Article



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*Article*

# The Impact of Digital Inclusive Finance on SME Innovation

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**Abstract:** This study analyzes data from companies listed on the Small and Medium Enterprise Board and the Growth Enterprise Market between 2011 and 2021 to assess the impact of digital inclusive finance on SME innovation. It also explores how this effect varies across different industries. The findings highlight the crucial role of digital inclusive finance in boosting SME innovation capacity. Additionally, the heterogeneity analysis underscores its significant impact on driving innovation within the secondary sector. Mechanism testing reveals that digital inclusive finance enhances the innovation ecosystem by reducing financing barriers and improving access to capital. The study recommends accelerating the development of a digital inclusive financial system and optimizing the allocation of financial resources. Furthermore, it emphasizes the need to support digital transformation, foster talent development, and implement targeted industrial policies to unlock the full innovation potential of SMEs, thereby promoting high-quality development.

**Keywords:** digital inclusive finance; innovation in SMEs; financial constraints; high-quality development

## 1. Introduction

The Third Plenary Session of the 20th Central Committee of the Communist Party of China introduced policies to enhance the synergy between digital and real economies, providing substantial assistance in advancing digital financial inclusion in China. This initiative emphasizes the necessity of institutional frameworks to promote sustainable economic expansion, drive extensive innovation, and improve macroeconomic regulation. The goal is to create a more equitable and efficient financial environment that supports the innovation of SMEs.

Advanced digital finance incorporates big data, AI, and blockchain to enhance access to financial services. These innovations deliver affordable and efficient financial solutions, aiding both SMEs and individuals. The recent progress in digital finance has enhanced financial inclusivity and accuracy, bolstering the infrastructure essential for SME innovation (OYEGBADE et al., 2023) [1].

The growth in digital inclusive finance practices has significantly lowered financial costs and expanded the scope of SMEs' funding. As a result, it has emerged as a key player in China's finance industry, overcoming inherent financial challenges and enhancing the distribution of resources. However, SMEs face critical hurdles, particularly in traditional banking finance methods, plagued by issues such as credit partiality, uncertain risks, and negative selection, all of which restrict their capacity for economic and societal benefits (Tang et al., 2020) [2].

The research delves deeply into China's digital inclusive finance terrain, exploring strategies for its progression. It underscores its effectiveness in reducing financial hurdles and fostering tech innovation in SMEs (Wahlstrøm and Becker, 2023) [3]. It offers an exhaustive exploration of theoretical frameworks, practical consequences, and tactical optimization strategies, granting vital

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understanding in surmounting financial hindrances, operational dangers, and digital evolution hurdles, with a focus on advancing sustainable SME expansion.

## 2. Review of Literature

While considerable research has explored digital inclusive finance in the context of enterprise technology and corporate governance, systematic studies on the innovation mechanisms of SMEs remain limited. Existing literature mainly focuses on the role of digital inclusive finance in promoting SME innovation and growth, but a deeper exploration of its underlying mechanisms and empirical validation is still needed. Most domestic scholars primarily investigate how digital technology drives the development of inclusive finance. For instance, Zou et al. (2020) [4] asserted that digital inclusive finance embodies the convergence and advancement of internet technology with financial systems, fostering economic progress and financial inclusion. Furthermore, Li et al. (2022) [5] stressed that China's digital finance expansion must adapt to evolving economic models to ensure sustainable growth. Likewise, Buchak et al. (2018) [6] noted that merging digital finance with cutting-edge financial technologies improves market reach, lowers financing expenses, and expands SMEs' funding opportunities. These advancements optimize resource allocation efficiency, ultimately strengthening SMEs' innovation capacity.

Currently, there are primarily two methods for measuring the innovation of SMEs. The first method assesses an enterprise's early-stage innovation investment in R&D. Common indicators include total R&D investment and its proportion relative to annual revenue (Booltink, 2018) [7]. The second approach examines firms' innovation output during advanced R&D stages. Commonly used indicators for this assessment include the proportion of annual revenue generated by new products, the number of patent applications or grants, and similar metrics (Teirlinck et al., 2022) [8].

In China, the disclosure of R&D expenditure is relatively brief and lacks sufficient standardization. Patent count is widely recognized as a key measure of a firm's innovation achievements. Moreover, the patent application and approval process are transparent, and data collection is relatively straightforward. Thus, many researchers in China and worldwide consider invention patents as the primary metric for evaluating SME innovation. Patent quantity currently serves as a crucial benchmark for evaluating corporate innovation capacity (Ponta et al., 2021; Ma and Yu, 2021; Lu et al., 2022) [9–11].

