

Xiong, Mingzhao; Li, Wenqi; Xian, Brain Teo Sheng; Yang, Ao

Article

Digital inclusive finance and enterprise innovation: Empirical evidence from Chinese listed companies

Journal of Innovation & Knowledge (JIK)

Provided in Cooperation with:

Elsevier

Suggested Citation: Xiong, Mingzhao; Li, Wenqi; Xian, Brain Teo Sheng; Yang, Ao (2023) : Digital inclusive finance and enterprise innovation: Empirical evidence from Chinese listed companies, Journal of Innovation & Knowledge (JIK), ISSN 2444-569X, Elsevier, Amsterdam, Vol. 8, Iss. 1, pp. 1-9, <https://doi.org/10.1016/j.jik.2023.100321>

This Version is available at:

<https://hdl.handle.net/10419/327233>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>

Digital inclusive finance and enterprise innovation—Empirical evidence from Chinese listed companies



Mingzhao Xiong^{a,b,c}, Wenqi Li^{b,*}, Brain Teo Sheng Xian^a, Ao Yang^{a,b}

^a Graduate School of Management, Management and Science University, Shah Alam, Selangor, Malaysia

^b School of Economics and Trade, Henan University of Technology, Zhengzhou 450001, China

^c Zhumadian Vocational and Technical College, Zhumadian 463700, China

ARTICLE INFO

Article History:

Received 29 April 2022

Accepted 1 January 2023

Available online 27 January 2023

Keywords:

Digital inclusive finance

Enterprise innovation

Financing constraint

Entrepreneur risk-taking spirit

ABSTRACT

The development of Digital Inclusive Finance (DIF) offers new opportunities for corporate innovation. This study empirically explores the influence of DIF on firms' R&D and innovation output via a two-way fixed-effects model and an instrumental variable method using the 2011–2018 Peking University Digital Financial Inclusive Index to match city-level data of A-share listed companies. The results show that DIF plays a positive role in boosting company R&D innovation. Among the three DIF sub-dimensions, DIF coverage is the most significant in promoting R&D innovation. The role of DIF in promoting corporate R&D and innovation is most prominent for private enterprises, small and medium-sized enterprises, secondary and tertiary industries, and high-growth enterprises. In addition, DIF helps foster enterprise R&D innovation and can gratify the desire for innovation felt by adventurous business owners. Further analysis reveals that internal financing constraints and external banking competition have intermediary effects on the promotion of enterprise innovation, which are observed for the three sub-dimensions of DIF. The results of an instrumental variable regression and other robustness tests confirm the main findings.

© 2023 The Authors. Published by Elsevier España, S.L.U. on behalf of Journal of Innovation & Knowledge. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Introduction

In recent years, Digital Inclusive Finance (DIF) has helped usher all aspects of the financial industry into an era of rapid innovation and upgrading. The emergence of DIF has reshaped China's financial landscape and transformed the country into a digital finance leader. Through modern technology, DIF has reduced the dependence of traditional finance on offline physical outlets, leading to a qualitative leap in China's inclusive financial development (Liu, Zhu, Guo & Cui, 2021). The concept of "inclusive finance" has been emphasized in government work reports since its introduction in the Third Plenary Session of the 18th Central Committee of the Communist Party of China. Studies have shown that DIF plays an important role in promoting economic growth (Jiang, Wang, Ren & Xie, 2021), narrowing the income gap between urban and rural areas (Ji, Wang, Xu & Li, 2021; Yu & Wang, 2021), driving the transformation and upgrading of industrial structures (Liu, Liu & Zhou, 2021; Su, Su & Wang, 2021), and promoting consumption (Li, Wu & Xiao, 2020). In this way, DIF not only empowers the real economy but also drives high-quality economic development (Lin, Prabhala & Viswanathan, 2013).

China's economic growth is driven mainly by investment, which is fueled by innovation. The report to the 19th CPC National Congress pointed out that innovation is the primary driving force for development and serves as a strategic underpinning for building a modernized economy. However, China's financial repression index, which was 1 in 1980 (indicating a high degree of financial repression), was 0.6 in 2015, ranking China 14th among more than 130 countries with available data. This indicates that China's intervention in the financial system remains relatively high. Moreover, real enterprises generally face supply shortages in the formal financial system; thus, enterprises with high risks and uncertainties tend to face difficulties in obtaining sustained and stable financial support for their R&D and innovation activities and in achieving high-quality and large-scale innovation (Brown, Martinsson & Petersen, 2012). The emergence of DIF provides a new way for these enterprises to face the challenges associated with traditional finance. By relying on big data, cloud computing, and other means, DIF can improve the loan approval efficiency of financial institutions, reduce their financing constraints, and help promote their R&D and innovation (Fuster, Plosser, Schnabl & Vickery, 2019; Yang & Zhang, 2020).

The new financial services model of digital finance has had profound impacts on the traditional financial industry. Since DIF is relatively new in China, research on its relationship with corporate

* Corresponding author.

