

Research on the Impact Mechanism of Digital Inclusive Finance on Enterprise Technological Innovation

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Abstract. Based on the data of China's A-share listed companies from 2011 to 2022, this paper empirically analyzes the incentive effect and mechanism of digital inclusive finance on enterprise technological innovation. The results show that digital inclusive finance has a significant role in promoting corporate technological innovation, and the results are robust, and digital inclusive finance can promote corporate technological innovation by alleviating corporate financing constraints. Further analysis shows that value monopoly positively moderates the relationship between digital inclusive finance and enterprise technological innovation, while competition intensity negatively moderates the relationship between digital inclusive finance and enterprise technological innovation. The grouping test finds that the innovation incentive effect of digital inclusive finance is stronger for private enterprises and capital-intensive and technology-intensive enterprises. The research conclusions enrich the relevant research on the impact of digital inclusive finance on corporate innovation, and provide theoretical basis and policy reference for how the financial market can better serve the real economy.

Keywords: Digital inclusive finance, financing constraints, Technological innovation, Mediating effect, Monopoly of value; Intensity of competition.

1. Introduction

Technological innovation is the core driving force to promote economic growth, enhance industrial competitiveness and achieve sustainable development. The report to the 20th National Congress of the Communist Party of China clearly put forward the requirement of accelerating high-level scientific and technological self-reliance and self-improvement. However, some core technologies in China are still facing the dilemma of "stuck neck" [1], which seriously restricts high-quality economic development. In order to overcome this dilemma, enterprise technological innovation is particularly important. Due to the large amount of technological innovation investment, long cycle and uncertain output, enterprises need stable and sufficient financial resources for protection. However, under the traditional financial system, there are problems such as information asymmetry and resource misallocation between enterprises and financial institutions, and enterprises are faced with strong external financing constraints.

In order to make up for the shortcomings of traditional finance and provide financial support for enterprises, China has deepened the supply-side structural reform of finance and enhanced the quality of financial services for the real economy. Digital inclusive finance is a major practice of financial supply-side structural reform. Digital inclusive finance integrates digital technology with financial services, reduces the cost of financial service products, broads the financing channels of enterprises, improves the efficiency of enterprises' access to financial resources, and effectively alleviates financing constraints. In recent years, digital inclusive finance has become a research hotspot for scholars at home and abroad, but there are still insufficient studies on the relationship between digital inclusive finance and enterprise technological innovation.

In this context, using the data of China's A-share listed companies from 2011 to 2022 as samples, this paper empirically analyzes the incentive effect of digital inclusive finance on corporate technological innovation, and explores the mediating effect of financing constraints and the moderating effect of value exclusivity and competition intensity. The contributions of this paper are as follows: (1) expand the research on digital inclusive finance and enterprise technological

innovation, and provide a theoretical basis for the country to further promote the development of digital inclusive finance. (2) From the perspective of alleviating corporate financing constraints, this paper empirically tests the mechanism of digital inclusive finance stimulating corporate innovation, and provides micro data support for the formulation of corporate innovation policies. (3) Value exclusivity and competition intensity are incorporated into the research framework as moderating variables to maximize the innovation enabling effect of digital inclusive finance.

2. Review of Relevant Literature

The research on how to drive enterprise technological innovation is very rich, and the core vein of research can be roughly divided into macro and micro aspects. From the micro perspective, existing literature has studied the impact of enterprise scale [2], executive shareholding [3], the number of female executives [4], and risk-taking [5] on enterprise innovation. From the macro perspective, scholars mainly studied the impact of government subsidies [6], market environment [7], industrial policies [8] and other aspects on enterprise innovation. It can be seen that scholars' research on the influencing factors of innovation is relatively mature, and a variety of economic measurement and operational research methods have been applied to the research on the influencing mechanism of innovation, producing rich research results.

The current academic research on the impact of digital inclusive finance on enterprise technological innovation is mainly reflected in the action path. Specifically, Yang et al. (2021) found that digital inclusive finance promotes corporate technological innovation by alleviating corporate financing constraints, optimizing the allocation of financial resources among departments and making up for the shortcomings of traditional finance. Yang et al. (2021) showed that digital finance can stimulate technological innovation of small and medium-sized enterprises by increasing liquidity, reducing financing costs and improving operating income. Zhang et al. (2023) believed that digital inclusive finance can improve the risk-taking level of enterprises, weaken the risk aversion tendency of the management, and enhance the willingness of enterprises to innovate. Chao et al. (2024) found that digital inclusive finance can improve corporate innovation efficiency through agency cost reduction. Research by Wang et al. (2024) shows that digital inclusive finance can improve the potential absorptive capacity of enterprises, thus improving their R&D level and promoting their technological innovation. Xu et al. (2022) found that the development of digital inclusive finance has a positive incentive effect on the innovation capability of enterprises by alleviating the distortion of regional factor markets.

However, with the development of digital inclusive finance, technological innovation may face the risk of knowledge leakage and intellectual property infringement, so the value exclusivity of enterprises plays a key role in their innovation activities [16]. Appropriability is an environmental factor outside the enterprise and market structure that affects innovators' ability to profit from innovation (Teece, 1986). It is the protection of innovators' exclusive innovation benefits (Pisona and Teece, 2007), which is conducive to enterprises to gain economic value from innovation activities and achievements, and improve the enthusiasm of enterprises in technological innovation. Therefore, it is particularly necessary to analyze the innovation-driving effect of digital inclusive finance based on the monopoly of enterprise innovation value. In addition, the technological innovation of enterprises is often affected by the competitive environment of the external market [19]. In-depth research on the relationship among digital inclusive finance, technological innovation and the external market competitive environment is of great significance for guiding the formulation of corporate strategy.