At the level of factors influencing SME innovation, government policy support and the optimization of the institutional environment play a critical role in fostering enterprise innovation. According to signaling theory, government subsidies can significantly boost firms' investment in innovation and their output of patents. This incentive mechanism is particularly pronounced in high-tech companies, those with robust internal control systems, and those operating in a favorable legal environment.(Sun, 2021) [12]. This study primarily focuses on the incentive mechanisms of high-tech enterprises and proposes strategies to improve these mechanisms. Furthermore, as economic policy uncertainty grows, the risk of bankruptcy increases, leading to a decrease in firms' investments in research and development (R&D) (Liu et al., 2022) [13]. Simultaneously, effective intellectual property protection laws, bankruptcy laws, and other legal frameworks can safeguard investors' rights and encourage their investment, thereby helping firms secure financial support for R&D activities. Thus, a sound legal and regulatory system is vital for promoting enterprise innovation (Zhao et al., 2022) [14]. Additionally, a competitive environment and a strong financial system foster a high-quality external financing climate for businesses. Financial institutions play a key role in providing enterprises with credit solutions essential for R&D and innovation, thereby supporting the sustained growth of the real economy (Yao and Yang, 2022) [15]. Furthermore, relaxing market access restrictions by banks in other regions can expand credit availability, reduce reliance on loan guarantees, and create more financing opportunities for firms, ultimately enhancing their innovation capabilities (Franquesa and Vera, 2021) [16]. Innovative financial models, such as fintech and digital inclusive finance, have alleviated financing pressures on enterprises by introducing advanced financing mechanisms and optimizing capital allocation, thereby enhancing investment efficiency

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and returns (Guet al., 2023) [17]. These models are instrumental in enhancing financial processes and driving corporate innovation.

From a mechanistic perspective, digital inclusive finance promotes SME innovation by mitigating financial inefficiencies that obstruct resource distribution. Li et al. (2022) [18] highlighted that financial constraints often impede SMEs' access to funding, affecting their innovation capacity. Digital inclusive finance effectively mitigates these inefficiencies, fostering sustainable corporate growth. Grounded in endogenous finance theory, Zhang et al. (2023) [19] examined how inclusive finance alleviates SME financing constraints. Zheng et al. (2023) [20] developed a theoretical framework of "fintech-financing constraints", analyzing its empirical impact across multiple dimensions, including dynamic effects, heterogeneity, and macro-micro mechanisms, in fostering corporate innovation. Additionally, based on endogenous growth theory, Li et al. (2024) [21] examined how digital inclusive finance impacts total factor productivity, highlighting critical structural factors that drive innovation. Employing data from firms registered on the New Third Board, Zhang et al. (2023) [22] determined that digital inclusive finance fosters SME innovation through reduced financing expenses. Li et al. (2021) [23] confirmed its contribution to strengthening corporate financial autonomy and resolving funding imbalances.

At the determinant level, Agwu (2021) [24] extensively assessed digital inclusive finance development, formulating an index with three key dimensions: coverage breadth, usage level, and digital support services. Their research analyzed how digital payment solutions fill voids in conventional financial systems across underdeveloped areas, offering significant advantages to SMEs, and highlighted the mechanisms through which digital inclusive finance fosters enterprise innovation. Yu et al. (2020) [25] outlined a framework illustrating how digital inclusive finance stimulates SME innovation through three main pathways: government policies, financial structures, and technological advancements. Lee et al. (2023) [26] conducted a detailed analysis of the mediating role played by financial structure optimization and corporate information transparency in linking digital inclusive finance development to enterprise value creation. Their results underscored the diverse influences of digital inclusive finance on SME innovation. Further, Ma et al. (2023) [27] investigated the interplay between digital inclusive finance, funding limitations, urban prosperity, and corporate green innovation. Employing an instrumental variable regression approach, their study affirmed digital inclusive finance as a key driver of green tech innovation in enterprises, highlighting urban wealth and funding restrictions as pivotal mediators.

In summary, prior studies have significantly deepened insights into digital inclusive finance and its influence on entrepreneurship, financial needs, and economic growth. This research offers key contributions. First, it introduces an effect model to examine how digital inclusive finance drives SME innovation, conducting a thorough theoretical analysis to establish a solid foundation for comprehending its impact on innovation. Second, focusing on SME innovation, this study develops a comprehensive evaluation index and empirically assesses the distinct impacts of digital inclusive finance. Third, this study explores strategies for enhancing SME innovation via various dimensions of digital inclusive finance, offering practical policy suggestions suited to current economic conditions.

## 3. Theoretical Mechanism and Model

Current studies suggest that advancing digital inclusive finance enhances financial resource availability and efficiency, particularly through broader coverage, deeper utilization, and greater digital adoption. Various financial services alleviate SME financing obstacles, mitigate financial limitations, and stimulate business innovation (Liang, 2018) [28]. This research integrates effective modeling and action mechanisms to explore how digital inclusive finance drives SME innovation, alongside assessing its targeted promotional effects.

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*3.1. Impact Model of Digital Inclusive Finance on SME Innovation*

When SMEs undertake innovative projects, financial support is crucial. This study utilizes the Von Neumann-Morgenstern utility function to represent enterprise preferences under financial limitations. It assumes that enterprise risk neutrality holds, i.e., $U' > 0$, $U'' = 0$, within the analytical framework.

At the first stage, the enterprise secures funding K, while at the second stage, the successful investment generates a return G. The probability of success $\alpha(E)$ $(0 \le E \le 1;\ 0 \le \alpha(E) = \alpha_0 + \alpha' E \le 1)$ depends on both objective factors and the enterprise's effort level (Jiang and Yi, 2022) [29]. The investment cost is given by $\beta E^2/2,\ (\beta > 0)$, and the probability of investment failure is $1-\alpha(E)$.

Innovative projects undertaken by SMEs are closely linked to financial support. In this context, the opportunity cost of lending to the investor is *l*. Due to information asymmetry, investors cannot fully assess enterprise risk and can only obtain partial risk information, denoted as $l_i$, for enterprise *i*, where $0 \le l_i \le 1$. Based on this risk information, financial institutions assess the likelihood of investment success, denoted as P($l_i$).