E-mail address: liwenqi@haut.edu.cn (W. Li).

innovation is still in the preliminary stage. Several scholars have explored how digital-related technologies in the financial sector impact corporate innovation from the perspective of financial technology. The development of science and technology can lead to the development of financial markets and Internet finance, which can multiply financing channels and opportunities for enterprises, improve the external financing environment for small and medium-sized enterprises, and foster innovative activities. Acharya and Xu (2017) analyzed patent numbers and patent citation data from 1976 to 2006 in the patent citation database of the National Bureau of Economic Research (NBER) and found that listed companies relying on external financial industry invested more in R&D and produced better innovation performance than private enterprises (Acharya & Xu, 2017). The research indicates that financing difficulties have impacted both private and foreign-funded enterprises in China, as well as the innovation ability of state-owned enterprises (Guariglia & Liu, 2014) and that the real economy needs to have its financing constraints alleviated; an enterprise needs sufficient "blood" in order to have the energy required to carry out innovation (Wellalage & Fernandez, 2019). Zhang and Chi (2018) studied how the development of Internet inclusive finance impacts the innovation activities of micro and small enterprises using data obtained from 1857 questionnaires distributed to micro and small enterprises plus data from P2P online lending platforms. They found that the development of Internet finance in a region can not only promote firms' capital investment in innovation activities but also increase the frequency of their innovation (Zhang & Chi, 2018). Tang, Ding, Gao & Zhao (2022) used data on A-share strategic emerging enterprises listed on the Shanghai and Shenzhen stock exchanges covering 2011 to 2018 to explore the impact of digital finance on the value of strategic emerging enterprises. The study found that the development of digital finance has a structural driving effect on the value of such enterprises. Enterprise innovation ability is an important aspect reflecting the value of strategic emerging enterprises, and it is thus worthwhile investigating its internal correlation with digital finance (Tang, Ding, Gao & Zhao, 2022).

The continuous development of DIF and related metrics, especially the Peking University Digital Inclusion Index released by the Peking University Digital Finance Research Center, has prompted an increasingly number of scholars to study the impact of DIF on corporate innovation activities. Matching the digital inclusive finance index with the innovation output data of listed companies, Wan, Zhou & Xiao (2020) found that DIF can significantly contribute to innovation output and that financing constraints play an important mediating role in this process. The effect of DIF on corporate innovation is most significant among small and medium-sized enterprises (SMEs) and private firms (Wan, Zhou & Xiao, 2020). Yu, Ping, Dou and Junxia (2020) similarly found that the innovation promotion effect of digital inclusive finance on SMEs is seen mainly in its alleviation of financing constraints and is concentrated in firms that have poor internal governance and that operate in regions with better institutional environments (Yu & Dou, 2020). Zhao, Zhong and Guo (2021) found that DIF can alleviate financial mismatch between enterprises and that the mediating effect of financial mismatch is significant for all three DIF sub-dimensions (Zhao et al., 2021).

A review of the domestic and international literature indicates that most scholars agree that the development of DIF can help alleviate the financing constraints of enterprises, which in turn increases their expenditure on innovation and R&D and promotes their innovation activities. However, relatively few scholars have focused on how DIF impacts corporate innovation. Therefore, this study examines the relationship between DIF and corporate R&D innovation from the perspective of R&D investment in order to provide new experimental data.

This study makes several important contributions to the literature. First, it expands the existing analytical framework on financial development level and enterprise R&D innovation behavior while

examining the influence of DIF on the innovation R&D behavior of micro-enterprises with varying company holding risk and manager risk characteristics. Second, by using the mediating effect model, this study empirically examines the effect mechanism of DIF on the R&D innovation of enterprises from two perspectives: external banking competition and internal financing constraints. The results provide reliable empirical evidence that can be used to optimize DIF for real economy innovation and offer theoretical guidance, empirical support, and inspiration for promoting the innovation and R&D of micro-enterprises.

The rest of this paper is structured as follows. The next section presents a theoretical analysis and hypotheses. The third section explains the study's data sources and empirical models. The fourth section presents the study's empirical results and analysis, including a regression of DIF on enterprise innovation, heterogeneity analysis, and action mechanism test. Finally, the fifth section concludes the paper and discusses its implications.

Theoretical background and hypothesis development

The development of China's traditional financial system is still imperfect and faces several problems, such as a distorted allocation of financial factors and resources, imperfect financial facilities in underdeveloped areas, small coverage of financial services, and severe external financing constraints for SME. These problems have hindered the country's economic development. This is especially true for SMEs, which have long been subject to financial exclusion. Although China has established an SME Board and GEM Board to broaden the financing channels for MSMEs, they still face strong external financing constraints and higher financing costs, due either to a lack of capital, irregular operation, and the small scale of their development before their listing or to high operational risks, unstable revenues, and information misalignment after their listing. The development of DIF can alleviate the problems posed by difficult and expensive financing for MSMEs and thus promote their R&D and innovation activities. Digital inclusive finance and digitalization can provide a large number of MSMEs pursuing active innovation and facing large capital gaps with a better financing channel than traditional finance can provide (Han & Gu, 2021). Digital inclusive finance promotes enterprise innovation in several ways.

First, DIF lowers the funding threshold for enterprises and thus widens financing channels. Funding from the traditional financial industry depends mainly on firms' collateral, and SMEs have difficulty obtaining loans because of their small development estimates, unstable operations, and lack of high-value collateral. However, the dynamic and innovative activities of SMEs often require significant and continuous funding. Digital inclusive finance can collect data on SMEs' usage and daily transaction activities through the Internet and other financial technologies, and use these data as the basis for credit risk assessment, so as to provide efficient and convenient financial services to "long-tail" customers such as SMEs while imposing relatively low financial service thresholds and costs.

Second, DIF reduces financing costs and prevents credit risks. It uses advanced technology to establish enterprise risk control, information processing, and detection systems. These systems can collect SMEs' credit information quickly; help financial institutions more comprehensively and systematically analyze SMEs' profitability, solvency, and growth capacity; assess SMEs' credit rating and default risks efficiently; and reduce the information asymmetry present in traditional lending activities. These information screening and risk identification functions can thus reduce information collection, processing, risk assessment, and transaction costs, thereby reducing the financing costs of SMEs.