To sum up, although the academia has discussed the relationship between digital inclusive finance and enterprise technological innovation more, there are also obvious shortcomings. On the one hand, existing studies mainly start from the internal perspective of enterprises, and rarely consider the impact of external market competition environment on the relationship between digital inclusive finance and enterprise innovation. On the other hand, the existing literature has ignored the

moderating effect of corporate value exclusivity on the relationship between digital inclusive finance and corporate innovation. Therefore, the research on digital inclusive finance and enterprise technology innovation still needs to be further improved.

3. Theoretical Analysis and Research Hypotheses

3.1. The Impact of Digital Inclusive Finance on Enterprise Technological Innovation

Technological innovation is a long-term and high-risk activity with typical sunk input and irreversible process. It is prone to be troubled by the "double high" problem of high adjustment cost and high financing cost [20], and its sustainability requires the support of a large and stable cash flow. Moreover, due to characteristics such as output uncertainty, revenue lag, and spillover [21], technological innovation may face the risks that the research and development results cannot be implemented or commercialized in the short term, as well as knowledge leakage. Furthermore, the innovation process relies heavily on the knowledge and skills of R&D personnel. Once R&D personnel leave, innovation activities will have to be forced to stop, and the previous investment of the enterprise will not be recoverable [22]. Therefore, enterprises with a smaller capital stock tend to invest funds in "quick and easy" projects or make profits by imitating the innovative achievements of innovators. However, powerful enterprises may choose to use their profits for the expansion of production scale to achieve economies of scale in the input of production factors such as capital and labor, reduce production costs and obtain monopoly profits. As a result, the research and development incentives of enterprises are suppressed.

Digital inclusive finance can provide enterprises with diversified financial services, lower the service threshold of financial institutions, reduce the financing costs of enterprises to a certain extent, improve the financing efficiency of enterprises, alleviate the financing constraints in the process of enterprise innovation, and promote the improvement of enterprise innovation capabilities. On this basis, digital inclusive finance can enhance the risk-bearing level of enterprises, weaken the risk-aversion tendency of management, curb the short-sighted behavior of managers, and boost the innovation enthusiasm of enterprises. Meanwhile, digital inclusive finance enhances the transparency of enterprise information disclosure, improves the interaction efficiency of management, reduces the internal agency costs of enterprises, expands external supervision channels, stimulates joint governance of external supervision, and increases innovation output. In addition, enterprises can attract R&D personnel from different backgrounds and specialties through digital financial platforms, expand the scale of the enterprise's R&D team, enhance the potential absorption capacity of the enterprise [13], and strengthen the enterprise's R&D level.

Based on the above analysis, Hypothesis 1 is proposed: The development of digital inclusive.

3.2. The Intermediary Mechanism of Digital Inclusive Finance and Enterprise Technological Innovation

Enterprise technological innovation cannot do without long-term and stable financial support. Due to the high demand for financial funds in innovation activities and the low supply of financing for high-risk innovation projects in the financial system, enterprises are facing a huge funding gap in innovation, and financing constraints have become a prominent problem in the process of enterprise innovation [23]. Domestic scholars, taking Chinese enterprises as research samples, have found that financing constraints have a significant inhibitory effect on technological innovation of enterprises [24, 25]. Digital inclusive finance, as a new type of financial service model, may alleviate the financing constraints of enterprises through the following channels and thereby promote the innovation activities of enterprises:

On the one hand, digital inclusive finance has broadened financing channels, thereby alleviating the financing constraints on enterprises. Digital inclusive finance innovates financial products and services by applying emerging technologies such as the Internet of Things, cloud computing and big data. Diversified financing platforms such as microcredit, third-party payment and crowdfunding

financing are constantly expanding, lowering the financing threshold for enterprises and broadening their financing channels. In addition, digital inclusive finance, by innovating investment business models, attracts smaller and scattered "long-tail" investors in the financial market, further expanding the sources of enterprise financing.

On the other hand, digital inclusive finance reduces financing costs, thereby alleviating the financing constraints on enterprises. Digital inclusive finance effectively alleviates the information asymmetry problem between the "financial sector - enterprise entities" by deeply mining massive amounts of standardized and non-standardized data, thereby reducing the search cost and risk identification cost of the financial market as well as the risk premium cost of financial institutions. Meanwhile, digital inclusive finance innovatively changes the way traditional services are provided, significantly reducing the transaction costs of financial services and thereby lowering the financing costs of enterprises.

Finally, digital inclusive finance has enhanced financing efficiency, thereby alleviating the financing constraints of enterprises. Digital inclusive finance can accelerate the approval process for enterprise financing, build a credit service system through Internet technology, optimize the credit granting technical process of existing financial institutions, shorten the credit review time for customers, and improve financing efficiency. In addition, digital inclusive finance, as a form of financial spillover, forces traditional commercial banks to transform, enhance the efficiency of financial resource allocation, and further improve financing efficiency.

Based on the above analysis, Hypothesis 2 is proposed: Digital inclusive finance promotes technological innovation of enterprises by alleviating their financing constraints.

3.3. Digital Inclusive Finance, Value Monopoly and Enterprise Technological Innovation

While digital inclusive finance promotes enterprise innovation, it also poses risks such as knowledge leakage. Value monopoly refers to the degree to which an enterprise acquires innovative value from its own technological innovation. High-value exclusivity can prevent or delay the imitation or replication of an enterprise's technological innovation knowledge by competitors, and get rid of negative problems such as knowledge leakage brought about by digital finance [26]. Therefore, this paper will further analyze the moderating effect of value exclusivity on the relationship between digital inclusive finance and enterprise technological innovation.

