led by digital inclusive finance, eased traditional bank financing difficulties and broadened corporate financing channels through information remote interaction during COVID-19 [7,32]. Digital inclusive finance (as has been emphasized in Europe and other countries in recent years) the construction of blockchains to connect local financial institutions to businesses, allowing the financial system to access business information through simpler information [33] gathering and alleviating information asymmetries between lenders and borrowers [34]. Liang Bang and Zhang Jianhua (2019) find that digital inclusive finance has a positive effect on corporate technology innovation by matching digital inclusion data with corporate patent data [35]. Lei and Degong (2020) point out that digital inclusive finance can reduce not only the lending risk of financial institutions, but also the financing risk of enterprises [36]. Xiuhua (2020), Qadir et al. (2021), using the intermediary role of digital technology, investigated that digital inclusive finance shortens the review time of credit applications of economic agents through digital technology advancement, reduces the review cost, and enterprises are able to spend more funds on innovation and research and development, and reduces the financing burden of enterprises [37,38]. Fuster et al. (2019) found through a case study of digital inclusive finance lending that by using online services of

<sup>1</sup> Data from the Asian Development Bank's (ADB) SME Monitor Asia 2020, released in December 2020.

digital inclusive finance accelerated the speed of loan lending approval by financial institutions for businesses, and there were no incidents of credit defaults due to faster approval while the efficiency was increased [39].

The following shortcomings exist in the existing studies. (1) There is a lack of effective measures of innovation capability of SMSEs. Most of the existing studies on the index measurement of enterprise innovation capability also only select the number of patent applications, R&D expenses and the number of patent personnel respectively [40–42]. However, measuring a firm's innovation capability only in terms of the quantity associated with the number of patents may ignore the quality of innovation as well as the overall capability, so this paper fills the gap regarding the measurement of a firm's innovation capability. (2) There is a lack of research on how digital inclusive finance affects the innovative capacity of SMSEs. There is relatively little literature on the impact of digital inclusive finance on enterprise innovation, and some of this literature focuses on the innovation development of large and medium-sized enterprises. However, SMSEs are often in the “long tail” of the financing process and are more likely to be ignored by financial services. (3) There is a lack of research that considers both digital inclusive finance and the problems encountered in the development of traditional financial models (financial mismatch) on enterprise innovation, without focusing on the impact and mechanism of the role of digital inclusive finance and alleviation of financial mismatch on enterprise innovation, and without providing more explanations in terms of digital inclusive finance alleviating the problem of financial mismatch to promote the innovative ability of SMSEs.

In response to the above research shortcomings, the innovations in this paper are: (1) In measuring the innovation capability of SMSEs, indicators such as the quality of patents and the return on net assets brought by innovation output are added, hoping to measure the innovation capability of SMSEs in a more comprehensive way. (2) In studying the impact of digital inclusive finance on the innovation ability of enterprises, the specific object of SMSEs is selected as the research object, and the total indicators and three segmentation indicators (depth of use, breadth of coverage and degree of digitization) of digital inclusive finance are empirically tested to study the impact of digital inclusive finance on the innovation ability of SMSEs. (3) Financial mismatch is a challenge left over from the development of traditional finance, and ignoring research on financial mismatch may not explain the fact that digital inclusive finance improves the service model of traditional financial institutions by alleviating the financial mismatch problem. In this paper, we discuss the impact that financial mismatch may have on enterprises' ability to innovate and the role of digital inclusive finance in influencing financial mismatch in our study.

The work after the article is organized as follows. The second part is the research hypothesis to analyze the influence mechanism of digital inclusive finance to promote the innovation ability of SMSEs. The third part is the basic framework of the model, which lies in explaining each variable, model and method. The fourth part is the empirical regression. Taking China as an example, this paper links digital inclusive finance, financial mismatch and innovation capability of SMSEs for the first time, and analyzes the impact of digital inclusive finance and financial mismatch on the innovation capability of SMSEs through a Two stage least square (all of the following are abbreviated as 2SLS to indicate) regression model to study the mediating role of financial mismatch on the basis of digital inclusive finance. After that, the two-step systematic Gaussian mixture model (all of the following are abbreviated as GMM to indicate) robustness test is used to test again whether the mechanism of the three effects has changed. The fifth part is the conclusion and implication.

## 2. Research hypotheses

### 2.1. *The impact of digital inclusive finance on small and medium-sized enterprises technology innovation*

Take the development of China's financial market as an example, China's current market environment and the existence of the financial market is not sound development and other factors, long-term reliance on external financing of SMSEs often face the problem of difficult and expensive financing: difficult financing that traditional commercial banks in the investment and financing business more inclined to choose a company with strong solvency and good business base performance [6]. According to the statistical results of the Chinese Academy of Finance, private enterprises have the phenomenon of “short loans and long investments”, and the average financing scale of non-state enterprises in 2019 was 26.95 million yuan, while the average financing scale of state-owned enterprises reached 97.38 million yuan, which is 3.6 times of the financing scale of non-state enterprises.<sup>2</sup> Financing expensive that SMSEs through traditional financial institutions financing loans, often to financial institutions offline business outlets to submit relevant materials, waiting for the lending department after the level of approval also need to pay high audit and risk assessment fees [43], which invariably increased the cost of financing enterprises. The development of digital inclusive finance has alleviated the financing problems of SMSEs. Specifically, the impact of digital inclusive finance on SMSEs financing is mainly reflected in alleviating the financing constraints of SMSEs, reducing financing costs, alleviating information asymmetry between borrowers and lenders and other problems, thus helping SMSEs to obtain funds and helping SMSEs to carry out technological innovation.

Firstly, digital inclusive finance makes up for the shortage of traditional financial services and eases the financing constraints of SMSEs. Compared with large and medium-sized enterprises, SMSEs have difficulty in meeting the loan conditions of traditional financial institutions because they lack sufficient assets as collateral, and these financial institutions are less willing to provide financial services for SMSEs [44]. Digital inclusive finance breaks the “long tail effect” of the traditional financial market (i.e., the large group of SMSEs cannot obtain financial services in a timely manner), shortens the time for collecting enterprise information and material review, breaks through the limitation of time and space, improves the docking ability and service level with potential loan customers,

<sup>2</sup> Data from the “2019 “Enterprise Costs” Research Report” published by the Chinese Academy of Finance 2020.

extends the field and depth of financial services, and makes up for the inadequate services of traditional financial institutions for SMSEs in the “long tail” [45,46], and is a powerful supplement to traditional financial services. Digital Inclusive Finance for SMSEs enhances the technological innovation capability of SMSEs through credit support [47], timely access to funds and use of funds for innovative R&D.