Finally, DIF can help build a credit system and improve financing efficiency. It provides financial institutions with the opportunity to provide loans to SMEs mainly based on their credit information,

without requiring physical collateral as a guarantee to mitigate financial risks; this can lead to a credit system for SMEs. Digital inclusive finance can collect, mine, organize, and analyze SMEs' financial data in great detail; integrate SMEs' past transaction records; and make more accurate development predictions. This can lead to a more multidimensional and effective credit system for SMEs and alleviate the information asymmetry between enterprises and financial institutions.

In addition, with the strong support of national policies, DIF is benefiting an increasing number of SMEs, providing them with continuous and affordable financial support. The overall abundance of resources in the industry has also brought about increased competition in the industry, and this digital inclusive competitive effect will force SMEs to engage in technological innovation to gain new competitive advantages. Based on the above analysis, we propose the following:

Hypothesis 1. Digital financial inclusion can promote enterprise R&D and innovation.

Digital inclusive finance can promote SMEs' R&D investment in innovative activities. Different firms face different financing constraints; thus, the effect of this promotion is heterogeneous across SMEs.

Ownership difference, between state-owned and private enterprises, is a concrete manifestation of enterprise heterogeneity. State-owned enterprises are highly connected to local governments. Through their "fatherly motivation," local governments provide support to state-owned enterprises in order to alleviate the financing constraints associated with their R&D and innovation investment across various stages of the economic cycle (Liu, Luan, Wu, Zhang & Hsu, 2021). By contrast, private enterprises have more financing needs, and DIF thus plays a more significant role in promoting their R&D and innovation.

Moreover, SMEs face greater financing constraints than larger firms and often encounter difficulties in securing loans from formal financial institutions. The introduction of DIF aims to improve access among various institutions and vulnerable groups that are ignored by traditional financial institutions and help them secure appropriate and effective financial services (Zhong & Jiang, 2021). Therefore, the development of DIF has been viewed as a breakthrough in solving the financing difficulties of SMEs.

High-growth companies have more growth opportunities; these tend to be newly established enterprises with relatively low profitability and insufficient cash flow. These enterprises are also accompanied by high risks and uncertainties. Companies that want to raise funds for investment projects need to secure external financing to fill their funding gaps, and DIF provides an effective solution to this problem (Luo, Zhang & Zhou, 2018). Given their relatively mature profit model and sufficient cash flow, most low-growth companies have a relatively weak demand for external capital.

Digital inclusive finance is also conducive to the innovation and development of enterprises with a stronger risk-taking spirit. Innovation is defined as investment in the research and development of new products and technologies. This process usually involves large investments, a long R&D cycle, and a high risk of failure. When formulating an innovation strategy, managers must bear huge decision-making risks, while the enterprise needs to eliminate its dependence on stable cash flow projects and look for creative and profitable high-risk projects. The risk-taking spirit of entrepreneurs serves as the basis for an enterprise's engagement in such high-risk activities (Santos-Vijande, López-Sánchez, Loredo, Rudd & López-Mielgo, 2022). Entrepreneurs with a higher risk-taking spirit tend to invest their capital in innovative activities at the same capital level. The R&D and innovation of an enterprise depend on its ability and willingness to innovate. The development of DIF solves the innovation problems associated with limited capital, and the risk-taking spirit of

entrepreneurs is the preferred path of enterprise innovation activities. Based on the above analysis, we propose the following:

Hypothesis 2. DIF's role in promoting R&D and innovation is more significant for private enterprises than for state-owned enterprises.

Hypothesis 3. DIF's role in promoting R&D and innovation is more significant for SMEs than for large enterprises.

Hypothesis 4. DIF's promotion effect on R&D innovation is more significant for high-growth enterprises than for low-growth enterprises.

Hypothesis 5. A stronger risk-taking entrepreneurial spirit is associated with a more significant promotion effect of DIF on enterprise R&D and innovation.

Data and empirical model

Data sources

This study explored the impact of DIF on enterprise R&D innovation by matching the DIF development index with the firms' registration locations using data on A-share listed companies covering 2011 to 2018. The data were collected from several sources. First, data on DIF were retrieved from the DIF index of Peking University. Second, data for enterprise R&D innovation and the control variables were mainly collected from the CSMAR and WIND databases. These data were processed as follows, in line with previous research. First, financial firms and listed companies being processed (ST) were excluded from the sample. Second, to eliminate the possible influence of extreme values, the top and bottom 1% of the company level were winsorized.

Model specification

To verify hypothesis 1, this study constructed the following empirical model to analyze the relationship between DIF and enterprise R&D innovation:

$$Inno_{ijt} = \beta_0 + \beta_1 DIF_{jt} + \sum \beta_j X_{it} + \sum year + \sum ind + \varepsilon_{it} \quad (1)$$

where the dependent variable $Inno_{ijt}$ represents the innovation capability of enterprises. Most studies have measured innovation in terms of patent output, patent authorization, and patent applications. Given that the most direct impact of DIF on enterprise innovation is alleviating financing problems, innovation output was measured using the ratio of R&D investment to operating income (Yao & Yang, 2022).

The explanatory variable DIF_{jt} represents the DIF index. Given that DIF is characterized by multidimensional development, the impacts of the three dimensions of DIF on enterprise R&D innovation were explored in a basic regression to ensure that the analysis was comprehensive (Li et al., 2020).

X_{it} represents a series of control variables that may affect enterprise innovation. In line with previous studies, the following control variables were selected: net profit margin of total assets (ROA), the logarithm of total assets (Asset), asset-liability ratio (Lev), number of directors (Bsize), the logarithm of the total compensation of the top three executives (Gpe), the shareholding proportion of the largest shareholder (Top share), and age of the company (Age). To minimize the influence of other factors (e.g., location of the enterprise) on enterprise R&D innovation, a two-way fixed-effects model was used in the benchmark regression, where the year effect (year) and industry effect (ind) were fixed.