On the one hand, value exclusivity helps reduce externality problems and protect the expected returns of innovation entities, thereby strengthening the driving role of digital inclusive finance in technological innovation. Value monopoly can, to a certain extent, safeguard the rights and interests of innovation entities and promote enterprises to increase their efforts in independent research and development and innovation. Enterprises with strong value monopoly capabilities can utilize the advantages of pioneers, unique knowledge, etc. to safeguard the interests of innovation. Enterprises with weak value monopoly capabilities tend to have their technological innovations imitated by competitors, and their innovation achievements cannot be protected. Therefore, enterprises with strong value monopoly capabilities can avoid problems such as knowledge leakage, are more likely to obtain financial services from digital inclusive finance platforms, and continuously optimize core technologies.

On the other hand, value exclusivity helps reduce the uncertainty of innovation achievements and the problem of information asymmetry in the financing process, thereby strengthening the driving role of digital inclusive finance in technological innovation. Due to the characteristics of research and development activities such as high risk and high uncertainty.

Investors are unable to learn about the technological level of the enterprise and the status of the project, and thus make decisions such as not investing or reducing the investment amount. Unlike the forced stance to prevent knowledge leakage, enterprises with strong value monopoly capabilities will make strategic knowledge disclosures based on their own expectations to obtain direct or indirect benefits, such as Tesla opening up its battery production technology and fast charging technology patents, etc. The information it publicly discloses is often genuine and valid, which can provide

investors with more research and development information, help alleviate the information asymmetry between the supply and demand sides of funds, and facilitate digital inclusive financial services.

In conclusion, enterprises with strong value exclusivity capabilities can comprehensively design knowledge protection and knowledge disclosure strategies to profit from innovation. Weak value monopoly ability not only increases the uncertainty of the transformation of enterprises' innovation achievements, but also inhibits the knowledge disclosure behavior of enterprises. At this time, the incentive effect of digital inclusive finance innovation weakens.

Based on the above analysis, Hypothesis 3 is proposed: Value monopoly has a positive moderating effect on the relationship between digital inclusive finance and enterprise technological innovation.

3.4. Digital Inclusive Finance, Competitive Intensity and Enterprise Technological Innovation

From the perspective of the external market environment, the promoting effect of digital inclusive finance on enterprise technological innovation may also be affected by the intensity of competition. The classic Schumpeter theory of innovation once proposed that the weaker the market competition, the stronger the innovation ability of enterprises [27]. This is because the weaker the degree of market competition, the more stable the market environment, and the smaller the inhibitory effect of uncertain factors on the driving force of enterprise innovation. Judging from the current progress in this field, a considerable number of research results support Schumpeter's view that enterprises with a weaker degree of market competition are more likely to obtain returns from innovation and thereby achieve continuous innovation [28]. This article holds that market competition influences the innovation-driven effect of digital inclusive finance in the following aspects:

On the one hand, market competition drives both enterprises and financial institutions to avoid risks. Industries with high competitive intensity are characterized by low concentration, free capacity and low differentiation. The technical distances between enterprise knowledge bases are close, the appropriation cost for outsiders is small, and the innovation achievements are easily imitated, which in turn leads to the loss of competitive advantages of key enterprises [29]. Therefore, when enterprises are confronted with fierce market competition, they will enhance the degree of protection of knowledge, reduce the possible risk of knowledge leakage, and weaken their reliance on digital inclusive finance funds. Financial institutions, due to the difficulty in obtaining information related to enterprise innovation, will reduce financial support for enterprises' research and development activities from the perspective of risk avoidance. Therefore, the intensity of competition has a greater negative impact on the innovation-driven effect of digital inclusive finance.

On the other hand, market competition weakens the intensity of enterprises' innovation investment. When facing fierce market competition, in order to meet investors' requirements for performance and the needs of corporate earnings management, the management is more likely to short-sighted focus on quick-profit bestsellers and neglect long-term sustainable development, thereby reducing investment in innovation. Meanwhile, in order to strive for a larger market share, enterprises tend to accelerate the commercialization of core technologies and quickly obtain innovation benefits by increasing market investment. The role of digital inclusive finance has been distorted. Enterprises use the financial support from digital financial platforms for market investment and reduce investment in technological innovation. As a result, the innovative effect of digital inclusive finance has weakened accordingly.

Based on the above analysis, Hypothesis 4 is proposed: The intensity of competition has a negative moderating effect on the relationship between digital inclusive finance and enterprise technological innovation.

4. Research Design

4.1. Sample Selection and data Sources

The A-share listed companies in China from 2011 to 2022 were selected as the research samples and the following screening was conducted: ① The data of companies in the financial industry were excluded; ② Exclude the data of companies with ST, *ST and PT warnings; ③ After eliminating the company data with abnormal or missing financial data, a total of 16,763 sample observation values were finally obtained. The above research data mainly came from the CSMAR database of Guotai 'an and the Wind database. Some missing financial data values were manually collected and filled in the annual reports by the author. Meanwhile, Winsorize tailing was performed on all continuous variables at the 1% and 99% levels to eliminate the influence of extreme values on the regression analysis, and Stata15.0 was used for data processing and econometric analysis.

4.2. Variable definition

4.2.1. Technological Innovation (Innovation)

Drawing on the practice of CAI Weixing et al. [46], in this paper, the logarithm of the number of authorized invention patents is adopted to measure the technological innovation of enterprises, and the number of invention patent applications is used as a proxy variable for the robustness test of enterprise technological innovation. The main reasons are as follows: First, since it is full of uncertainties whether enterprises can successfully produce innovative achievements, the selection of innovation input may overestimate the innovation level of enterprises [30]; Secondly, the earlier a patent is applied for, the higher its citation count will be, and there may be a certain "tail breakage" problem (Akcigit et al., 2016); Thirdly, an authorized patent is a legally recognized right. Specifically, among the three types of patents stipulated in China's Patent Law (invention patents, utility model patents, and design patents), the application conditions and authorization process for invention patents are stricter, and they can more accurately measure the technological innovation level of enterprises.