Initially, SME A seeks a loan from financial institution $B_1$, using assets worth M as collateral (discount rate $\delta$, where $0 \le \delta \le 1$), and pay transaction cost $C_0$ and loan interest $r_1 \cdot K$. At the same time, SME A can also choose to finance from informal financial institution $B_2$, and the loan interest it needs to pay is $r_2 \cdot K$. In addition, formal financial institution $B_1$ needs to bear the pre-loan examination cost $C_1$. If the review is passed, the loan is granted; if the review is not passed, the loan is denied. If the loan is rejected, the guaranteed return equals $r_3 \cdot K$.

At the second stage, SME A decides on defaulting or repaying. Defaulting will incur losses in areas such as reputation, represented by Q. If the enterprise repays on time, the likelihood of repayment is $\pi$.

In the first stage, SME A determines its effort level *e* based on the prevailing conditions. In the second stage, financial institution $B_1$ chooses the best decision $p_1$ from the available set *P* after assessing the firm's effort level *e*.

Assuming that the returns for SME A and financial institution $B_1$ are given by $u_1(e)$ and $u_2(e, p_1)$, respectively, the decision-making process of $B_1$ is expressed as follows:

$$u_2(e, p_1) \tag{1}$$

During the execution of this innovation project, given an enterprise effort level *e*, the financial institution determines a distinct optimal solution $u_1(e, O_2(p_1))$. Meanwhile, the SME can anticipate the financial institution's potential action plan for each *e* and adjust its optimal response $e^*$ accordingly to maximize its benefits. Consequently, the SME's decision to seek funding from informal financial institutions can be expressed as:

$$u_1(e, O_2(p_1)) \tag{2}$$

Then $u_1(e^*, O_2(p_1))$ is the optimal solution of Equation 2.

*3.2. Dynamics of Investment and Financing in Conventional Financial Markets*

Informal financial institutions often impose higher interest rates, denoted as $r_2 > r_1$. Consequently, SMEs typically seek financing from formal financial institutions, which offer lower financing costs. This study examines the financing dynamics between SMEs and formal financial institutions, where the expected profit for SMEs is $V_{A_1}$, and the expected profit for formal financial institutions is $V_{B_1}$.

If SMEs cannot obtain financing from formal financial institution $B_1$, then:

$$V_{A_1} = \alpha(E)[G - K(1+r_2)] + [1-\alpha(E)][-K(1+r_2)] - C_0 \tag{3}$$

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In this case, the expected return of financial institution $B_1$ is:

$$V_{b_1} = K(1+r_3) \tag{4}$$

1. If SMEs successfully obtain financing from formal financial institution $B_1$, then:

$$V_{A_2} = \pi\alpha(E)[G-K(1+r_1)]+(1-\pi)[1-\alpha(E)][-M-Q]-C_0 \tag{5}$$

In this case, the expected return of financial institution $B_1$ is:

$$V_{A_2} = \pi\alpha(E)[G-K(1+r_1)]+(1-\pi)[1-\alpha(E)][-M-Q]-C_0 \tag{6}$$

In general, the expected income of SMEs is as follows:

$$V_{A_i} = [1-P(l_i)]\{\alpha(E)[G-K(1+r_2)]+[1-\alpha(E)][-K(1+r_2)]\}+P(l_i)\{\pi\alpha(E)[G-K(1+r_1)]+(1-\pi)[1-\alpha(E)](-M-Q)\}-C_0-\frac{1}{2}\beta E^2 \tag{7}$$

$$V_{B_i} = [1-P(l_i)]K(1+r_3)+P(l_i)\{\pi\alpha(E)K(1+r_1-l)+(1-\pi)[1-\alpha(E)](\delta M-K)-C_1\} \tag{8}$$

After SMEs secure financing for the innovative project, they can maximize their own benefits E by adjusting their subjective effort level. The constraints are as follows:

$$V_{A_i} \geq 0, G \geq K(1+r_2), G \geq K(1+r_1), [1-P(l_i)]V_{A_1}+P(l_i)V_{A_2} \geq \frac{\beta E^2}{2} \tag{9}$$

The optimal condition of effort level can be expressed as follows.

$$\frac{\partial V_{A_i}}{\partial E} = [1-P(l_i)]\alpha' G+P(l_i)\{\pi\alpha'[G-K(1+r_1)]-(1-\pi)\alpha'(-M-Q)\}-\beta E = 0 \tag{10}$$

Therefore, the subjective optimal effort level of enterprises can be expressed as:

$$E^* = \frac{[1-P(l_i)]\alpha' G+P(l_i)\{\pi\alpha'[G-K(1+r_1)]\}-(1-\pi)\alpha'(-M-Q)}{\beta} \tag{11}$$

Since each loan of formal financial institutions needs to meet the condition of non-negative expected returns, it is expressed as:

$$V_{B_i} \geq 0, K \geq L_0 = \frac{C_1-P(l_i)(1-\alpha)(1-\pi)\delta M}{[1-P(l_i)(1+r_3)]+P(l_i)[\pi(r_1-l)-1+\alpha+\pi]} \tag{12}$$