The study also determined whether DIF can promote the R&D and innovation activities of enterprises by alleviating their financing constraints and intensifying banking competition using the mediation effect test procedure proposed by Nitzl, Roldan and Cepeda (2016). In this procedure, the intermediary variables include the enterprise

financing constraint index (KZ) and the banking competition index (CR). The other variables were measured following the methods described above:

$$Inno_{ijt} = \alpha_0 + \alpha_1 DIF_{jt} + \alpha_2 Control_{it} + \sum year + \sum ind + \varepsilon_{it} \tag{2}$$

$$KZ_{ijt} = \beta_0 + \beta_1 DIF_{jt} + \beta_2 Control_{ijt} + \sum year + \sum ind + \theta_{ijt} \tag{3}$$

$$Inno_{ijt} = \gamma_0 + \gamma_1 DIF_{jt} + \gamma_2 KZ_{ijt} + \gamma_3 Control_{ij} + \sum year + \sum ind + \delta_{ijt} \tag{4}$$

$$Inno_{ijt} = \alpha_0 + \alpha_1 DIF_{jt} + \alpha_2 Control_{it} + \sum year + \sum ind + \varepsilon_{ijt} \tag{5}$$

$$CR_{ijt} = \beta_0 + \beta_1 DIF_{jt} + \beta_2 Control_{ijt} + \sum year + \sum ind + \theta_{ijt} \tag{6}$$

$$Inno_{ijt} = \gamma_0 + \gamma_1 DIF_{jt} + \gamma_2 C_{ijt} + \gamma_3 Control_{ij} + \sum year + \sum ind + \delta_{ijt} \tag{7}$$

Variable measurement

Dependent variables

Enterprise innovation is usually measured in terms of patent output, patent authorization, and patent application. However, given the number and availability of samples, the index that reflects R&D investment most directly was chosen to measure the innovation output of enterprises (Tagues, López, Basso & Areal, 2021). Innovation output (*Inno*) was measured as the ratio of R&D input to operating revenue for a given year. The robustness test uses the sum of practical patents and innovative patents plus the logarithm (Patent1) and the number of patent applications as alternative dependent variables to test the robustness of the results.

Explanatory variable

The study's explanatory variable is digital financial inclusion. The Digital Finance Research Center of Peking University and Ant Financial jointly compiled the DIF Index, which covers provincial, municipal, and partial county levels. It is divided into three sub-indexes: coverage of digital finance, depth of digital finance use, and degree of digitalization (Liu et al., 2021). This study selected prefecture-level data in the DIF index and matched them with data on A-share listed companies according to the prefecture-level city where they are registered. To eliminate model estimation errors caused by different

data levels, the components of the DIF Index were divided by 200, following the literature.

Mediating variables

① The study considered financing constraints. The KZ financing constraint index was constructed according to the enterprises' operating net cash flow, cash holdings, and other financial indicators. A higher index corresponds to greater financing constraints (Milani & Neumann, 2022). ② The study also considered banking competition. The annual number of branches of each bank in each prefecture-level city was calculated using the financial license information of banking institutions taken from the China Banking Regulatory Commission. The Herfindahl–Hirschmann index (CR) of the banking industry in each city was then formulated. Given the differences in corporate loan behavior between policy banks, rural cooperative banks, credit cooperatives, and other financial institutions, these three types of banks were excluded from the analysis, and only the data for commercial banks were retained. The CR value has a range of (0,1) and is treated as a negative indicator. A higher CR corresponds to lower competition in the banking industry (Lu, Wang, Toppinen, D'Amato & Wen, 2021).

Control variables

Several control variables were selected based on the literature (Aibar-Guzmán, García-Sánchez, Aibar-Guzmán & Hussain, 2022; Seddighi & Mathew, 2020; Yu, Wu, Zhang, Chen & Zhao, 2021): ① net profit margin on total assets (*ROA*), which reflects the comprehensive utilization effect of assets; ② enterprise-scale (*Asset*) or the logarithm of total enterprise assets, which was used to measure enterprise size; ③ the asset–liability ratio (*Lev*), which was used to reflect the degree of leverage of an enterprise and was computed as the ratio of total liabilities to total assets; ④ number of board members (*Bsize*); ⑤ total compensation of the top three executives in logarithmic form (*Gpe*); ⑥ top share of the largest shareholder; and ⑦ enterprise age (*Age*), defined as the number of years since the enterprise was established in the market.

Empirical analysis

Descriptive statistics of variables

The descriptive statistics of the study's variables are shown in Table 1.

Table 1
Descriptive statistics of variables.

| Variable | | Mean | Standard Deviation | Min | Max | Sample Size |
|-----------------------|----------|--------|--------------------|---------|--------|-------------|
| Dependent variable | Inno | 4.614 | 5.473 | 0 | 151.61 | 16,697 |
| | Patent | 3.778 | 1.499 | 0 | 10.8 | 7949 |
| Explanatory variables | DIF | 0.958 | 0.325 | 0.088 | 1.514 | 16,697 |
| | DIF_B | 0.953 | 0.308 | -0.052 | 1.451 | 16,697 |
| | DIF_D | 0.945 | 0.353 | 0.008 | 1.628 | 16,697 |
| | DIG | 0.997 | 0.409 | 0.017 | 2.906 | 16,697 |
| Mediating variables | KZ | 0.619 | 1.846 | -14.533 | 11.241 | 16,697 |
| | CR | 0.152 | 0.022 | 0.129 | 0.232 | 16,697 |
| Control variables | ROA | 0.037 | 0.065 | -0.296 | 0.233 | 16,697 |
| | Asset | 21.794 | 1.217 | 18.787 | 25.366 | 16,697 |
| | Leverage | 0.425 | 0.221 | 0.041 | 1.119 | 16,697 |
| | Bsize | 8.6 | 1.701 | 5 | 15 | 16,697 |
| | Gpe | 14.26 | 0.697 | 12.101 | 16.1 | 16,697 |
| | Topshare | 34.815 | 14.975 | 8.716 | 74.965 | 16,697 |
| | Age | 14.986 | 7.41 | 3 | 28 | 16,697 |