4.2.2. Digital Inclusive Finance (Index)

For the measurement of digital inclusive finance, the "Peking University Digital Inclusive Finance Index" is commonly adopted. This index, leveraging the massive data of Ant Group, has constructed an indicator system that includes three first-level indicators: the breadth of digital finance coverage, the depth of usage, and the degree of digitalization. It is widely used in the measurement of digital finance (Yang Jun et al., 2021; Yang Xianming et al., 2021 Zhang Yun et al. (2023) [9] [10] [11]. This paper refers to the approach of Zhang Yun et al. (2023) [11] and adopts the digital inclusive finance index at the city level in the core empirical study.

4.2.3. Financing Constraints (FC)

The financing constraint measurement draws on the research idea of Zhang Yuemei et al. [32] to construct the financing constraint FC index. Firstly, take the enterprise scale, enterprise age and cash dividend payout ratio of the year as the sample pre-grouping variables and sort them in ascending order. Determine the financing constraint dummy variable QUFC. Listed companies with a value greater than the 66% percentile are defined as the low financing constraint group, with QUFC=0. Listed companies with a value less than the 33% percentile are defined as the high financing constraint group, with QUFC=1. Secondly, Five variables, namely enterprise size (size), asset-liability ratio (lev), ratio of cash dividends to total assets (Cash div /ta), ratio of market value to book value (MB), ratio of net working capital to total assets (NWC/ta), and ratio of earnings before interest and taxes to total assets (EBIT/TA), were selected. Construct the Logistic model. Finally, the Logistic model was subjected to binary logistic regression, and the financing constraint index FC was constructed based on the regression results. The larger the value of the FC index, the higher the degree of financing constraint that the enterprise is subject to. The model is as formula:

$$P(QUFC = 1 \text{ or } 0 | ZFC_{i,t}) = \frac{1}{1 + e^{-ZFC_{i,t}}} \quad (1)$$

$$ZFC_{i,t} = \mu_0 + \mu_1 size_{i,t} + \mu_2 lev_{i,t} + \mu_3 \left(\frac{CashDiv}{ta} \right)_{i,t} + \mu_4 MB_{i,t} + \mu_5 \left(\frac{NWC}{ta} \right)_{i,t} + \mu_6 \left(\frac{EBIT}{ta} \right)_{i,t} \quad (2)$$

4.2.4. Value Monopoly (PA)

According to Jia Jun's (2024) [26] definition of value exclusivity, in this paper, the operating income minus the derivative value of the patent in the current year is adopted for measurement. The specific measurement formula is as follows:

$$PA = \ln \left[1 + \text{Operating Income} * \left(1 - \frac{\text{Self-citation}}{\text{Total citations}} \right) \right] \quad (3)$$

4.2.5. Competition Intensity (CI)

Combined with the measurement method of Boone [33] et al., this paper adopts the reciprocal of the Herfindahl index and logarithms it for measurement. Among them, i is the operating income of enterprise i , and X is the operating income of the entire industry. The smaller the reciprocal value of the Herfindahl index of an industry is, the weaker the competition the enterprise is facing.

$$CI = \ln(1/HHI) = \ln \left[1 / \sum \left(\frac{X_i}{X} \right)^2 \right] \quad (4)$$

4.2.6. Control Variable

This study refers to the research of Zhang Yun et al. (2023) and sets the following control variables: Management expense ratio (Mfee), return on equity (ROE), management shareholding ratio (Mshare), Occupy of major shareholders, Female proportion of management, ChairHold of the chairman, total number of shareholders (TTN), and annual dummy variable (Year). The specific variable names and definitions are shown in Table 1 below:

Table 1. Variable Definition.

Variable Name	Variable Meaning	Calculation Method
<i>Innovation</i>	Technological Innovation	The logarithm of the number of authorized invention patents plus 1
<i>Index</i>	Digital Inclusive Finance Index	Report on "Peking University Digital Inclusive Finance Index (2011-2020)"
<i>FC</i>	Financing Restriction	It is calculated based on the regression results of the Logistic model constructed in this paper
<i>PA</i>	Value Monopoly	$\ln(1 + \text{Operating income} * (1 - (\text{self-cited} / \text{total cited})))$
<i>CI</i>	Competitive Intensity	$\ln(1/HHI)$
<i>Mfee</i>	Management Expense Ratio	Administrative expenses/Operating income
<i>ROE</i>	Return on Net Worth	Net profit/Average balance of owner's equity
<i>Mshare</i>	Managers Own Significant Stakes	The number of shares held by directors, supervisors and senior management/the total number of shares
<i>Occupy</i>	The Major Shareholder's Capital Occupation	Net other receivables/Total assets
<i>Female</i>	The Proportion of Women in Management	$\frac{\text{The number of women in management}}{\text{The total number of management}}$
<i>ChairHold</i>	The Number of Shares Held by The Echairman	The number of shares held by the chairman, unit: shares
<i>TTN</i>	Total Number of Shareholders	Total number of shareholders, unit: pieces
<i>SOE</i>	A State-owned Enterprise or not	State-controlled enterprises have 1, while others have 0
<i>LAB</i>	A Labor-intensive Enterprise or not	Labor-intensive is 1 and others are 0
<i>Year</i>	Year	The annual dummy variable takes the value of 1 if it belongs to that year, and 0 for others

4.3. Model Specification

Considering that this paper is an analysis and research based on panel data, and at the same time to alleviate possible missing variables and other issues in the model design.