Where $L_0$ represents the minimum loan size that formal institutions are willing to accept. If the loan amount is below $L_0$, financial institutions will refuse to provide loans to SMEs.

$$\frac{\partial L_0}{\partial M} = \begin{cases} > 0, \ 0 < P(l_i) < \dfrac{-1-r_3}{\pi\alpha(r_1-l)-2+\alpha+\pi-r_3}, & \text{greate risks} \\ \leq 0, \ \dfrac{-1-r_3}{\pi\alpha(r_1-l)-2+\alpha+\pi-r_3} \leq P(l_i) < 1, & \text{small risks} \end{cases} \tag{13}$$

In the context of incomplete market information, formal financial institutions face challenges in accurately assessing the true effort level of enterprises. They can only evaluate the risk associated with SMEs and make financing decisions based on the value of collateral. This information asymmetry makes it difficult to effectively address the financing challenges in traditional financial markets and hampers the ability to achieve an accurate balance in loan decisions between formal financial institutions and SMEs. Therefore, a thorough analysis of the effect model is essential to uncover the underlying mechanisms and influences.

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*3.3. Mechanism Effect*

This paper defines the extent of digitalization in digital inclusive finance as a measure of formal financial institutions' digital advancement $\gamma\ (\gamma > 1)$. As digitalization progresses, formal financial institutions gain increased access to information *i*. Their pre-loan assessment cost $C_1/\gamma$ steadily declines, nearing zero over time. In this scenario, the profit increment of formal financial institutions can be expressed as:

$$\Delta\prod = C_1 - \frac{C_1}{\gamma} \tag{14}$$

Formal financial institutions evaluate the success likelihood $P(l_i)$ of SME innovation projects. Given that banks approve investments based on a critical probability $p^*$, the corresponding probability distribution function is $f(p^*)$, while its density function is:

$$\dot{p} = \frac{\int_0^{p^*} p \cdot f(p)\,dp}{\int_0^{p^*} f(p)\,dp} \tag{15}$$

Given thatis a linear function of digitization level $\gamma$, its derivative with respect to $\gamma$ is:

$$\frac{\partial \dot{p}}{\partial \gamma} = \frac{1}{\gamma^2}\left[\frac{pC_1}{\pi\alpha(E)K(1+r_1-l)+(1-\pi)[1-\alpha(E)](\delta M-K)-C_1/\gamma-K(1+r_3)}\right]\times\left[\frac{f(p^*)}{F^2(p^*)}\right]\times\left[p^*\cdot F(p^*)-\int_0^{p^*} pf(p)dp\right] \tag{16}$$

On account of $p^*F(p^*)=\int_0^{p^*} f(p^*)dp^*$,

$$\int_0^{p^*} f(p^*)dp^* \geq \int_0^{p^*} pf(p)\,dp \tag{17}$$

Hence, $p^*F(p^*)\geq\int_0^{p^*} pf(p)\,dp$,

$$p^*F(p^*)-\int_0^{p^*} pf(p)\,dp \geq 0 \tag{18}$$

For $p\in[0,p^*]$ with $F(p)\geq 0$, it follows that $\frac{\partial \dot{p}}{\partial \gamma}\geq 0$.

3.3.1. Analysis of Direct Mechanism

According to Equation (18), as digital inclusive finance expands, formal financial institutions become increasingly likely to offer loans to SMEs. This underscores the essential function of digital inclusive finance in easing SMEs' financial barriers. The rise in digitalization enhances SMEs' access to credit. Higher digitalization levels $\gamma$ enhance information symmetry between financial institutions and SMEs, i.e., $\partial l_i/\partial\gamma\geq 0$. Based on the derivation of $\partial\dot{p}/\partial\gamma\geq 0$, it can be concluded that a higher level of digitalization exerts a positive impact on SMEs.

Accordingly, as bank digitalization advances, financial institutions can assess the success probability $P(E)$ of innovative projects based on the subjective effort level *E* of SMEs and make financing decisions accordingly, guiding financing decisions, represented as:

$$P(E^*)=\frac{\beta E-\alpha' G}{\pi\alpha'[G-K(1+r_1)]-(1-\pi)\alpha'(-M-Q)-\alpha' G} \tag{19}$$

The derivation of the subjective effort level E of SMEs can be obtained as follows:

$$\frac{\partial P}{\partial E}=\frac{\beta}{\pi\alpha'[G-K(1+r_1)]-(1-\pi)\alpha'(-M-Q)-\alpha' G}>0 \tag{20}$$

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With the progression of digital inclusive finance, SMEs' efforts become clearer to financial institutions, reducing adverse selection issues stemming from information asymmetry. Moreover, financial institutions rely less on SMEs' collateral in financing decisions, thereby reducing borrowing costs.