Results of regression of digital inclusive finance on business innovation

Table 2 presents the regression results of the fixed effects of digital inclusive finance on firms' R&D innovation and the endogeneity test. The regressions are first conducted on DIF and corporate R&D innovation. Model (1) presents the regression results after controlling for year and industry effects. The three sub-indicators of the Financial Inclusion Development Index were then tested; models (2) to (4) present the regression results for the breadth of DIF coverage (DIF_B), depth of DIF usage (DIF_D), and degree of digitization (DIG) on corporate R&D innovation. The coefficients of DIF_B, DIF_D, and DIG were all significantly positive, suggesting that the continuously increasing coverage, depth of use, and digitization of DIF have positive roles in promoting enterprise R&D and innovation, with DIF coverage playing the most significant role. Therefore, in the development process of DIF, its coverage should be expanded to the real economy and its advantages should be leveraged to supplement traditional financial services. At the same time, DIF's depth and long-term development should be fostered to create a favorable financial environment for enterprise R&D and innovation development. Models (5) and (6) tested a regression for endogeneity. Although the enterprise R&D innovation of the dependent variable and the DIF of the main explanatory variable had different data levels, there were no endogeneity problems caused by reverse causality. However, some unobserved variables may still affect DIF and enterprise R&D innovation at the same time, thereby generating endogeneity problems. The instrumental variable method was thus adopted to alleviate the possible endogeneity problems. Following Yao et al. (Yao & Yang, 2022), the product of the lag period of DIF and the first-order difference of the digital financial index in time were used as the instrumental variables, and IV-2SLS was applied for the estimation.

Where DF is the product of the first-order difference in time between the DIF lag period and the digital financial index, DIF still plays a significant role in promoting enterprise R&D and innovation when the possible endogeneity problems are considered, which is consistent with the prior. In addition, this study performed robustness tests on the data by replacing the variables and estimating them over time to verify the robustness of the experimental results, as shown in the accompanying table.

Heterogeneity analysis

Enterprise scale and growth

Enterprises were divided into large enterprises and SMEs according to number of employees. Following Medase (2020), these enterprises were then divided into high- and low-growth enterprises according to their growth characteristics, which can be formulated as follows: Enterprise growth = (operating income in the current year – operating income in the previous year)/operating income in the previous year.

Models (7) and (8) in Table 3 were obtained from the regression of enterprise size, while models (9) and (10) were obtained from the regression of enterprise growth. The influence of the three sub-dimensions of DIF on enterprise R&D innovation under different enterprise characteristics was not reported here for brevity. These regression results show that the promotion effect of DIF on enterprise R&D innovation is more significant among SMEs than among private enterprises, which is consistent with the theoretical expectations. Hypothesis 3 is therefore supported. The regression results also show that DIF's promotion effect on R&D innovation is especially significant in high-growth firms; thus, hypothesis 4 is confirmed.

Table 2
Regression results of fixed effects of digital inclusive finance on firms' R&D innovation and endogeneity test.

| | (1) Inno | (2) Inno | (3) Inno | (4) Inno | First stage (5) DF | Second stage (6) Inno |
|-----------------|------------------------|------------------------|------------------------|------------------------|-----------------------|--------------------------|
| DIF | 4.033*** (8.88) | | | | | |
| DIF_B | | 3.272*** (9.69) | | | | |
| DIF_D | | | 1.701*** (4.42) | | | |
| DIG | | | | 1.197** (2.17) | | |
| DIF | | | | | | 4.2*** (6.24) |
| DF | | | | | 2.810*** (140.12) | |
| ROA | -11.687*** (-15.31) | -11.605*** (-15.20) | -11.902*** (-15.57) | -11.884*** (-15.53) | -4.397*** (-2.58) | -11.860*** (-14.66) |
| Asset | -0.310*** (-6.33) | -0.309*** (-6.33) | -0.325*** (-6.64) | -0.344*** (-7.04) | -0.663*** (-6.21) | -0.329*** (-6.31) |
| Leverage | -6.814*** (-26.36) | -6.824*** (-26.41) | -6.817*** (-26.31) | -6.855*** (-26.45) | -1.699*** (-3.04) | -6.709*** (-24.26) |
| Bsize | -0.102*** (-3.85) | -0.099*** (-3.73) | -0.113*** (-4.24) | -0.122*** (-4.56) | -0.236*** (-3.87) | -0.108*** (-3.79) |
| Gpe | 0.839*** (10.89) | 0.819*** (10.63) | 0.937*** (12.28) | 1.010*** (13.46) | 4.127*** (23.87) | 0.848*** (10.01) |
| Topshare | -0.041*** (-13.62) | -0.041*** (-13.64) | -0.041*** (-13.42) | -0.040*** (-13.29) | 0.021*** (3.01) | -0.040*** (-12.34) |
| Age | -0.065*** (-9.21) | -0.064*** (-9.12) | -0.069*** (-9.87) | -0.073*** (-10.48) | -0.160*** (-10.44) | -0.075*** (-9.91) |
| Annual effect | yes | yes | yes | yes | yes | yes |
| Industry effect | yes | yes | yes | yes | yes | yes |
| _cons | 1.853* (1.65) | 2.231** (1.99) | 1.641 (1.46) | 1.405 (1.24) | 23.670*** (9.76) | -1.664 (-1.22) |
| N | 14,940 | 14,940 | 14,940 | 14,940 | 16,914 | 13,226 |
| r2_a | 0.175 | 0.176 | 0.172 | 0.171 | 0.942 | 0.176 |
| F | 199.03 | 200.17 | 194.56 | 193.43 | 112.45 | 137.82 |

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; the brackets represent t values.