This paper adopts a bidirectional fixed effect for empirical analysis and constructs the following model to explore the aforementioned research hypotheses:

To explore Hypothesis H1, Model (5) is constructed:

$$\begin{aligned} Innovation_{i,t} = & \alpha_0 + \alpha_1 Index_{i,t} + \alpha_2 Mfee_{i,t} + \alpha_3 ROE_{i,t} + \alpha_4 Mshare_{i,t} + \alpha_5 Occupy_{i,t} + \\ & \alpha_6 Female_{i,t} + \alpha_7 ChairHold_{i,t} + \alpha_8 TTN_{i,t} + \varphi_{i1} + \lambda_{t1} + \varepsilon_{it} \end{aligned} \quad (5)$$

To explore Hypothesis H2, Model (6) and Model (7) were constructed respectively:

$$\begin{aligned} FC_{i,t} = & \beta_0 + \beta_1 Index_{i,t} + \beta_2 Mfee_{i,t} + \beta_3 ROE_{i,t} + \beta_4 Mshare_{i,t} + \beta_5 Occupy_{i,t} + \\ & \beta_6 Female_{i,t} + \beta_7 ChairHold_{i,t} + \beta_8 TTN_{i,t} + \varphi_{i2} + \lambda_{t2} + \sigma_{it} \end{aligned} \quad (6)$$

$$\begin{aligned} Innovation_{i,t} = & \gamma_0 + \gamma_1 Index_{i,t} + \gamma_2 FC_{i,t} + \gamma_3 Mfee_{i,t} + \gamma_4 ROE_{i,t} + \gamma_5 Mshare_{i,t} + \\ & \gamma_6 Occupy_{i,t} + \gamma_7 Female_{i,t} + \gamma_8 ChairHold_{i,t} + \gamma_9 TTN_{i,t} + \varphi_{i3} + \lambda_{t3} + \theta_{it} \end{aligned} \quad (7)$$

Among them: i represents the enterprise, t represents the year, φ_i is the individual effect of the enterprise, λ_t is the time effect, and $\varepsilon_{i,t}$, $\sigma_{i,t}$ and $\theta_{i,t}$ respectively represent the random disturbance terms of each model. α_1 Is the key parameter for exploring Hypothesis H1? If α_1 is significantly greater than 0, hypothesis H1 is verified, indicating that the development of digital inclusive finance can effectively promote enterprise technological innovation, and vice versa. β_1 , γ_1 and γ_2 are the key parameters for exploring Hypothesis H2. If β_1 is significantly less than 0, it indicates that digital inclusive finance can alleviate the financing constraints faced by enterprises. If α_1 , β_1 and γ_2 are all significant, it indicates that financing constraints play a mediating role in promoting the technological innovation of enterprises by digital inclusive finance. Further exploration shows that if parameter γ_1 is significant and $\gamma_1 < \alpha_1$, it indicates that financing constraints play a partial mediating role between the two. If parameter γ_1 is not significant, it indicates that financing constraints play a completely mediating role between the two (Wen Zhonglin and Ye Baojuan, 2014).

5. Empirical Analysis

5.1. Descriptive Statistical Analysis

Table 2 reports the descriptive statistical results of the main variables. The standard deviation of enterprise technological Innovation is 1.246, the maximum value is 5.124, and the minimum value is 0, indicating that there are significant differences in the level of technological innovation among the sample enterprises. The average degree of financing constraints (FC) faced by enterprises is 0.456, indicating that Chinese enterprises as a whole face relatively severe financing constraints during their development process. This also reflects the current situation of difficult financing for Chinese enterprises. The minimum value of the DIFI indicator for measuring the degree of digital inclusive finance is 57.88, the maximum value is 351.55, and the standard deviation is 72.00, indicating that there are significant differences in the development of digital inclusive finance in the regions where various physical enterprises are located.

Table 3 reports the Pearson correlation coefficients among the main variables. The multicollinearity test results for each variable of the model show that the maximum value of the variance inflation factor is 2.07 and the mean is 1.38, which is much smaller than the empirical critical value of 10, indicating that there is no severe multicollinearity in the above model Settings. The core variable we focus on, digital inclusive finance, is positively correlated with the technological

innovation level of enterprises and is significant at the 1% significance level. Considering that the above observation results do not take into account the heterogeneity characteristics such as individual companies and time, as well as other factors that may affect the relationship between the two, further tests and investigations will be conducted through regression analysis.

Table 2. Basic Statistics.

Variable	Sample Value	Average	Standard Deviation	Minimum Value	Maximum Value
<i>Innovation</i>	16,763	1.515	1.246	0	5.124
<i>Index</i>	16,763	234.6	72.00	57.88	351.5
<i>FC</i>	16,763	0.456	0.279	0.00381	0.932
<i>PA</i>	16,763	21.64	1.414	18.79	25.76
<i>CI</i>	16,763	2.004	0.680	0.106	3.243
<i>Mfee</i>	16,763	0.0888	0.0646	0.00999	0.374
<i>ROE</i>	16,763	0.0670	0.117	-0.489	0.340
<i>Mshare</i>	16,763	13.86	19.20	0	66.66
<i>Occupy</i>	16,763	0.0143	0.0197	0.000232	0.121
<i>Female</i>	16,763	18.53	10.80	0	47.06
<i>ChairHold</i>	16,763	4.451e+07	8.844e+07	0	4.965e+08
<i>TTN</i>	16,763	49,475	52,402	5,230	309,005
<i>Number of code</i>	2,982	2,982	2,982	2,982	2,982

Table 3. The Correlation Coefficient Matrix of the Main Variables.