Secondly, digital inclusive finance reduces the financing cost of SMSEs. Digital inclusive finance greatly reduces the marginal management costs of enterprises through digital technologies such as big data and cloud computing [48], and reduces the costs of financial institutions to obtain enterprise information through the digital update of traditional financial products and the transformation of business models through modern technologies [49], such as network platforms and real-time dynamic identification of information [50]. By transforming the supply of financial services, online credit lending to SMSEs can be realized through mobile terminal devices [51], and the cost of financial services decreases with the reduction of human and material capital invested by financial institutions [52]. The reduced cost of financing helps SMSEs to access more available funds, which in turn helps SMSEs to carry out innovative activities.

Finally, the development of digital inclusive finance has reduced the problem of information asymmetry between lenders and borrowers. Kaplan and Zingales (1997) argue that information asymmetry exacerbates the creation of financing constraints. The construction of digital information platform helps financial institutions to establish a perfect information collection and processing system, credit risk supervision system and risk avoidance system [53]. By uploading the company's publicly available financial information, loan demand and credit materials to the digital financial service platform, financial institutions can process customer data and information in a timely and efficient manner, and understand the operating conditions and investment risks of SMSEs in a comprehensive manner [54]. Digital inclusive finance accurately matches the loan needs of SMSEs with the loan amount, alleviating the adverse selection and moral risks caused by information asymmetry [55–57], ultimately enhancing the ability of SMSEs to obtain loans and helping them to innovate technology.

Based on the above analysis, the first research hypothesis of this paper is proposed.

**H1.** The development of digital inclusive finance enhances the technological innovation capability of SMSEs.

## 2.2. *The moderating role of digital inclusive finance in the technological innovation impact of financial mismatches on SMSEs*

### 2.2.1. *Financial mismatch and technological innovation in SMSEs*

Financial mismatch is a phenomenon that currently prevails in financial markets around the world and has been having a profound impact on the operation of financial markets [58]. Financial mismatch means that financial resources cannot be allocated effectively and rationally [59]. In terms of micro-entities, financial mismatch makes enterprises unable to obtain financial support in time, thus missing production, innovation and R&D opportunities [6].

The impact of financial mismatch on enterprises' science and technology innovation activities is mainly reflected in two aspects: on the one hand, financial mismatch directly affects enterprises' innovation R&D and upgrading. The financial mismatch inhibits enterprises from upgrading their patent quality by limiting their access to financial support and increasing their investment and financing costs [12]. Under the financing method mainly based on commercial bank loans, in order to prevent SMSEs from failing to repay their loans in time due to business risks, banks will tend to allocate funds to state-owned enterprises or large enterprises through government administrative intervention [9], resulting in huge differences in access to financial resources among enterprises [60]. In order to obtain sufficient financial resources, SMSEs have to increase their own costs of obtaining financial resources, and accordingly, the funds available to them for innovative R&D and technological upgrading will be reduced, which ultimately slows down the improvement of SMSEs' innovation capability [22]. On the other hand, financial mismatch acts indirectly on the innovation of SMSEs. When SMSEs encounter financial mismatch, they face shortage of funds and high financing costs, which put them in liquidity problems [55].

The financial system is usually influenced by government departments in the provision of financial services. Local governments need to intervene in the resource allocation of financial institutions through administrative means, taking into account factors such as administrative level, economic factors and regional GDP [61]. The existence of financial mismatch makes it necessary for SMSEs to obtain excess profits through rent-seeking means [51]. When the firm obtains excess profits, due to the “crowding out effect” (where the total wealth of the firm is fixed, and when the firm occupies too much capital in the short-term profit side, it will reduce the capital available for the innovation sector), the firm will invest the only capital available in short-term profitable production projects to obtain the flow of funds [62], thus abandoning innovation R&D and patent quality upgrading, inhibits the improvement of enterprise innovation capacity. At the same time, rent-seeking activities intensify information asymmetry between enterprises and financial institutions, and financial resources tend to choose sectors with low marginal efficiency [41], leaving SMSEs at the “tail” without financial services and lacking financial support for innovation R&D. The financial mismatch leads to a reduction in the risk identification ability of financial institutions for enterprise innovation, resulting in the misallocation of innovation resources and exacerbating the innovation risk of SMSEs [58].

Based on the above analysis, the second hypothesis of this paper is proposed.

**H2.** Financial mismatches have a disincentive effect on the innovative capacity of SMSEs.

### 2.2.2. *Digital inclusive finance, financial mismatch, and small and medium-sized enterprises technology innovation*

The “MM” theory proposed by Modigliani and Miller argues that in a perfectly competitive market where firms' investment and financing decisions are separate [63], information asymmetry in financial markets leads to adverse selection and moral hazard. These risks increase the cost of financing for firms and thus inhibit their ability to obtain external financing and increase the degree of

financial mismatch between firms and financial institutions [64]. The information matching between lenders and borrowers is the main direction of modern financial market reform, while traditional financial institutions are limited by time and space to obtain sufficient information about enterprises, and financial institutions cannot grasp the information dynamics of enterprises in a timely manner, thus slowing down the rate of investment in enterprise loans [59]. Digital inclusive finance relies on digital platforms to enhance the information collection and processing capabilities of financial institutions [7]. Digital inclusive finance can obtain relevant credit and financial information of enterprises at low cost through a variety of emerging Internet technologies, realizing the organic combination of enterprise operating capacity [23], loan demand and credit data, and accelerating the risk assessment of enterprise loans by digital financial platforms. The development of digital inclusive finance makes up for the shortcomings of the traditional financial system [24], stimulates healthy competition among traditional financial institutions, and to a certain extent, alleviates financial mismatch. At the same time, the digital inclusive finance platform, with the advantages of its services and data processing, broadens the financing channels of enterprises, reduces the financing costs of SMSEs, optimizes the allocation of financial resources, alleviates the financial mismatch problem and thus helps SMSEs to obtain financing and stimulates the innovative vitality of enterprises.

Based on the above analysis, the third hypothesis of this paper is proposed.

**H3.1.** The development of digital inclusive finance alleviates the financial mismatch problems faced by SMSEs.

**H3.2.** The development of digital inclusive finance promotes the ability of SMSEs to innovate with technology by alleviating the financial mismatch challenges they face.

### 3. Study design

#### 3.1. Sample selection and data sources

In this paper, the number of employees of enterprises is used as the criterion, and enterprises with less than 100 employees are selected as SMSEs, considering that different industries have different requirements on the number of employees. Since the research on digital inclusive finance in China started late, the measurement on digital inclusive finance index started from 2010. In order to unify the data time, the panel data of SMSEs in China A-share market from 2010 to 2021 are selected for the study. Screening was performed according to the principles of previous scholars dealing with data of listed companies: excluding financial and ST and PT companies; excluding companies with too many missing values or incomplete data in the sample data [25]; excluding the sample of state-owned enterprises among SMSEs [9]; using interpolation to supplement the few missing values and finally obtaining 4900 observations for 490 micro and small listed companies. The number of patents, the number of patent R&D personnel, and corporate financial data of listed companies from 2010 to 2021 used in this paper's model are all from the Guotaian database.<sup>3</sup> The three subdivision indicators of total digital financial inclusion, depth of use, breadth of coverage, and degree of digitization are all from the data results of the Digital Financial Inclusion Research Center of Peking University since 2010 [65], which are divided into provincial, municipal, and county-level indicators. Referring to previous scholars' treatment of digital financial inclusion indicators, this paper matches digital financial inclusion indicators by the province where the SMSEs are registered, and uses provincial digital financial inclusion indicators in the regression analysis [66]. The enterprise patent quality, financial mismatch index is manually calculated and collated, and the degree of financial mismatch of enterprises is defined by measuring the deviation between enterprise liabilities, interest expenses and the average interest rate level of the industry in which they are located [67]. The statistical analysis tool was EvIEWS 8.0 with Stata 16.0 statistical software.