Table 3
Heterogeneity test of enterprise characteristics.

| variable | Enterprise Size Group | | Enterprise Growth Group | | |
|---|------------------------------|------------------------------------|-----------------------------------|-------------------------|---------------------|
| | (7) | (8) | (9) | (10) | |
| | large enterprises | small and medium-sized enterprises | low-growth enterprises | high-growth enterprises | |
| DIF | 3.151*** (4.97) | 4.977*** (7.69) | 1.973*** (3.70) | 5.629*** (8.27) | |
| Heterogeneity test of enterprise nature and industry nature | | | | | |
| variable | Heterogeneity of firm nature | | Industrial property heterogeneity | | |
| | (11) | (12) | (13) | (14) | (15) |
| | State-owned enterprises | The private enterprise | The first industry | The second industry | The third industry |
| DIF | 0.634 (0.96) | 5.973*** (10.10) | 2.483* (5.90) | 7.095*** (4.49) | 11.964*** (6.28) |
| Heterogeneity of managers' risk traits | | | | | |
| variable | (16) | (17) | (18) | | |
| | Risk aversion | Risk neutral | Risk appetite | | |
| DIF | 3.677*** (4.64) | 4.072*** (7.28) | 7.858** (2.22) | | |

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; brackets represent t values.

Nature of enterprises and property rights

The results of the theoretical analysis show that the promotion effect of DIF on enterprise R&D innovation differs across enterprises according to ownership type. Private enterprises have higher market information symmetry, higher financial uncertainty, and more severe credit discrimination than state-owned enterprises. Therefore, the sample was divided into state-owned enterprises and private enterprises (Chen, Xie & Van Essen, 2021) to examine the ownership heterogeneity in DIF's relation to enterprise R&D innovation. The enterprises' industries were then classified following the three-part industrial division in the *China Statistical Yearbook* and the *Guidance*

Investigation based on entrepreneurial risk-taking spirit

Enterprises need to bear high risks when engaging in innovation due to its uncertainty. This may force an enterprise to break their trust due to cash flow problems. Companies that employ more risk-taking entrepreneurs have a higher tendency to invest the same level of capital in innovative activities (Watts, Steele & Den Hartog, 2020). Thus, *DIG* shows heterogeneity in innovation across enterprises with different entrepreneurial risk-taking levels. Given China's imperfect capital market and other practical factors, this study used the available data and followed Lu et al. (2021) to calculate the risk characteristics of enterprise managers, as follows:

$$\text{Character} = \frac{\text{Totalriskassets}}{\text{Totalassets}} = \frac{\text{Shorttermriskyassets} + \text{longtermriskyassets}}{\text{Totalassets}} = \frac{\text{Tradingfinancialassets} + \text{Accountsreceivable} + (\text{Financialassetsavailableforsale} + \text{held} - \text{to} - \text{maturityinvestment} + \text{investmentrealestate})}{\text{Totalassets}} \quad 8$$

on *Industry Classification of Listed Companies* (CSRC, 2012 edition). Specifically, the listed enterprises in category A of the sample were classified as "primary industry" enterprises, those in categories B to E were classified as "secondary" industry enterprises (including industry and construction), and all other enterprises were classified as "tertiary industry" enterprises. Primary industry enterprises are mainly engaged in agriculture, forestry, animal husbandry, and fishery and have low R&D efficiency and limited R&D effect from capital injection. Meanwhile, secondary and tertiary industries are mainly engaged in manufacturing and service and are characterized by a frequent adoption of new technologies, strong R&D foundation, high innovation willingness, and excellent innovation ability. The impact of DIF on R&D innovation may show heterogeneity across industries. Models (11) to (15) in Table 3 present the results of the regression on firm and industry heterogeneity. The results show that DIF significantly promotes R&D and innovation among private enterprises but not among state-owned enterprises. The promotion effect of DIF on enterprise innovation is not significant in the primary industry but is significantly positive in the secondary and tertiary industries, with the tertiary industry showing the highest significance. These results may occur because the primary industry is limited by its own characteristics and low R&D efficiency. Despite receiving external financial support, such resources cannot be easily used to support R&D and innovation. Meanwhile, secondary and tertiary industries have a relatively high resource endowment, and the capital and human capital provided by DIF are synergistically coupled, thereby improving enterprise output levels.

According to the management risk trait index (character), entrepreneurial risk-taking was classified into risk-aversion, risk-neutral, and risk-preference types. Models (16) to (18) in Table 3 report the results for the heterogeneity of DIF's effect on enterprise R&D innovation across entrepreneurial risk-taking types. The results indicate that DIF plays an increasingly significant role in promoting enterprise R&D and innovation as entrepreneurial risk-taking increases. In other words, stronger entrepreneurial risk-taking corresponds to a greater ability for DIF to promote enterprise innovation. Therefore, DIF can satisfy the strong innovation motivation of entrepreneurs who have an adventurous spirit and is conducive to promoting enterprise innovation. This finding can be ascribed to the fact that entrepreneurial risk-taking reflects the willingness of innovation subjects to take risks and face potential failure in their innovation activities. The smooth promotion of innovation activities requires an increased tolerance of enterprise innovation activities on the one hand and increased financial support for enterprise R&D and innovation on the other. The development of DIF allows enterprises to obtain effective financial support, eliminates financial hindrances to innovation, and satisfies the innovative ambition of adventurous entrepreneurs.