Employing comparative static analysis (Equation 21) and the implicit function derivative method (Equation 22), the link between effort level $E$ and digitization $\gamma$is further examined.

$$\frac{\partial E}{\partial \gamma}=\frac{\partial V_{B_i}/\partial \gamma}{\partial V_{B_i}/\partial E} \tag{21}$$

$$\frac{\partial V_{B_i}}{\partial \gamma}=\frac{P(E)C_1}{\gamma^2}>0 \tag{22}$$

$$\frac{\partial V_{B_i}}{\partial E}=P'(E)\left\{\pi\alpha(E)K(1+r_1-l)+(1-\pi)[1-\alpha(E)](\lambda M-K)-\frac{C_1}{\gamma}-K(1+r_3)\right\}+P(E)[\pi\alpha'K(1+r_1-l)]-\alpha'(1-\pi)(\delta M-K)>0 \tag{23}$$

3.3.2. Analysis of Indirect Mechanism

Therefore, with $\partial E/\partial \gamma > 0$ , the level of subjective effort exerted by the degree of digitalization is positively associated with SMEs. This indicates that enhanced digitalization makes the efforts of enterprises more easily recognized by formal financial institutions, significantly increasing the likelihood of securing financing. Increased digitalization provides formal financial institutions with more comprehensive information, enabling them to assess the efforts of firms more accurately. As enterprises invest greater efforts, the probability of success for their innovative projects rises accordingly. Given these advantages, formal financial institutions are more inclined to provide financing to enterprises exhibiting higher effort levels, increasing loan approval likelihood.

The effect model indicates that digital information technology enhances traditional financial institutions' credit processes, mitigating information asymmetry in conventional credit markets. Moreover, digital inclusive finance reduces SMEs' financing expenses, encouraging higher investment and improving financial institutions' profitability. As loan yields increase, formal financial institutions exhibit a higher willingness to provide credit support to SMEs.

However, notable variations exist in the profitability of innovation projects across industries. This results in significant variations in how digital inclusive finance influences SME innovation. For instance, in technology-intensive sectors (e.g., information technology and manufacturing), digital inclusive finance is instrumental in driving innovation by overcoming barriers to financing and reducing barriers to technological research and development. In contrast, in labor-intensive industries, where capital demand for innovation is relatively low, the enabling effect of digital inclusive finance remains limited.

Thus, digital inclusive finance is crucial in reducing information asymmetry for SMEs, eliminating loan bias from formal financial institutions, and lowering financing hurdles. Additionally, it exhibits varying impacts across different sectors. Based on these perspectives, the study presents the following hypotheses:

Hypothesis 1: Digital inclusive finance can boost SMEs' innovation investments.

Hypothesis 2: Digital inclusive finance supports SMEs' innovation by reducing financial constraints.

Hypothesis 3: SME innovation under digital inclusive finance depends on different dimensions of digital finance and the specific industry context.

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## 4. Research Methodology

### *4.1. Data Processing and Interpretation*

This study examines domestic firms registered on the SME Board and Growth Enterprise Board between 2011 and 2021. The data processing procedures include:

(1) Exclusion of financial and real estate enterprises, as their distinct operational models may introduce biases in digital inclusive finance research.

(2) Removal of enterprises with significant missing data for key variables or those delisted during the study period.

(3) Elimination of missing values and outliers in financial data to enhance reliability.

After screening and data refinement, 7,700 valid records remain. Key data sources include the Peking University Digital Inclusive Finance Index (2011–2021), the CSMAR database, and the China Statistical Yearbook.

### *4.2. Variable Description*

1. Explanatory variable: This study uses enterprise innovation output (*innov*) as a measure of innovation capability. While existing literature commonly assesses corporate innovation from both input and output perspectives, factors such as earnings management and outsourcing may compromise the reliability of innovation input data. Additionally, issues such as statistical errors and missing data often arise in relevant databases. Thus, this study utilizes the natural log of total patents, including inventions, utility models, and designs (plus 1), as a metric for evaluating enterprise innovation output and capability.
2. This study's primary explanatory variable is the Digital Inclusive Finance Index, published by Peking University's Institute of Digital Finance, evaluating digital inclusive finance progress from 2011 to 2021. This index comprises three sub-indices: coverage breadth (*cover*), usage depth (*depth*), and degree of digitalization (*digital*). To ensure dimensional consistency across variables, each sub-index was standardized by dividing it by 100 and used as the final variable in the analysis.
3. This study employs the financial constraints index (SA) as an intermediate variable, measuring the extent of financial limitations faced by enterprises. Since the index is expressed as a negative value, its absolute value is utilized for analysis, with a higher absolute value signifying more significant financing constraint.

   The calculation formula is:

$$SA = -0.737size + 0.043size^2 - 0.04age \tag{24}$$

   where size and age represent:

   (1) *size*, measured as the natural log of total assets at year-end.

   (2) *age*, calculated as the current year minus the establishment year, plus one.
4. This study includes control variables to evaluate SMEs' characteristics: enterprise age (*age*), size (*size*), and financial leverage ratio (*lev*), defined as total liabilities divided by total assets at year-end. Additionally, enterprise growth ability (*growth*) is quantified by the growth rate of operating income, while chairman-CEO integration (*dual*) is represented as a dummy variable, where 1 indicates role integration and 0 indicates separation. The independent director ratio (*indratio*) is determined by the number of independent directors relative to the total board members. The fixed assets share (*fas*) reflects the percentage of total assets comprising fixed assets and depreciation. Lastly, the management shareholding ratio (*msh*) denotes management's ownership percentage in total shares.