#### 3.2. Variable selection and definition

The main object to be studied in this paper is the relationship between digital inclusive finance and technological innovation of SMSEs, so SMSEs' technological innovation is chosen as the explanatory variable, and the total digital inclusive finance index is the main explanatory variable; the enterprise financial mismatch index is secondary explanatory variable, and other factors that may affect enterprise technological innovation are used as control variables.

##### 3.2.1. Explained variables

The explanatory variable is the technological innovation capability (Innovation) of SMSEs. Although it can directly measure the innovation capability of enterprises to a certain extent, it cannot describe the overall characteristics of the technological innovation capability of enterprises comprehensively. In this paper, based on the number of patent applications, we draw on the previous scholars' treatment, add the number of R&D personnel, the capital investment in the R&D process, the ROE brought by innovation output, and innovatively add the index of enterprise patent quality to construct the enterprise technology innovation index, and calculate the enterprise comprehensive technology innovation index manually through the entropy weight method. Through the calculation of the entropy weighting method, the index weights of enterprise R&D personnel input, R&D cost, patent application quantity, enterprise patent quality, and ROE are 0.364, 0.065, 0.161, 0.406, and 0.004 respectively, and the sum of each weight and index product is taken

<sup>3</sup> Guotaian database website address: <https://www.gtarsc.com/>.

as the enterprise comprehensive innovation index.

### 3.2.2. Explanatory variables

The main explanatory variables are the overall digital inclusive finance metrics (Index) and the corporate financial mismatch index (FM) in China. Among them, to investigate the impact of digital inclusive finance on enterprise technology innovation in-depth, this paper uses three subdivision indicators of digital inclusive finance, namely, depth of digital inclusive finance usage (Depth), breadth of coverage (Breadth), and digitalization (Digital) in China, and discusses the impact of each of the three indicators on enterprise technology innovation as sub explanatory variables.

## 4. Control variables

Referring to the methods used by previous scholars to study the relationship between digital financial inclusion, financial mismatch, and corporate technology innovation, this paper selects inventory turnover, net profit, firm age, size, firm Tobin's Q, and firm management capability of SMSEs and innovatively adds the level of executive education of firms as control variables from the micro-level. The variables that may have an impact on firm innovation are controlled for in terms of both firm performance and executive education.

Each variable is defined as shown in Table 1.

### 4.1. Models and methods

In this paper, the three proposed hypotheses are tested by using two-stage least squares (2SLS) as well as a two-step systematic GMM model. With reference to the previous treatment of data regression by many scholars, the underlying regression estimation model as in Equation (1) is developed.

$$\ln y_{i,t} = \alpha_0 + \alpha_1 \ln y_{i,t-1} + \alpha_1 \ln x_1 + \alpha_2 \ln x_2 + \dots + \alpha_n \ln X + \lambda \quad (1)$$

To eliminate the effect of heteroskedasticity, all variables were treated logarithmically before calculation. Where  $i$  is the SMSEs and  $t$  is the year.  $y_{i,t}$  is the innovation capability of the SMSEs in year  $t$ ;  $t-1$  is to consider the technological innovation of enterprises as a dynamic process, and the patent quality in the current period may have an impact on the output in the later period, so with one period lag is chosen as the explanatory variable in the GMM model for robustness testing;  $\lambda$  denotes the error term;  $\alpha_0$  is the intercept;  $\alpha_n$  is the variable coefficient;  $x_1$   $x_2$  etc. are independent variables, and  $X$  is the control variable.

In this paper, on the basis of equation (1), and based on the assumptions presented in Chapter 2 of the article, we investigate the impact of total digital inclusive finance indicators on the innovation ability of SMSEs; the impact of digital inclusive finance on the financial mismatch phenomenon; the impact of financial mismatch on the innovation ability of SMSEs and the impact of the dual effect of digital inclusive finance and financial mismatch on the innovation ability of SMSEs, respectively. The specific steps correspond to Equation (2) to Equation (5), respectively:

$$\ln \text{Innovation} = \alpha_0 + \alpha_1 \ln \text{Index} + \alpha_2 \ln X + \lambda \quad (2)$$

Equation (2) investigates the impact of digital inclusive finance on the innovation capability of SMSEs. The explained variable

**Table 1**  
Variable definition.

Variable Name	Variable Symbols	Variable Description
Enterprise innovation composite index	Innovation	Calculated from the entropy method to derive the firm's overall innovation performance
China Digital Inclusive Finance Overall Metrics	Index	The degree of development of digital inclusive finance in China by province - total metrics
China Digital Inclusion	Depth	The degree of development of digital inclusive finance in China by province-use of depth indicators
Financial usage depth indicators	Breadth	China's Digital Inclusive Finance Development by Province - Breadth of Coverage Index
China Digital Inclusion	Digital	The degree of development of digital inclusive finance in China by province - digitalization
Financial Coverage Breadth Indicator	FM	Listed company's current year [interest expense/(liabilities a payable) - industry average interest rate]/industry average interest rate
China Digital Inclusion	Inventory	Cost of the main business of the listed company for the year/average inventory balance
Digitization of finance	Education	The ratio of the total number of directors, supervisors, and senior management of listed companies with bachelor's degrees or above
Financial Mismatch	Profit	Annual net profit of listed companies
Enterprise inventory turnover rate	Age	The span of time between the year of listing of the listed company and the current period plus 1
The educational level of the senior management team	Size	Total assets of listed companies are taken as the natural logarithm
Corporate net profit	Tobin's Q	Market value of the listed company's equity for the year + market value of net debt/total assets at the end of the period
Company Age	Management	Business Management Capability
Enterprise size		
Corporate Tobin's Q		



Innovation is the level of technological innovation of SMSEs; the explanatory variable Index is the total measure of digital inclusive finance in China, and in the subsequent study, the digital The explanatory variable Index is the total measure of digital inclusive finance in China, and in the subsequent study, the three sub-indicators of the depth of use, breadth of coverage and digitalization in digital inclusive finance are studied separately as explanatory variables; X denotes a series of control variables.

$$\ln FM = \alpha_0 + \alpha_1 \ln Index + \alpha_2 \ln X + \lambda \quad (3)$$

Equation (3) investigates the impact of digital inclusive finance on the financial mismatch phenomenon. The explanatory variable FM is the corporate financial mismatch index; the explanatory variable Index is the total measure of digital inclusive finance in China, and X denotes a series of control variables.