Mediation effect analysis

Digital inclusive finance, financing constraints, and enterprise R&D innovation

Amid the development of DIF in recent years, scholars have gradually begun to examine its relationship with corporate financing

Table 4
Digital financial inclusion, financing constraints, and firm R&D innovation.

| variable | (19) KZ | (20) KZ | (21) KZ | (22) KZ | (23) Inno | (24) Inno | (25) Inno | (26) Inno |
|-----------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| DIF | -0.087** (-2.31) | | | | 3.440*** (6.91) | | | |
| DIF_B | | -0.086** (-2.26) | | | | 2.801*** (7.55) | | |
| DIF_D | | | -0.090** (-2.37) | | | | 1.520*** (3.60) | |
| DIG | | | | -0.090** (-2.37) | | | | 0.817* (2.36) |
| KZ | | | | | -0.049** (-7.76) | -0.036** (-8.01) | -0.032** (-6.11) | -0.024** (-3.25) |
| Control | Yes |
| Annual effect | Yes |
| Industry effect | Yes |
| _cons | 0.082*** (6.10) | 0.086*** (6.40) | 0.080*** (5.95) | 0.087*** (6.40) | 2.769** (2.13) | 3.100** (2.38) | 2.524* (1.94) | 2.302* (1.75) |
| N | 16,637 | 16,637 | 16,637 | 16,637 | 11,720 | 11,720 | 11,720 | 11,720 |
| r2 | 0.102 | 0.102 | 0.101 | 0.100 | 0.184 | 0.184 | 0.181 | 0.180 |
| F | 118.351 | 118.628 | 116.769 | 114.913 | 154.836 | 155.498 | 152.341 | 151.544 |

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; brackets represent t values.

constraints. Digital inclusive finance may affect corporate financing constraints in three ways. First, enterprises' external and internal financing constraints cannot be freely replaced given the market's information asymmetry. Therefore, enterprises show different degrees of financing constraints when their internal financing cannot easily meet their development needs and when external financing costs are high. Amid the vigorous development of DIF, the emergence of innovative technologies such as information technology, big data, and cloud computing can help reduce information asymmetry, increase the availability of financial services, and lower the financing cost of enterprises. Second, the information technology innovation brought about by DIF has both improved the traditional credit investigation system and supplemented it. Financial institutions usually raise the threshold and cost of borrowing for enterprises with imperfect credit profiles due to their credit risk. Third, enterprises tend to face a series of capital supervision problems, such as excessive financing and inefficient investment behavior after financing. Internet-based DIF reduces the financing constraints faced by enterprises and the information communication and supervision mechanism and prevents any potential future financing constraints due to the non-standard operation of the external capital market. Therefore, the development of DIF can alleviate enterprises' financing problems and

improve their R&D innovation. Overall, then, financing constraints have mediating effects on DIF and enterprise R&D innovation (Hai & Li, 2019).

The study verified the mediating effect of financing constraints by treating the DIF Development Index and its three sub-dimensions as explanatory variables and incorporating financing constraints into the analysis framework as mediating variables. Table 4 presents the regression results for the mediating effect of financing constraints. The regression results of DIF and the three sub-dimensions on enterprise R&D innovation were described in the basic regression and will not be repeated here. The effect of DIF on financing constraints was then explored. Models (19) to (22) present the results of the regression for the influence of the DIF index and its three sub-dimensions on financing constraints. These results show that DIF significantly reduces corporate financing constraints. The potential mediating role of financing constraints in the relationship between DIF and enterprise R&D innovation was then tested. Models (23) to (26) show that the coefficients of financing constraint are all significant at the 5% level, indicating that financing constraint is a significant mediator variable. The coefficients of DIF and the three sub-indicators all decreased yet were still significant at the 1% level, indicating that financing constraints play a partial intermediary role.

Table 5
Digital inclusive finance, banking industry competition, and enterprise R&D innovation.

| variable | (27) CR | (28) CR | (29) CR | (30) CR | (31) Inno | (32) Inno | (33) Inno | (34) Inno |
|-----------------|-----------------------|-----------------------|-----------------------|---------------------|--------------------|--------------------|----------------------|----------------------|
| DIF | -0.125*** (-88.98) | | | | 3.965*** (7.28) | | | |
| DIF_B | | -0.093*** (-88.99) | | | | 3.342*** (8.29) | | |
| DIF_D | | | -0.087*** (-68.20) | | | | 0.981** (2.25) | |
| DIG | | | | 0.018*** (9.10) | | | | 1.504*** (2.60) |
| CR | | | | | -0.169 (-0.07) | 0.911 (0.40) | -6.910*** (-3.20) | -9.239*** (-4.77) |
| Control | yes | yes | yes | yes | yes | yes | yes | yes |
| Annual effect | yes | yes | yes | yes | yes | yes | yes | yes |
| Industry effect | yes | yes | yes | yes | yes | yes | yes | yes |
| _cons | 0.185*** (59.76) | 0.176*** (56.82) | 0.189*** (57.52) | 0.184*** (49.87) | 1.988* (1.66) | 2.177* (1.83) | 3.060** (2.55) | 3.203*** (2.69) |
| N | 16,637 | 16,637 | 16,637 | 16,637 | 14,841 | 14,841 | 14,841 | 14,841 |
| r2 | 0.322 | 0.322 | 0.232 | 0.057 | 0.175 | 0.176 | 0.172 | 0.172 |
| F | 592.984 | 593.082 | 377.395 | 75.791 | 184.687 | 185.807 | 181.283 | 181.4 |

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; brackets represent t values.