	Innovation	Index	FC	CI	PA	Mfee	ROE	Mshare	Occupy	Female	ChairHold
<i>Index</i>	0.151***										
<i>FC</i>	-	0.260***	-0.00500								
<i>CI</i>	0.067***	0.028**	0.096**								
<i>PA</i>	0.332***	0.051**	0.765**	0.114**							
<i>Mfee</i>	-	0.155**	0.282**	0.069**	0.510**						
<i>ROE</i>	0.074***	0.023**	0.019**	0.029**	0.193**	0.209**					
<i>Mshare</i>	-	0.109**	0.425**	0.066**	0.349**	0.128**	0.063**				
<i>Occupy</i>	-	-0.0120	0.117**	-0.016**	0.064**	0.054**	0.154**	0.081**			
<i>Female</i>	-	0.215**	0.181**	0.067**	0.224**	0.062**	-0.019**	0.182**	0.015*		
<i>ChairHold</i>	0.077***	0.160**	0.026**	0.041**	-0.018**	0.022**	0.037**	0.579**	-	0.131**	
<i>TTN</i>	0.249***	0	0.517**	0.075**	0.546**	0.168**	0.024**	0.300**	0.054**	-	-0.017**
<i>Index</i>	0.151***										

Note: "*", "**", and "***" respectively indicate significance at the 10%, 5%, and 1% significance levels, the same below.

5.2. Regression Analysis

Column (1) of Table 4 analyzes the impact of digital inclusive finance on enterprise technological innovation. The regression coefficient of digital inclusive finance is 0.0042 and is significant at the 1% significance level, indicating that digital inclusive finance helps solve the "double high" problem of enterprises, improve the risk-bearing level and governance efficiency of enterprises, expand the R&D team, and promote enterprise technological innovation. Suppose H1 is verified.

Drawing on the research methods of Wen Zhonglin and Ye Baojuan (2014), the stepwise test regression coefficient method was first adopted to test the mediating effect of financing constraints. The regression results of Model (1) show that digital inclusive finance can significantly improve the technological innovation level of enterprises; the regression results of Model (2) show that digital inclusive finance significantly alleviates the financing constraints of enterprises. Model (3) adds the financing constraint (FC) to the control variables based on the setting of Model (1). The results in column (3) of Table 4 show that the regression coefficients of digital inclusive finance and financing constraint are 0.0038 and -0.409 respectively, both of which are significant at the 1% significance level. After adding the financing constraint variable on the basis of Model (1), the regression coefficient of digital inclusive finance decreased from the original 0.0042 to 0.0038, indicating that the financing constraint plays a partial mediating effect between digital inclusive finance and enterprise technological innovation. Digital inclusive finance can alleviate the financing constraints of enterprises by broadening financing channels, reducing financing costs and improving financing efficiency, thereby promoting the innovation activities of enterprises. Hypothesis H2 is verified.

Furthermore, if the Sobel method is used to test whether the regression coefficients in model (2) are significantly different from 0, it indicates that the mediating effect holds; otherwise, there is no mediating effect. The results of the Sobel test are shown in Table 4. It is significantly not zero at the 1% level, indicating that financing constraints play a partial mediating role between digital inclusive finance and enterprise technological innovation, and the mediating effect ratio is 10.49%.

Column (4) of Table 4 analyzes the empirical results of the moderating effect of value exclusivity on the relationship between digital inclusive finance and enterprise technological innovation. The regression coefficient of the cross-multiplication term $PA \times Index$ is 0.001 and significant at the 1% significance level. It can be seen from this that enterprises with strong value exclusivity capabilities can comprehensively design knowledge protection and knowledge disclosure strategies, and thereby enhance the incentive effect of digital inclusive finance innovation.

Column (5) of Table 4 analyzes the empirical results of the moderating effect of competitive intensity on the relationship between digital inclusive finance and enterprise technological innovation. The regression coefficient of the cross-multiplication term $CI \times Index$ was -0.001 and significant at the 1% significance level. It can be seen from this that when facing fierce market competition, enterprises and financial institutions will avoid risks. At the same time, enterprises will reduce innovation investment, and the promoting effect of digital inclusive finance on enterprise technological innovation will weaken.

Table 4. The Correlation Coefficient Matrix of the Main Variables.

VARIABLES	(1) Innovation	(2) FC	(3) Innovation	(4) Innovation	(5) Innovation
Index	0.0043*** (3.75)	-0.0011*** (-5.63)	0.0038*** (3.36)	0.0032*** (2.88)	0.0040*** (3.47)
FC			-0.4092*** (-8.22)		
PA*Index				0.0009*** (12.16)	
PA				0.1995*** (13.11)	
CI*Index					-0.0006*** (-4.40)
CI					-0.0557*** (-2.78)
Mfee	-0.3817** (-2.15)	0.3030*** (10.01)	-0.2577 (-1.45)	0.3118 (1.64)	-0.4021** (-2.26)

Continued Table 4. The Correlation Coefficient Matrix of the Main Variables.

VARIABLES	(1) Innovation	(2) FC	(3) Innovation	(4) Innovation	(5) Innovation
ROE	-0.1502** (-2.32)	0.2512*** (22.69)	-0.0475 (-0.72)	-0.3083*** (-4.76)	-0.1481** (-2.29)
Mshare	-0.0010 (-1.10)	0.0029*** (18.37)	0.0002 (0.19)	-0.0024** (-2.53)	-0.0011 (-1.15)
Occupy	-0.7168* (-1.70)	-0.0096 (-0.13)	-0.7207* (-1.71)	-0.7334* (-1.76)	-0.7285* (-1.72)
Female	-0.0042*** (-3.79)	0.0004* (1.87)	-0.0040*** (-3.67)	-0.0029*** (-2.68)	-0.0043*** (-3.88)
ChairHold	0.0000*** (4.95)	-0.0000*** (-21.87)	0.0000*** (3.37)	0.0000*** (4.35)	0.0000*** (5.16)
TTN	0.0000*** (7.90)	-0.0000*** (-7.14)	0.0000*** (7.40)	0.0000*** (5.38)	0.0000*** (7.85)
Year	Yes	Yes	Yes	Yes	Yes
Sobel Test	Mediating variable: Financing constraint 0.0045 * * *				
Ind_eff Test (P_value)	Effective mechanism - positive transmission 0.000 The indirect effect holds.				
Constant	0.5691*** (5.84)	0.5348*** (32.13)	0.7879*** (7.82)	-3.5920*** (-10.55)	0.7100*** (6.77)
Observations	16,763	16,763	16,763	16,763	16,763
R-squared	0.146	0.252	0.150	0.166	0.147
Number of code	2,982	2,982	2,982	2,982	2,982
F test	0	0	0	0	0
r2_a	-0.0406	0.0887	-0.0356	-0.0160	-0.0391
F	123.5	243.8	121.2	130.4	112.9

Note: The t-statistic in parentheses is adjusted for robust standard errors after clustering at the enterprise level. The same applies below.