$$\ln Innovation = \alpha_0 + \alpha_1 \ln FM + \alpha_2 \ln X + \lambda \quad (4)$$

Equation (4) investigates the impact of financial mispairing on the innovation capacity of SMSEs. The explanatory variable is the innovation capacity of SMSEs, and the rest are as above.

$$\ln Innovation = \alpha_0 + \alpha_1 \ln Index + \alpha_2 \ln FM + \alpha_3 \ln X + \lambda \quad (5)$$

After analyzing the impact of digital inclusion finance on financial mismatch and the impact of financial mismatch on technological innovation of SMSEs, both indicators of digital inclusion finance and financial mismatch are put together as explanatory variables in equation (5) to investigate whether digital inclusion finance alleviates the inhibitory effect of financial mismatch on the innovation ability of enterprises under the joint action of both and based on this, the impact of digital inclusive finance on technological innovation of enterprises The impact of digital inclusion on enterprise technological innovation. Equation (5) uses the innovation capability of SMSEs as the explained variable, and the rest is as above.

## 5. Analysis of empirical results

### 5.1. Descriptive analysis

Table 2 shows the basic statistical table of the variables in the paper. Among them, the mean value of the corporate innovation index is 0.105; the mean value of digital financial inclusion is 256.637, while the comparison between the minimum and maximum values shows that the overall degree of digital financial inclusion varies significantly from region to region. The mean value of the financial mismatch index (FM) is 0.571, where the maximum value is 66.815 and the minimum value is 0.001, indicating that there may be a large variation in a financial mismatch between companies.

### 5.2. Correlation analysis

Before the regression test of the variables, the Pearson correlation test was first conducted to check whether there is correlation and cointegration between the explanatory variables and the explanatory variables. As shown in Tables 3A–3C, there is a correlation between the explanatory variables and the explained variables. Also their correlation coefficients do not exceed 0.8, so it can indicate that there is correlation but not cointegration between the variables. The model in this paper does not produce large errors in the regression results due to multiple cointegration in the subsequent processing, and can be studied in the next step.

### 5.3. Unit root test

The smoothness of the data series needs to be verified before conducting panel data analysis on the data related to this paper. This is because the direct use of non-stationary series may lead to pseudo-regression problems and affect the analysis of the results. Therefore, the Levin, Lin & Chu t unit root test needs to be performed on the variables before conducting the data analysis. From Table 4, it can be

**Table 2**  
Descriptive statistics.

Variable	Obs	Mean	Std.Dev.	Min	Max
Innovation	4900	0.105	0.134	0.001	0.666
Index	4900	256.637	103.542	16.220	431.928
Depth	4900	266.667	110.366	29.74	488.683
Breadth	4900	240.302	97.425	3.370	397.002
Digital	4900	292.361	127.861	7.580	462.228
FM	4900	0.571	4.970	0.001	66.815
Inventory	4900	713.447	8220.704	0.009	107130.900
Education	4900	0.534	0.278	0.000	1.000
Profit	4900	5.860e + 07	2.480e + 08	−3.42e + 09	1.70e + 09
Age	4900	20.061	7.351552	11	32
Size	4900	20.880	1.014	19.078	23.474
Tobin's Q	4900	3.590	3.155	0.694	22.717
Management	4900	0.225	0.346	0.005	5.208

**Table 3A**  
Correlation coefficient test.

	LnInnovation	LnIndex	LnDepth	LnBreadth	LnDigital
LnInnovation	1.000				
LnIndex	0.161***	1.000			
LnDepth	0.153***	0.975***	1.000		
LnBreadth	0.139***	0.973***	0.930***	1.000	
LnDigital	0.177***	0.856***	0.815***	0.755***	1.000
LnFM	−0.032***	−0.017*	−0.009*	−0.013*	−0.022**
LnInventory	0.011*	0.116**	0.113**	0.125**	0.093*
LnEducation	0.032**	0.098**	0.097**	0.107**	0.047
LnProfit	0.017*	0.007	0.009	0.013	0.009
LnAge	−0.036***	−0.018	0.002	−0.041	−0.032
LnSize	0.025*	0.190***	0.195***	0.173***	0.135***
LnTobin's Q	0.005**	0.158***	0.100**	0.151***	0.199***
LnManagement	0.028*	0.006	−0.021	0.003	0.069

Note: \*, \*\*, \*\*\* indicate significant correlation at the 10%, 5%, and 1% levels, respectively, and the same below.

**Table 3B**  
Correlation coefficient test.

	LnFM	LnInventory	LnEducation	LnProfit
LnFM	1.000			
LnInventory	−0.034***	1.000		
LnEducation	−0.013**	0.144***	1.000	
LnProfit	−0.011***	−0.060	0.083*	1.000
LnAge	−0.104	−0.034	0.103**	0.096**
LnSize	−0.013**	0.177***	−0.113**	0.695***
LnTobin's Q	−0.056***	0.153***	0.192***	0.460***
LnManagement	−0.028***	−0.034	0.131***	0.379***

**Table 3C**  
Correlation coefficient test.

	LnAge	LnSize	LnTobin's Q	LnManagement
LnAge	1.000			
LnSize	0.153***	1.000		
LnTobin's Q	0.076*	−0.624*	1.000	
LnManagement	−0.033	−0.426*	0.331***	1.000

**Table 4**  
Unit root test.

Variable	Test type (c,t,k)	Levin, Lin & Chu t value	P -value	Conclusion
LnInnovation	(c,t,1)	−8.067	0.000***	Smooth and stable
LnAllindex	(c,t,1)	−44.150	0.000***	Smooth and stable
LnDepth	(c,t,1)	−31.319	0.000***	Smooth and stable
LnBreadth	(c,t,1)	−1.612	0.044**	Smooth and stable
LnDigital	(c,t,1)	−23.187	0.000***	Smooth and stable
LnFM	(c,t,1)	−26.8353	0.000***	Smooth and stable
LnInventory	(c,t,1)	−4.030	0.000***	Smooth and stable
LnEducation	(c,t,1)	−6.430	0.000***	Smooth and stable
LnProfit	(c,t,1)	−26.0715	0.000***	Smooth and stable
LnAge	(c,t,1)	−8.185	0.000***	Smooth and stable
LnSize	(c,t,1)	−8.400	0.000***	Smooth and stable
LnTobin's Q	(c,t,1)	−12.566	0.000***	Smooth and stable
LnManage	(c,t,1)	−8.110	0.000***	Smooth and stable

Note: 1. Ln denotes taking logarithms of the variables; 2. c,t,k denote the intercept term, trend term and lag order, respectively, and the lag selection criteria refer to the AIC and SC guidelines; 3. \*, \*\*, \*\*\* denote significant correlation at the 10%, 5%, 1% level; 4. Levin, Lin & Chu t-values are used to judge the smoothness of the panel data; 5. P-values are used to judge the results in relation to the original hypothesis, whether there is a unit root.



seen that the variables passed the unit root test at the 1% level of significance after taking logarithms and there is no unit root.