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*4.3. Metrological Model Design*

This study conducts the LM and Hausman tests, revealing that the fixed effect model aligns well with the dataset's characteristics and analytical needs. As a result, the paper takes into account both time effects and industry effects, constructing a two-way fixed effect model.

$$innov_{i,t} = \alpha + \beta_1 index_{i,t} + \beta_2 control + year + ind + \varepsilon_{i,t} \quad (25)$$

Here *i* represents an enterprise, *t* denotes time, and $innov_{i,t}$ captures the innovation output of the *i*th firm in year *t*; The variable $index_{i,t}$ quantifies digital inclusive finance development for the *i*th firm in year *t*; while *control* includes the control variables, and c $\varepsilon_{i,t}$ denotes the random disturbance term. Moreover, *year* reflects time-fixed effects, while *ind* represents industry-fixed effects, addressing industry heterogeneity and time-varying unobserved factors.

To examine how digital inclusive finance supports SME innovation and growth by easing financing constraints, the following model is introduced:

$$SA_{i,t} = \gamma_0 + \gamma_1 index_{i,t} + \gamma_2 control + year + ind + \varepsilon_{i,t} \quad (24)$$

Where $SA_{i,t}$ serves as the mediating variable, representing the financing constraints experienced by the *i*th firm in year *t*.

*4.4. Empirical Examination*

4.4.1. Summary Statistics

Table 1's descriptive analysis indicates that the average enterprise innovation output (*innov*) is 0.880, ranging from 0 to 2.183, demonstrating considerable differences in innovation capabilities among sampled firms. The digital inclusive finance index (*index*) averages 2.558 with a standard deviation of 1.072, highlighting differences in development among firms.

**Table 1.** Summary Statistics of Key Variables.

| Variable | Observations | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| *innov* | 7700 | 0.880 | 0.612 | 0.000 | 2.183 |
| *index* | 7700 | 2.558 | 1.072 | 0.180 | 4.590 |
| *cover* | 7700 | 2.373 | 1.046 | 0.020 | 4.330 |
| *depth* | 7700 | 2.636 | 1.118 | 0.070 | 5.110 |
| *digital* | 7700 | 3.025 | 1.240 | 0.080 | 4.620 |
| *sa* | 7700 | 3.721 | 0.236 | 2.974 | 4.751 |
| *size* | 7700 | 8.058 | 0.967 | 5.878 | 12.206 |
| *age* | 7700 | 23.369 | 4.471 | 15.000 | 43.000 |
| *lev* | 7700 | 0.355 | 0.186 | 0.051 | 0.888 |
| *growth* | 7700 | 0.189 | 0.474 | -0.949 | 5.046 |
| *dual* | 7700 | 0.349 | 0.477 | 0.000 | 1.000 |
| *indratio* | 7700 | 37.673 | 5.432 | 25.000 | 66.670 |
| *fas* | 7700 | 0.100 | 0.086 | 0.002 | 0.616 |
| *msh* | 7700 | 20.685 | 20.611 | 0.000 | 89.725 |

For control variables, the mean enterprise age (*age*) is 23.369 years, with an SD of 4.471, suggesting that most firms are well-established, with their ages concentrated within a narrow range. The minimum enterprise growth capacity (*growth*) is −0.949, signifying operational challenges and revenue fluctuations for certain firms. Additionally, the mean management shareholding ratio (*msh*)

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is 20.685, with an SD of 20.611 and a maximum nearing 90%, implying variation in ownership structures and governance models.

Overall, the distribution of the sample data is statistically reasonable, ensuring its suitability for subsequent empirical analysis.

4.4.2. Baseline Regression Result

Table 2's analysis shows that the index remains significant at the 1% level, even after incorporating control variables (as seen in Model 1), with all coefficients displaying positive effects. Models (2-5) examine three key facets of digital inclusive finance separately: —*cover*, *depth*, and *digital*. Findings suggest that cover and depth play the most crucial roles in driving corporate innovation, whereas digital exerts a comparatively weaker positive effect. However, it remains significant at the 10% level. Furthermore, expanding coverage and enhancing usage prove more influential in fostering innovation than merely increasing digitalization levels. Therefore, Hypothesis 1 is supported.

**Table 2.** Digital Inclusive Finance and SME Innovation: Benchmark Regression Estimates.

| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** |
|---|---|---|---|---|---|
| *index* | 0.095*** [1] | 0.083*** | | | |
| | (0.026) | (0.026) | | | |
| *cover* | | | 0.062*** | | |
| | | | (0.024) | | |
| *depth* | | | | 0.063*** | |
| | | | | (0.019) | |
| *digital* | | | | | 0.080* |
| | | | | | (0.043) |
| _cons | 0.309*** | -0.004 | 0.003 | -0.001 | -0.011 |
| | (0.072) | (0.114) | (0.114) | (0.114) | (0.114) |
| Control | No | Yes | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes |
| N | 7700 | 7700 | 7700 | 7700 | 7700 |
| $R^2$ | 0.094 | 0.111 | 0.111 | 0.111 | 0.110 |

[1] t statistics in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$, the same below.

4.4.3. Robustness Test

This paper will conduct robustness tests using three methods: variable substitution, sample selection, and changes in estimation techniques.

1. The substitution variable replaces the dependent variable with corporate profitability (*roa*), a crucial metric evaluating a firm's net profit generation capability. *roa* captures how digital inclusive finance supports enterprise growth in terms of economic performance. Digital inclusive finance eases financing constraints, lowers transaction costs, and encourages innovation investment, leading to better resource allocation, efficient asset use, and higher profitability. Unlike corporate innovation output as an indirect factor, *roa* directly assesses digital inclusive finance's impact on corporate profitability. This approach broadens the research scope from an innovation-centric view to an economic benefits perspective, offering robust empirical support for policy and practical improvements. The regression results using this substitution variable are presented in Table 3.