5.3. Endogeneity Test

Robust standard errors and the control of fixed effects can help avoid the interference of heteroscedasticity on the estimation results. However, measurement errors between the explanatory variables and the explained variables, as well as omitted variables, may still lead to endogeneity problems. In order to control this endogeneity bias problem, drawing on the practice of Du Yongshan

et al. [35], the digital inclusive finance index lagging by one period was adopted as the instrumental variable, and the GMM two-stage method was used for endogeneity testing.

Table 5 shows the regression results of the two-stage method of GMM. The results in column (1) of Table 5 show that the instrumental variable (*Lindex*) is significantly positively correlated with enterprise technological Innovation at the significance level of 1%. The results in column (2) show that the instrumental variable (*Lindex*) is significantly negatively correlated with the enterprise financing constraint (FC) at the significance level of 1%. The results in column (3) show that after adding the financing constraint variable (FC), the regression coefficient of the instrumental variable (*Lindex*) decreased from the original 0.0067 to 0.0064, and the financing constraint (FC) played a partial mediating effect between the instrumental variable (*Lindex*) and enterprise technological Innovation (Innovation). The above test results are completely consistent with the regression analysis results in the previous text, indicating that the endogenous bias problem caused by measurement errors and omitted variables has little influence on the research conclusion of this paper. The aforementioned research conclusion is robust.

Table 5. Regression Results of the Instrumental Variable Method.

VARIABLES	(1) Innovation	(2) FC	(3) Innovation
<i>L.Index</i>	0.0067*** (4.91)	-0.0009*** (-3.92)	0.0064*** (4.68)
<i>FC</i>			-0.3798*** (-6.09)
<i>Control Variable</i>	Yes	Yes	Yes
<i>Observations</i>	12,471	12,471	12,471
<i>R-squared</i>	0.119	0.245	0.122
<i>Number of code</i>	2,498	2,498	2,498
<i>F test</i>	0	0	0
<i>r2_a</i>	-0.104	0.0537	-0.0996
<i>F</i>	74.70	179.0	72.98

Note: Due to space limitations, only the regression results of the main explanatory variables are listed in the table. The same below.

There is an uncertainty risk in patent granting, and the patent technology may have an impact on the investment of enterprise performance during the application process. Therefore, in order to ensure the robustness of the results, this paper adopts the number of invention patent applications as an indicator of enterprise technological innovation (Innovation2). The new regression results are shown in Table 6. The results in columns (1) - (3) indicate that there are no significant changes in the regression coefficients and significance of the main variables. The partial mediating effect of the financing constraint still holds significantly. The regression results are consistent with the original empirical results, and the test results still support the research hypotheses mentioned earlier.

Table 6. Robustness Test.

VARIABLES	(1) Innovation2	(2) FC	(3) Innovation2
<i>Index</i>	0.0035*** (2.75)	-0.0011*** (-5.63)	0.0026** (2.07)
<i>FC</i>			-0.8062*** (-14.67)
<i>control variable</i>	Yes	Yes	Yes
<i>Observations</i>	16,763	16,763	16,763
<i>R-squared</i>	0.197	0.252	0.209
<i>Number of code</i>	2,982	2,982	2,982
<i>F test</i>	0	0	0
<i>r2_a</i>	0.0214	0.0887	0.0364
<i>F</i>	177.2	243.8	181.7

6. Further Analysis

6.1. Heterogeneity of Property Rights Characteristics

There exists the problem of ownership discrimination in credit services under the traditional financial system [25]. State-owned enterprises, with the government as an implicit guarantor, can obtain a greater amount of financial support with a longer term. However, there exists an information asymmetry problem between private enterprises and financial institutions. Financial institutions are unable to accurately assess the credit status of enterprises, making it difficult for enterprises to obtain a sufficient amount of loans with low costs and long terms, and failing to meet the requirements of high costs and long cycles for innovation investment. The emergence of digital inclusive finance has alleviated the degree of information asymmetry, reduced financing costs, broadened financing channels, and provided research and development fund support for private enterprises. In addition, private enterprises are more open and inclusive towards new business models and technologies, and are more proactive in exploring and applying digital inclusive finance, which to a certain extent promotes the innovation and upgrading of enterprises. Therefore, compared with state-owned enterprises, the innovation-driven effect of digital inclusive finance in private enterprises is more obvious.

The samples were divided into two sub-samples, namely non-state-owned enterprises and state-owned enterprises, based on the nature of enterprise property rights. Regression analyses were conducted respectively, and the results are shown in columns (1) and (2) of Table 7. The results show that the regression coefficient of the digital inclusive finance (Index) in the non-state-owned enterprise sample group is 0.006 and significant at the 1% significance level, while the estimated coefficient of the Index in the state-owned enterprise sample group is not significant, verifying the aforementioned theoretical analysis results.