#### 5.4. Fixed effects test

The choice of data treatment also needs to be made before regression operations can be performed. Since the premise of this paper is to assume that the direction and effect sizes of the findings are essentially the same, i.e., that the results of the independent studies converge, only the interactions of the variables within the specific scope of this article are studied. In this paper, the results of Table 5 were obtained after the Hausman test of fixed versus random effects on the model, i.e., the original hypothesis was rejected at the 5% level of significance and the fixed effect was chosen to be used for the subsequent study.

#### 5.5. Results of the empirical analysis

##### 5.5.1. Baseline regression results

**5.5.1.1. Digital inclusive finance total indicator test.** According to the previously proposed hypothesis H1, does the total digital inclusion indicator promote the technology innovation capability of SMSEs?

As shown in Table 6, the impact of total digital inclusive finance indicators on the technology innovation capability of SMSEs in China without considering control variables are tested in Model 1. Model 2 tests whether the impact of total digital inclusive finance indicators on the technology innovation capability of SMSEs changes after considering the impact of control variables. Model 1 in Table 6 is estimated by the 2SLS method. When only the impact of digital inclusive finance on the innovation capability of enterprises is considered, the total digital inclusive finance indicator is significantly correlated at the 1% level at this point. The estimated coefficient is 0.432. As shown in Model 2, all the control variables pass the confidence test, except for the educational level of the executive team, which does not pass the confidence test, indicating that the educational level of the executive team does not have a significant impact on the innovation capability of the enterprise. When the influence of the control variables on the innovation capability of enterprises is also considered, the total digital financial inclusion index still has a positive influence on the innovation capability, and this positive influence becomes more obvious with the addition of the control variables related to enterprises (the coefficient is 0.492 at this time).

The result of Table 6 illustrates that there is a significant positive influence between the total index of digital inclusive finance and the innovation ability of SMSEs, and the continuous promotion of digital inclusive finance, it will enhance the innovation ability of SMSEs, which shows that digital inclusive finance will promote the level of technological innovation of enterprises. The biggest difference between digital inclusive finance and traditional finance is that digital inclusive finance emphasizes the “universality” of the financial industry, i.e., financial capital can flow more effectively to where it is needed, so that society can enjoy the effective allocation of financial resources and all subjects can enjoy financial services equally and conveniently at an acceptable cost. The results of Table 6 also show that with the support of digital inclusive finance, SMSEs are able to obtain sufficient funds in a timely manner through electronic application, online credit platform review, and online operation of the financial platform, which provides significant incentives for technological innovation of SMSEs. With the financial support, SMSEs can, on the one hand, directly obtain the funds needed for innovation and carry out innovative R&D and patent application and quality improvement through the funds obtained from financing and borrowing; on the other hand, they can use the funds obtained from financing to carry out production and maintain the normal operation of the enterprise so as to enhance the profitability of the company, and after the revitalization of funds, they can increase the investment in the innovation sector of the enterprise and increase the innovation capability of the enterprise. According to

**Table 5**  
Fixed effects tests.

Variable	(b) fe	(B) re	(b-B) Difference
LnAllindex	0.314	0.363	−0.049
LnFM	0.003	0.001	0.002
LnInventory	0.098	0.065	0.033
LnEducation	−0.110	−0.196	0.086
LnProfit	0.084	0.032	0.052
LnAge	0.074	0.057	0.017
LnSize	12.356	8.020	4.336
LnTobin's Q	0.096	0.141	−0.045
LnManagement	0.141	0.098	0.043
chi2 (6) = 14.79			
P > chi2 = 0.039**			

Note: 1. t-values inside the parentheses and coefficients with an asterisk; 2. \*, \*\*, \*\*\* indicate significant correlation at the 10%, 5%, and 1% levels, respectively; 3.  $R^2$  is the goodness of fit; 4. F-values are chi-square tests to determine significant differences in sample variances; 5. yes indicates effective control of control variables when conducting fixed effects; 6. Fe(b) is the calculated value for fixed effects rejecting or acceptance of the original hypothesis and re(b) is the calculated value of the random effect rejection or acceptance of the original hypothesis; 7.  $chi2(6)$  is calculated as  $chi2(6) = (b - B)'[(V_b - V_B)^{-1}](b - B)$ .

**Table 6**  
Total digital inclusive finance indicator test.

Variable	LnInnovation (Model 1)	LnInnovation (Model 2)
LnIndex	0.432*** (3.610)	0.492*** (2.930)
LnInventory		0.012*** (2.870)
LnEducation		−0.033 (−0.340)
LnProfit		0.011*** (3.950)
LnAge		−0.287*** (−4.670)
LnSize		0.172*** (2.850)
LnTobin's Q		0.241** (2.080)
LnManagement		0.196*** (3.110)
_cons	−5.450*** (−8.320)	−4.757** (−2.800)
R <sup>2</sup>	0.737	0.781

the above study, the previously proposed hypothesis [H1](#) is verified.

**5.5.1.2. Digital inclusive finance segmentation dimensional test.** The previous study concluded that the total indicators of digital inclusive finance contributed to the technology innovation capability of SMSEs, i.e., as the overall development of digital inclusive finance, the higher the technology innovation capability of SMSEs. In the above Pearson correlation coefficient test, it can be seen that all three segmentation indicators of digital inclusive finance have a positive impact on enterprise innovation. The 2SLS test is also conducted first for these three segmentation indicators in the benchmark regression, and the results are shown in [Table 7](#), where the depth of use, breadth of coverage, and digitization of digital finance all positively contribute to the STI capability of SMSEs.

Based on previous studies conducted by scholars, this paper subdivides the digital finance index into the depth of use (frequency of using the Internet for various financial services) and breadth of coverage (coverage of electronic financial accounts) [\[8\]](#). The new index of digitization (Internet infrastructure usage such as access devices, communication facilities, etc.) is added to the previous study to measure the impact of each of the three subdivided indexes on technological innovation of SMSEs. The results in Model 1 of [Table 7](#) show that, under the assumption of constant control variables, the depth of digital inclusive financial usage passes the significance test at the 1% level, and the depth of digital inclusive financial usage has a positive contribution to SMSEs (coefficient of 0.443); the results in Model 2 show that the breadth of digital inclusive financial coverage passes the significance test at the 5% level, and the breadth of digital inclusive financial coverage has a positive contribution to SMSEs. The results of Model 2 indicate that the breadth of digital inclusive financial coverage passes the significance test at the 5% level, and the breadth of digital inclusive financial coverage has a positive contribution to SMSEs (coefficient of 0.367); the results of Model 3 indicate that the degree of digital inclusive financial digitization passes the significance test at the 1% level, and the degree of digital inclusive financial digitization has a positive contribution to SMSEs (coefficient of 0.599).