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**Table 3.** Digital Inclusive Finance and SME Innovation: Benchmark Regression Estimates.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *index* | 0.007*** | | | |
| | (0.002) | | | |
| *cover* | | 0.007*** | | |
| | | (0.002) | | |
| *depth* | | | 0.005*** | |
| | | | (0.002) | |
| *digital* | | | | -0.014*** |
| | | | | (0.004) |
| _cons | -0.096*** | -0.096*** | -0.096*** | -0.089*** |
| | (0.010) | (0.010) | (0.010) | (0.010) |
| Control | Yes | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes |
| N | 7000 | 7000 | 7000 | 7000 |
| $R^2$ | 0.257 | 0.257 | 0.257 | 0.258 |

Table 3 illustrates that digital inclusive finance, along with its individual components, plays a crucial role in shaping corporate profitability (*roa*). Cover and depth exhibit positive effects, with coefficients of 0.007 and 0.005, both statistically significant at the 1% level. The coefficient for digital is -0.014, still maintaining significance at the 1% level. These findings suggest that *roa* may not fully capture digital inclusive finance's long-term effects on enterprise growth, as its influence is more pronounced in short-term financial performance. Short-term digitalization raises operational expenses, encompassing IT infrastructure, workforce training, and system upgrades. Although such investments boost long-term competitiveness, they also drive up fixed and operating costs, squeezing profit margins and reducing *roa*, thereby impacting profitability.

2. Wind-down treatment (Table 4): To address potential reverse causality, where SME innovation might impact digital inclusive finance, the study introduces a one-period lag in the key explanatory variables. Even with this adjustment, digital inclusive finance continues to have a distinct and significant impact on SME innovation.

**Table 4.** Robustness Test: Core Explanatory Variables Lagged by One Period.

| | (1) | (2) |
|---|---|---|
| *lindex* | 0.263*** | 0.280*** |
| | (0.076) | (0.076) |
| | 0.791*** | 0.852*** |
| _cons | (0.171) | (0.224) |
| | 0.263*** | 0.280*** |
| Control | No | Yes |
| Industry | Yes | Yes |
| Year | Yes | Yes |
| N | 7000 | 7000 |
| $R^2$ | 0.049 | 0.057 |

Alternative Estimation Method: This study employs enterprise innovation output (*innov*) as a proxy for innovation capability. Table 5 results validate the stability of the baseline regression analysis.

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**Table 5.** Robustness test: Tobit model test.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *index* | 0.119*** | | | |
| | (0.036) | | | |
| *cover* | | 0.091*** | | |
| | | (0.033) | | |
| *depth* | | | 0.087*** | |
| | | | (0.025) | |
| *digital* | | | | 0.116* |
| | | | | (0.059) |
| _cons | -0.274* | -0.264* | -0.269* | -0.283* |
| | (0.160) | (0.160) | (0.160) | (0.161) |
| Control | Yes | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes |
| N | 7700 | 7700 | 7700 | 7700 |
| $R^2$ | 0.053 | 0.053 | 0.053 | 0.052 |

4.4.4. Mediating Effect Test

Table 6's analysis highlights how digital inclusive finance mitigates corporate financing limitations. Model (1) shows that digital inclusive finance effectively alleviates SME financing difficulties, with a 1% significance level. Model (2) demonstrates that financing constraints at the same significance level hinder SME innovation. Models (3-5) indicate that broader coverage, increased utilization depth, and digitalization of inclusive finance significantly lessen financing barriers. The results show that digital inclusive finance improves financing conditions by broadening service access, strengthening business-financial institution ties, and enhancing financial service efficiency.

Mechanistically, expanding digital inclusive finance eases SME financing constraints via multiple channels. Broadening service coverage improves financial resource accessibility, enabling more enterprises to secure formal funding. The increased depth of use fosters long-term collaboration between firms and financial institutions, improving financial accessibility and convenience. Furthermore, advancements in digitalization optimize credit approval processes, minimize information asymmetry and decrease financing costs. Overall, digital inclusive finance is essential in broadening access to financial services, enhancing resource allocation efficiency, and optimizing the financing environment. Hypothesis 2 is confirmed.

**Table 6.** Robustness test: Tobit model test.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| *index* | 0.1161*** | | | | |
| | (143.71) | | | | |
| *innov* | | -0.0094*** | | | |
| | | (-3.95) | | | |
| *cover* | | | 0.1175*** | | |
| | | | (140.36) | | |
| *depth* | | | | 0.1034*** | |
| | | | | (119.07) | |
| *digital* | | | | | 0.0927*** |
| | | | | | (115.09) |

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| | | | | | |
|---|---|---|---|---|---|
| _cons | 2.3470*** | 2.0844*** | 2.3577*** | 2.3065*** | 2.2943*** |
| | (224.64) | (105.39) | (221.51) | (194.51) | (190.61) |
| Control | Yes | Yes | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes |
| N | 7700 | 7700 | 7700 | 7700 | 7700 |
| $R^2$ | 0.9201 | 0.7062 | 0.9173 | 0.8965 | 0.8931 |

4.4.5. Heterogeneity Test

Examining how digital inclusive finance influences SME innovation under varying intra-industry competition highlights the diverse profitability of innovation projects across sectors. The likelihood of financial institutions granting SME loans depends on their evaluation of project success, which varies accordingly. Table 7 explores how digital inclusive finance differently impacts SME innovation.