6.2. Heterogeneity of Resource Endowment

According to the classification standard of factor intensity, enterprises can be divided into three categories: labor-intensive, capital-intensive and technology-intensive enterprises. Compared with labor-intensive enterprises that create value through simple labor, capital-intensive enterprises and technology-intensive enterprises rely more on capital and technology and pursue innovation in products and technologies more [37]. The large amount of capital investment in enterprise innovation activities has led to a more urgent demand for financing. Digital inclusive finance can help enterprises better obtain financial support, thereby promoting the innovative development of enterprises. In addition, capital-intensive enterprises and technology-intensive enterprises usually possess a large amount of data and information resources, which can better leverage the data analysis advantages of digital inclusive finance, further explore the value of data, and apply it to the innovation and development of enterprises. Therefore, compared with labor-intensive enterprises, the innovation-driven effect of digital inclusive finance is more obvious in capital-intensive enterprises and technology-intensive enterprises.

Referring to the research of Xu Hui et al. (2024), in this paper, enterprises with a proportion of fixed assets higher than the median are classified as capital-intensive enterprises, enterprises with a proportion of R&D expenses higher than the median are classified as technology-intensive enterprises, and the remaining enterprises are classified as labor-intensive enterprises. Then, capital-intensive and technology-intensive enterprises were combined into one group, namely the capital-technology-intensive enterprise sample group. Regression analyses were conducted on the two sub-samples of capital-technology-intensive enterprises and labor-intensive enterprises respectively. The results are shown in columns (3) and (4) of Table 7. The results show that the regression coefficient of digital inclusive finance (Index) for capital and technology-intensive enterprises is 0.004, and it is significant at the 5% significance level, while the estimated coefficient of the Index for the labor-intensive enterprise sample group is not significant, verifying the aforementioned theoretical analysis results.

Table 7. Heterogeneity analysis.

	Private Enterprise	State-owned Enterprises	Capital and technology-intensive	Labor-intensive
VARIABLES	(1) Innovation	(2) Innovation	(3) Innovation	(4) Innovation
<i>Index</i>	0.0056*** (2.78)	0.0040 (1.60)	0.0040** (2.08)	0.0031 (1.31)
<i>Control Variable</i>	Yes	Yes	Yes	Yes

Continued Table 7 Heterogeneity analysis				
	Private Enterprise	State-owned Enterprises	Capital and technology-intensive	Labor-intensive
VARIABLES	(1) Innovation	(2) Innovation	(3) Innovation	(4) Innovation
<i>Observations</i>	10,961	5,802	12,142	4,621
<i>R-squared</i>	0.131	0.176	0.156	0.111
<i>Number of code</i>	2,164	986	2,223	981
<i>r2_a</i>	0.130	0.174	0.155	0.107
<i>F</i>	.	24.23	.	14.19

7. Conclusions and Suggestions

Digital inclusive finance, as an emerging form of financial services, has had a significant impact on the development of China's real economy. This paper takes A-share listed companies in China from 2011 to 2022 as samples and adopts the fixed effect model and the mediating effect model to empirically test the impact and transmission path of digital inclusive finance on enterprise technological innovation. The research results show that: First, digital inclusive finance has a significant positive impact on enterprise technological innovation. Secondly, mechanism tests show that digital inclusive finance can promote the improvement of enterprises' technological innovation level by alleviating their financing constraints. Thirdly, value monopoly positively moderates the relationship between digital inclusive finance and enterprise technological innovation. The intensity of competition negatively regulates the relationship between digital inclusive finance and enterprise technological innovation. Fourth, digital inclusive finance has a significantly better promoting effect on technological innovation in private enterprises than in state-owned enterprises, and a significantly better promoting effect on technological innovation in capital-intensive and technology-intensive enterprises than in labor-intensive ones.

Based on the above conclusions, this paper puts forward the following suggestions:

First, actively promote the rapid development of digital inclusive finance and achieve precise alignment between digital inclusive finance and the real economy. In terms of specific policy implementation, the government should encourage the digital transformation and upgrading of financial institutions, deepen the reform of the traditional financial system, and enable financial institutions to better serve the real economy. In addition, improve the credit assessment system, reduce the degree of information asymmetry between enterprises and financial institutions, promote the development of financial services towards multiple channels, low cost and high efficiency, and assist enterprises in technological innovation.

Secondly, to avoid the risks that may be brought about by the application of digital technology in the financial field, especially for enterprises with low exclusive value capabilities or those in industries with high competitive intensity, managers should adopt appropriate innovation exclusive mechanisms, strengthen the protection of knowledge, and prevent relevant information from being stolen by competitors. Financial institutions should enhance the protection of platform information security to ensure that the acquisition and use of customer data are legal and compliant. In addition, government departments should accelerate the establishment of digital finance laws and regulations, improve the intellectual property protection system, crack down on illegal acts such as intellectual property infringement, promote the realization of enterprises' innovation value, and enhance their enthusiasm for innovation.

Thirdly, the government should guide enterprises to correctly understand the relationship between innovation investment and commercialization investment, rationally allocate financial assets, and ensure the sustainability of enterprise technological innovation while achieving the commercialization of technological innovation. Furthermore, the government should create a fair competitive environment and avoid vicious competition. For industries with excessive competition, the government's regulatory role should be strengthened to avoid the reduction of enterprises' motivation for technological innovation caused by vicious price competition.

Local governments should deepen the reform of "streamlining administration, delegating power, improving regulation and upgrading services", give equal treatment to state-owned enterprises and private enterprises in terms of financial subsidies and investment and financing, and eliminate the implicit guarantees of state-owned enterprises. Meanwhile, the government should guide digital inclusive finance to provide financial support to capital-intensive and technology-intensive enterprises, and fully unleash the innovation-driven effect of digital inclusive finance. The government can also ensure enterprises' investment in technological innovation through tax reduction or exemption or research and development subsidies.

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