Comparing the regression coefficients of the three models, we can see that the degree of digitalization has the most significant impact on SMSEs, followed by the depth of use and breadth of coverage, indicating that for SMSEs, strengthening digitalization is more likely to promote technological innovation of SMSEs. If enterprises want to improve the positive impact brought by digital inclusive finance, they first need their own Internet access capability and network infrastructure platform to break the barriers between their own networks and digital inclusive finance platforms. Comparing the two indicators of digital inclusive finance usage depth and coverage breadth, the impact of usage depth on SMSEs is greater, indicating that with the rapid development of digital inclusive finance, it is more obvious to enhance the service depth of digital inclusive finance, improve service quality, and deeply optimize the way and structure of SMSEs' use of digital inclusive finance than to simply increase the degree of digital inclusive finance coverage on the technological innovation of SMSEs.

**Table 7**  
Digital inclusive finance segmentation dimensional test.

Variable	LnInnovation (Model 1)	LnInnovation (Model 2)	LnInnovation (Model 3)
LnDepth	0.443*** (2.720)		
LnBreadth		0.367** (2.390)	
LnDigital			0.599*** (3.850)
LnInventory	0.015*** (2.710)	0.016*** (2.780)	0.022*** (2.971)
LnEducation	−0.034 (−0.340)	−0.030 (−0.300)	−0.015 (−0.160)
LnProfit	0.011*** (3.910)	0.015*** (3.980)	0.019*** (4.070)
LnAge	−2.310*** (−14.840)	−2.284*** (−4.560)	−2.277*** (−14.710)
LnSize	5.482*** (3.310)	0.473*** (3.010)	4.192** (2.270)
LnTobin's Q	0.290** (2.570)	0.254** (2.180)	0.165** (2.032)
LnManage	0.204*** (3.220)	0.197*** (3.110)	0.182*** (2.900)
_cons	−16.501*** (−3.160)	−15.976*** (−2.820)	−12.423** (−2.340)
R <sup>2</sup>	0.781	0.731	0.868

Note: 1. z-values inside the parentheses and coefficients with asterisks; 2. \*, \*\*, \*\*\* indicate significant correlation at the 10%, 5%, and 1% levels, respectively; 3. \_cons is the intercept; 4. R2 is the goodness-of-fit, same below.

**5.5.1.3. A test of the impact of digital inclusion on financial mismatch.** The financial mismatch is derived from the theory of resource allocation efficiency, which means that capital, as a scarce “resource”, does not achieve Pareto optimality in the allocation process [12]. In the long-term development of the financial market, the financial mismatch is still a major problem for China’s economic development. Financial mismatch makes enterprises lack financial support for their research activities, which seriously affects their R&D in science and technology [13]. As shown in Table 8, in Model 1, the impact of China’s total digital inclusive finance indicators on enterprises’ financial mismatch indicators are tested without considering control variables; Model 2 tests whether the impact of total digital inclusive finance indicators on enterprises’ financial mismatch phenomenon changes after considering the impact of control variables. When only the effect of digital inclusive finance on financial mismatch is considered, the total digital inclusive finance indicator is significantly correlated at the 1% level at this point. The estimated coefficient is  $-0.295$ . As shown in Model 2, all of the control variables pass the confidence test at this point, except for the age of the firm, which does not pass the confidence test, indicating the insignificant effect of the time of existence of the firm on financial mismatch. When the effect of control variables on financial mismatch is also considered, the total digital financial inclusion indicator still has a negative effect on financial mismatch, but this negative effect is weakened with the inclusion of firm-related control variables (the coefficient is  $-0.269$  at this point).

The higher the degree of financial mismatch, the more vulnerable firms are to financial resource constraints, increased financing costs, and information asymmetry. The result of Table 8 illustrates a significant negative effect between the total digital financial inclusion index and financial mismatch. With the continuous promotion of digital inclusive finance, it weakens the negative influence of financial mismatch on enterprises (the coefficient of the total digital inclusive finance index is negative), indicating that digital inclusive finance can promote the rational allocation of financial resources and reduce the financial mismatch problems that SMSEs may encounter in the financing process.

At present, the pace of reform in China’s traditional financial industry lags far behind the changes in the market, and the ownership and scale discrimination in the financial market, as well as various capital mismatches and information asymmetries appear through the depth of development of the regional financial industry and the regional economic development with obvious geographical differences [10,11]. The emergence and development of digital inclusive finance have shortened the distance between enterprises and financial lending institutions through digital service platforms, big data, and AI intelligent services. On the one hand, through enterprise integrity data, enterprise information is uploaded to the cloud and connected to the digital financial platform, financial lending institutions can grasp enterprise information in a timely manner, alleviating the information asymmetry between lenders and borrowers [26]. On the other hand, the development of digital inclusive finance can benefit a wider area and reach a deeper depth. For some regions in northwest and southwest China where the financial industry is not well developed, digital inclusive finance can also obtain timely investment and financing services through Internet services. the “last mile” [22] that alleviates the financial mismatch problem of SMSEs. Through the above study, the hypothesis H3.1 proposed above has also been verified.

#### 5.5.1.4. The impact of digital inclusive finance, financial mismatching on small and medium-sized enterprises technology innovation.

Through the aforementioned study, digital inclusive finance makes up for the deficiencies of traditional financial institutions in terms of both breadth of coverage and depth of use through the use of digital platforms. On the one hand, according to Table 9, the digital service optimizes the experience of SMSEs in financial lending and enables them to obtain sufficient funds for technological innovation; on the other hand, the study in Table 9 also shows that digital inclusive finance alleviates the information asymmetry that may be encountered by both borrowers and lenders through timely and convenient services, reduces the financing cost of enterprises, and weakens the financing constraints of financial mismatch enterprises. The subsequent study examines whether the variable of digital inclusive finance can enhance the technological innovation capability of SMSEs while alleviating the financial mismatch problem of SMSEs by using the method of mediating effects.

As shown in Table 9, Model 1 verifies the impact of the financial mismatch issue on the technological innovation capability of SMSEs when the variable of total digital inclusive finance indicator in China is not considered; Model 2 verifies the impact of digital inclusive finance on financial mismatch and how to adjust the degree of financial mismatch on the technological innovation of enterprises under the influence of digital inclusive finance when the variable of total digital inclusive finance indicator is added. When only the impact of financial mismatch on the innovation ability of SMSEs is considered, at this point financial mismatch is significantly correlated at the 1% level. The estimated coefficient is  $-0.307$ . As shown in Model 2, all the control variables passed the confidence test except for the educational level of the executive team, which did not pass the confidence test. At this point, because of the influence

**Table 8**  
Test of the impact of digital inclusive finance on financial.

Variable	LnFM (Model 1)	LnFM (Model 2)
LnIndex	$-0.295^{***}$ ( $-3.610$ )	$-0.269^{***}$ ( $-2.857$ )
LnInventory		$-0.007^*$ ( $-1.370$ )
LnEducation		$-0.008^*$ ( $-1.382$ )
LnProfit		$-0.019^{**}$ ( $-2.121$ )
LnAge		$-0.001$ ( $-0.42$ )
LnSize		$-0.027^*$ ( $-2.153$ )
LnTobin’s Q		$-0.014^{***}$ ( $-2.113$ )
LnManagement		$-0.044^{**}$ ( $-2.343$ )
_cons	$-4.450^{***}$ ( $-5.448$ )	$-3.864^{***}$ ( $-2.769$ )
R <sup>2</sup>	0.897	0.723

**Table 9**

Impact of digital inclusive finance, financial mismatching on micro and small business technology innovation.