The digital inclusive finance index positively influences enterprise innovation in the secondary sector, showing a coefficient of 0.082 at a 1% significance level. However, it does not exhibit a notable effect on primary and tertiary industries. This finding highlights the sectoral differences in how digital inclusive finance impacts innovation capabilities. From a mechanistic standpoint, the secondary industry, which is mainly driven by manufacturing, is characterized by high capital and technological requirements, making enterprises within this sector more reliant on external financing for innovation. Conversely, the primary industry, reliant on natural resources and infrastructure, has a low demand for technological innovation, restricting digital inclusive finance's capacity to foster innovation. In the tertiary sector, the service industry employs a flexible innovation approach with minimal technological investment needs, leading to more diverse financing options. These findings support Hypothesis 3.

**Table 7.** Heterogeneity analysis.

| | **(1)** primary industry | **(2)** secondary industry | **(3)** tertiary industry |
|---|---|---|---|
| *index* | 0.100 | 0.082*** | 0.073 |
| | (0.511) | (0.029) | (0.062) |
| _cons | 1.152 | 0.331*** | 1.406*** |
| | (1.315) | (0.104) | (0.214) |
| Control | Yes | Yes | Yes |
| Industry | Yes | Yes | Yes |
| Year | Yes | Yes | Yes |
| N | 73.000 | 6151.000 | 1476.000 |
| $R^2$ | 0.263 | 0.046 | 0.075 |

## 5. Theoretical Mechanism and Model

Using data from domestic firms listed on the SME and Growth Enterprise Boards (2011–2021) alongside digital inclusive finance records, this study examines its impact on SME innovation through theoretical and empirical approaches. The main conclusions are as follows:

Firstly, digital inclusive finance significantly boosts SMEs' innovation. Among its various aspects, broader coverage and more extensive utilization have a greater impact than digitalization alone.

Secondly, digital inclusive finance alleviates SMEs' financial constraints, offering vital support for innovation. Through expanded coverage, deeper usage, and digitalization, it improves financing conditions and simplifies access to funds for innovative projects.

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Thirdly, the effect of digital inclusive finance on SME innovation varies across industries. Its impact is most pronounced in the secondary sector, outpacing its influence on the primary sector.

## 6. Recommendations

First, Enhance the Digital Inclusive Finance System and Improve the Allocation of Financial Resources.

Advancements in digital inclusive finance serve as a key driver in enhancing SMEs' innovation capacity. For greater effectiveness, policymakers should focus on improving the service framework of digital inclusive finance, expanding its reach, and extending financial services to underserved regions and industries. Furthermore, maximizing digital finance's potential requires fostering financial institutions' innovation through new financial products and service models. This approach facilitates tailored and differentiated financing solutions for SMEs while fostering long-term, cooperative relationships between financial institutions and enterprises. Additionally, establishing an efficient resource allocation mechanism is crucial to addressing the disparity in financial resource distribution among SMEs. A structured and efficient system guarantees fair financial resource distribution, strengthening digital inclusive finance's role in fostering SMEs' sustainable innovation.

Second, support for digital transformation should be strengthened, and short-term financial pressures alleviated.

In the process of digital transformation, SMEs often face significant initial costs, which increase the financial burden on businesses in the short term. Therefore, it is necessary to focus on establishing a cost compensation mechanism for digital transformation. This includes promoting the implementation of targeted financial support, tax reduction and exemption policies, and technology subsidies to help small and medium-sized enterprises balance their short-term expenditures with long-term benefits. Simultaneously, the government should encourage third-party technical service institutions to offer expert assistance to facilitate the digital transformation of SMEs. This support will help shorten the adaptation cycle, improve transformation efficiency, and enable businesses to quickly convert digital technologies into competitive advantages, thereby promoting sustainable development. Moreover, enterprises should strengthen the training of digital talents and build specialized teams to ensure that the effects of transformation are quantifiable and traceable, this, in turn, accelerates technological advancements within small and medium-sized enterprises.

Third, targeted industrial support strategies should be implemented to unlock the innovation potential of enterprises.

The government needs to provide targeted support for different industries based on their specific characteristics. For the primary industry, the focus should be on agricultural technological innovation, promoting the widespread adoption of digital technologies in agricultural production, circulation, and management through financial support, in order to assist in the modernization of agriculture. In the secondary industry (manufacturing), strengthening collaboration between financial institutions and high-tech manufacturing enterprises is essential, particularly in supporting research and development investments and the implementation of digital production systems in technology-driven companies. This approach facilitates the shift of manufacturing enterprises from conventional models to smart, advanced, and high-tech operations. For the tertiary industry, support for the digital transformation of the service sector should be reinforced, encouraging the deep integration of new business models and digital technologies. Efforts should be made to explore new growth opportunities in fields such as financial technology, e-commerce, and digital culture and innovation. By implementing targeted measures tailored to the characteristics of each industry, the government can effectively unlock the potential for industrial innovation, fostering coordinated development across the entire industrial chain and promoting high-quality economic growth.

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