Variable	LnInnovation (Model 1)	LnInnovation (Model 2)
LnIndex		0.352** (2.758)
LnFM	−0.307*** (−2.712)	−0.264*** (−2.920)
LnInventory	0.049** (2.434)	0.012*** (2.870)
LnEducation	0.006** (1.624)	−0.033 (−0.340)
LnProfit	0.065** (3.700)	0.011*** (3.950)
LnAge	0.014** (2.280)	−0.287*** (−4.670)
LnSize	−0.020* (−1.830)	0.172*** (2.850)
LnTobin's Q	0.142*** (4.480)	0.241** (2.080)
LnManagement	0.082** (3.420)	0.196*** (3.110)
_cons	−5.450*** (−3.320)	−4.757** (−2.800)
R <sup>2</sup>	0.771	0.831

Two conclusions can be drawn by analyzing the regression results in Table 9.

of digital inclusion, there is a negative impact of financial mispairing on the innovation ability of SMSEs, but this negative impact is weakened with the inclusion of digital inclusion (the coefficient is −0.264 at this point). There is also a significant positive effect of digital inclusion on firms' innovation capacity (coefficient of 0.352).

First, there is a negative influence between financial mismatch and enterprise innovation ability, and as the degree of financial mismatch continues to deepen, it will lead to a decline in enterprise patent innovation ability. Financial mismatch will inhibit the ability of enterprise patent R&D and hinder the progress of enterprise innovation. The financial mismatch phenomenon in the market makes enterprises unable to judge investment information through effective information, and the financial market is unable to allocate funds effectively to enterprises that really need them in order to enhance the ability of enterprise patent research and development and promote enterprise innovation. The financial mismatch makes the enterprises' capital cost increase, and the increase of capital cost makes the enterprises need to squeeze the capital to invest in patent R&D and improve patent quality; at the same time, due to the profit-seeking nature of capital, the difficulty of financing makes the enterprise capitalists more willing to use capital for arbitrage, and invest more resources in the sectors that can obtain capital quickly [15]. At the same time, the difficulty of financing leads to the capitalists' willingness to use capital to arbitrage and invest more resources in the sectors where they can obtain funds quickly, which has a "crowding-out effect" on patent R&D and reduces the innovation ability of SMSEs, which confirms the previous hypothesis H2.

Second, digital inclusive finance can indeed enhance the technological innovation capability of SMSEs, and at the same time has a suppressive effect on the financial mismatch problem faced by SMSEs (the coefficient of financial mismatch changes from −0.307 to −0.264), weakening the negative impact of financial mismatch.

The channels of funds required for enterprise innovation can usually be divided into two categories, one for enterprises to invest a certain percentage of profit funds to the enterprise's science and technology innovation department every year according to their own profitability (the positive profit coefficient of the control variable in the test results also proves this statement), the other category is the enterprises through external financing channels, by releasing information about their own technological innovation capital needs to the market, introducing their innovative projects to gain the attention of investors, and absorbing financial investment or loans from outside. However, due to the large number and scattered layout of many small and micro enterprises, traditional financial institutions mostly use business outlets for investment and financing services, which require face-to-face processing services with enterprises, so there is a distance and cost gap between the two, and it is difficult for the services of traditional financial institutions to truly benefit SMSEs [22]. The services of traditional financial institutions can hardly benefit SMSEs. Digital inclusive finance, through its "universal" and "beneficial" aspects, can provide financing loans for SMSEs that break the time and space restrictions, and benefit SMSEs through big data, cloud platforms, and other technologies to enhance the ability of SMSEs to obtain financial services. The development of digital inclusive finance has further broadened the financing and lending channels for SMSEs and alleviated the financial

**Table 10**

GMM robustness tests.

Variable	LnInnovation (Model 1)	LnInnovation (Model 2)
L. LnInnovation	0.296*** (3.440)	0.285*** (2.494)
LnIndex		0.381** (2.758)
LnFM	−0.274** (−2.204)	−0.218*** (−2.330)
Control variables	Yes	yes
Obs	4900	4900
AR1	0.000	0.000
AR2	0.410	0.302
Hansen	0.171	0.213

Note: 1. t-values are inside the parentheses, and those with asterisks are coefficients; 2. \*\*, \*\*\* indicate significant correlation at the 5% and 1% levels, respectively; 3. AR(1), AR(2) determine whether there is first-order and second-order autocorrelation after the original hypothesis is differenced; 4. Hansen test whether the over-identification constraint is valid; 5. Obs are sample observations, and this data is 4900 observations; 6. GMM test is operated on Stata16, and the command used is system xtabond2.

pressure of SMSEs that cannot obtain funds in time for technological innovation due to financial mismatch. The above study verifies the hypothesis H3.2 proposed above.

#### 5.5.2. Two-step system GMM robustness test

**5.5.2.1. Analysis of test results.** After examining the impact of digital inclusive finance on financial mismatch and firms' ability to innovate in technology, this paper corrects for unobserved individual heterogeneity by performing a two-step systematic GMM regression method on the grouping of variables. The inclusion of the variable of total digital inclusive finance indicator is tested for measurement error and potential endogeneity. The results are shown in [Table 10](#): both Model 1 and Model 2 passed the second-order AR test and Hansen test, indicating that both model settings are valid. From the test results of model 1, the innovation ability of the early stage enterprises will have a significant positive contribution to the patent quality in the later stage at the 1% level, and the financial mismatch has a significant negative impact on the innovation ability of enterprises at the 5% level (the coefficient is  $-0.274$ ), i.e., it also confirms the previously proposed hypothesis H2 and the regression estimation results that the financial mismatch does have a negative impact on the innovation ability of enterprises; from the results of Model 2, after the inclusion of digital inclusive finance, the positive impact of the lagged period of corporate innovation capability on the current period of corporate science and innovation capability is weakened, but still shows a positive trend of promotion, and financial mismatch has a significant negative impact on corporate STI capability at the 1% level (coefficient of  $-0.218$ ), while digital inclusive finance has a significant positive impact on corporate patent quality at the 5% level (coefficient of  $-0.218$ ). This also confirms hypothesis H3 and the mediating effect in which the addition of digital inclusive finance moderates the impact of financial mismatch on enterprise innovation ability: with the addition of digital inclusive finance, the financing, and lending environment of SMSEs is optimized and the negative impact of financial mismatch on SMSEs' technology innovation is suppressed.

**5.5.2.2. Robustness tests.** The robustness and endogeneity tests of Model 1 and Model 2 are conducted through the above two-step systematic GMM, and the 2sls regression estimates of the mechanism of the effect of the final digital inclusion financial regulation on financial mispairing SMSEs in the paper are validated from the variable of digital inclusion finance. As shown in [Table 10](#), the positive, negative, and significant coefficient estimates of the main independent variables of each model did not change and, consistent with the 2sls model, all exhibited the inhibitory effect of financial mispairing on the innovation of SMSEs; the positive effect of digital inclusive finance on the innovation ability of SMSEs as well as inhibiting the negative effect of financial mispairing on SMSEs. The models do not show serious errors with potential endogeneity. This can indicate the reliability of measuring the impact of digital inclusive finance on financial mismatch and enterprise innovation ability through mediating effect, and also further test hypotheses H3.1 and H3.2.

## 6. Conclusion and recommendation

### 6.1. Conclusion

The development of digital inclusive finance has benefited many aspects of society today, and current scholarly research on digital inclusive finance has focused on the impact on households, entrepreneurship, and society at large. These studies have focused on the "inclusiveness" of digital inclusive finance development, but they have also ignored the legacy of digital inclusive finance on traditional financial development, namely the impact of financial mismatch and the impact of digital inclusive finance on the innovative development of SMSEs. Based on existing research, this paper further explores how digital inclusive finance affects financial mismatch and, in turn, the innovation capability of SMSEs. Taking the development of digital inclusive finance in China as an example, we comparatively analyze the impact of digital inclusive finance on the technological innovation capability of SMSEs from both theoretical and empirical aspects, after which we study the problem of financial mismatch encountered by SMSEs in the financing process, and finally investigate the mechanism of the moderating effect of digital inclusive finance on the relationship between financial mismatch and the technological innovation capability of SMSEs. The results of the empirical study show that the overall indicators of digital inclusive finance have a significant contribution to the technological innovation of SMSEs. From the perspective of digital inclusive finance, the three sub-dimensions of digital inclusive finance (breadth of coverage, depth of use, and degree of digitalization) all positively contribute to the technological innovation capability of SMSEs, and the degree of digitalization has the most significant positive effect. The development of digital inclusive finance has changed the traditional financial model and promoted the technological innovation capability of SMSEs, while mitigating the negative impact of financial mismatch on the technological innovation of SMSEs.

### 6.2. Recommendation

#### 6.2.1. Academic recommendation

The empirical results of the article illustrate that: (1) digital inclusive finance can indeed enhance the innovation ability of SMSEs, and after innovatively studying three subdivision indicators of digital inclusive finance, it is found that the degree of digitalization can significantly improve the development level of regional digital inclusive finance and provide a solid guarantee for digital inclusive financial services to SMSEs' innovation. (2) After adding the study of financial mismatch, it can be clearer that the development of

digital inclusive finance alleviates the difficulty that financial capital as a resource cannot be effectively allocated under the traditional financial model, and enhances the financing ability of enterprises by alleviating the financial mismatch problem of SMSEs.

### 6.2.2. Practical recommendation

The new model of “digital platform + financial services” plays a positive role in promoting the reform of the traditional financial industry and improving the innovation capacity of SMSEs. The “digital platform” shows that digital inclusive finance collects data and information through the big data cloud service platform built by new technology finance companies, and builds a new development model for financial institutions, enterprises and consumers. The “financial services” are different from the traditional financial services model, as digital inclusive finance breaks the time and space limitations of traditional financial services and provides consumers with more “inclusive” financial services by reducing costs and alleviating the information asymmetry between the two sides of financial services.

In view of the “long tail effect” that may be encountered in the development of the financial services industry in the post-pandemic era in countries and regions around the world and the pace of innovation and development of SMSEs due to financing problems, we promote digital inclusive finance to benefit SMSEs’ financing and loans more effectively and conveniently, so as to enhance the technological innovation capability of SMSEs. This paper puts forward the following policy recommendations.

First, promote the steady development of digital inclusive finance and accelerate the innovation of digital inclusive finance products. In view of the existing financing difficulties and expensive problems of small and micro enterprises, digital inclusive finance can provide more accurate and convenient financial services for enterprises with the help of new financing channels such as network lending platforms and improved digital supply chain finance. In the future, developing countries should continue to learn from the experience of developed countries in developing digital inclusive finance, enhance the coverage and depth of digital inclusive finance, strengthen the construction of national and regional Internet infrastructure, improve the construction of online financial platforms, facilitate the connection between enterprises and platforms, and better play the role of digital inclusive finance in supporting the technological innovation of SMSEs.

Second, change the traditional financial regulatory model and improve the regulatory system of digital inclusive finance. There are still imperfections in the institutional mechanism of digital inclusive finance in the development process, such as the imperfect credit system for SMSEs, the opacity of the credit process, and the stability of the operating system, etc. Therefore, it is necessary for financial regulators in each country to continue to deepen the reform of traditional financial institutions and promote the digital utilization rate of traditional financial institutions on the one hand; on the other hand, they need to consider the development characteristics of digital inclusive finance to formulate Targeted regulatory programs.

Third, accelerate the construction of digital information platforms for small and micro enterprises, and encourage small and micro enterprises to use digital inclusive finance platforms to enhance their own technological innovation capabilities. Small and micro enterprises need to continuously improve their digitalization level, integrate their financial and credit information in a timely manner, improve the information disclosure system, and establish their own information aggregation cloud platform so that they can shorten the information review time by providing the required information to the suppliers of digital inclusive finance in a timely manner.

### 6.3. Research prospects

It is important to note that the most direct evidence to study the impact of digital inclusive finance on the innovation capability of SMSEs should examine the use of digital inclusive finance options at the SMSEs level from a practical perspective. Constrained by the data collation situation, this paper indirectly confirms the proposed view through a series of empirical tests. At the same time, since the data related to digital inclusive finance in China are only collated after 2010, it is not possible to conduct a longer time span study. In the study, there may be some shortcomings in the selection of control variables and the construction of indicators of firms’ innovation capability in this paper. It is expected that more detailed survey data can be obtained through enterprise field surveys and data cooperation in future studies, and the instrumental variables and robustness tests can be extended to provide more powerful evidence for expanding how digital inclusive finance affects the innovation capability of SMSEs.

### Ethical approval and consent to participate

The full text of this paper has not been submitted or published elsewhere and will not be submitted to another editorial board until the journal editorial process is complete. No human or animal studies were involved in the use of data in the paper. There is no conflict of interest between the authors of the paper. All authors were informed and agreed to before the article was submitted.

### Consent to publish

The authors agree to publish the article.

### Author contribution statement

Wenqi Li: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.  
Wenbin Pang: Contributed reagents, materials, analysis tools or data; Wrote the paper.



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## Data availability statement

The authors do not have permission to share data.

## Declaration of interest's statement

The authors declare no conflict of interest.

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