DIF, banking industry competition, and enterprise R&D innovation

The development of DIF has occupied a major share of the traditional financing business, thereby intensifying competition in the banking industry. Commercial banks cannot easily maintain their operations by merely relying on traditional deposit and loan spreads. Instead, they improve their performance through various off-balance-sheet and intermediate businesses, which can improve their external financing environment. The intensified competition in the banking industry expands the effect of resource allocation and improves the R&D and innovation ability of enterprises. Following Wen et al. (Huang, Wu & Deng, 2021), a CR index of the banking industry in various cities was built and incorporated into the analysis framework. Table 5 presents the regression results.

In Table 5, Models (27) to (30) present the results of the regression of the DIF index and its three sub-dimensions on banking competition. The results show that DIF in China reduces banking concentration and intensifies competition in the banking industry. The empirical results in Models (31) to (34) also indicate that the development of DIF intensifies competition in the banking industry. The convenience and scale of market subjects' access to resources is improved, thereby enhancing enterprises' R&D innovation levels. Therefore, the positive transmission mechanism through which DIF promotes competition in the banking industry and enterprise R&D innovation is verified.

Conclusion

This study uses the DIF Index of Peking University from 2011 to 2018 to match data taken from A-share listed companies. The influence of DIF on enterprise R&D innovation is analyzed from multiple perspectives, including in terms of heterogeneity and mechanism of action.

Three primary results are obtained. First, the development of DIF can significantly promote enterprise R&D and innovation. Among the three sub-dimensions of DIF, coverage exerts the most significant promotion effect. Second, the promotion effect of DIF on enterprise R&D innovation is most significant among private enterprises, SMEs, secondary and tertiary industries, and high-growth enterprises. We also find that DIF can satisfy the strong innovation motivation of entrepreneurs with an adventurous spirit, which is conducive to promoting enterprise R&D innovation. Third, internal financing constraints and external banking competition have mediating effects on the promotion of enterprise innovation. These effects remain significant across the three DIF sub-dimensions. Instrumental variable regression and other robustness tests are performed to ensure the robustness of these findings.

The development of DIF has been proven to promote enterprise R&D and innovation from the perspectives of internal financing constraints and external banking competition, thereby providing a reference useful for solving enterprises' financing difficulties and improving the service quality of the banking industry. This study organically combines data on macro-level DIF with those on micro-level enterprise R&D innovation and proposes ideas for developing digital finance in a way that better serves the real economy and micro-enterprises. The results also offer guidance on how to improve the independent innovation of Chinese enterprises and promote the construction of an innovative country, while also providing a benchmark for the global development of SMEs and associated finance.

The study's findings offer the following main implications. First, the development of DIF can help micro-enterprises achieve R&D innovation. Therefore, the construction of financial markets should be improved, and DIF should be vigorously developed. Second, DIF demonstrates heterogeneity in R&D innovation across enterprises. Thus, DIF should be vigorously developed for private enterprises, SMEs, and the secondary and tertiary industries by promoting the development of traditional finance, increasing their R&D

investments, applying advanced financial science and technology, and improving the efficiency of DIF services offered to the real economy. Third, the development of DIF can promote sound financial and business environments, which can improve the efficiency and quality of enterprise R&D. This is another reason why DIF should be vigorously developed. Policies leaning toward DIF should also be formulated, and the development of DIF should be promoted to ensure that systemic financial risks have no bottom line. Future research should study how to assess and control risks under China's separate regulatory framework.

Appendix

Robustness tests

(1) With dependent variable replaced

(2) Time division

(Table A1, A2)

Table A1
Changing variables.

| Variables | (35) Patent1 | (36) Patent | (37) Patent | (38) Patent | (39) Patent |
|-----------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| DIF | 0.896*** (4.00) | 0.977*** (5.41) | | | |
| DIF_B | | | 0.801*** (6.00) | | |
| DIF_D | | | | 0.590*** (3.84) | |
| DIG | | | | | 0.457** (2.18) |
| Control | yes | yes | yes | yes | yes |
| Annual effect | yes | yes | yes | yes | yes |
| Industry effect | yes | yes | yes | yes | yes |
| _cons | -6.404*** (-10.88) | -9.293*** (-21.18) | -9.184*** (-20.90) | -9.394*** (-21.39) | -9.270*** (-21.00) |
| N | 3984 | 7129 | 7129 | 7129 | 7129 |
| r2 | 0.145 | 0.193 | 0.194 | 0.191 | 0.190 |
| F | 41.94 | 106.18 | 106.70 | 105.06 | 104.29 |

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; brackets represent t values.

Table A2
Robustness test of time period estimates.

| Variable | (40) 2011–2012 | (41) 2013–2018 |
|-----------------|--------------------|--------------------|
| DIF | 4.156*** (3.11) | 4.018*** (8.31) |
| Control | yes | yes |
| Annual effect | yes | yes |
| Industry effect | yes | yes |
| _cons | -2.331 (-0.81) | 1.007 (0.82) |
| N | 2157 | 12,783 |
| r2 | 0.231 | 0.169 |
| r2_a | 0.227 | 0.168 |
| F | 64.336 | 185.096 |

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively; brackets represent t values.

Author contributions

Conceptualization, M.X. and W.L.; Data curation, M.X.; Formal analysis, M.X.; Funding acquisition, W.L.; Investigation, M.X.; Methodology, M.X. and W.L.; Project administration, W.L. and Brain; Resources, M.X.; Software, M.X.; Supervision, W.L. and Brain; Validation, M.X.; Visualization, M.X. and A.Y.; Writing – original draft, M.X.; Writing – review & editing, W.L., A.Y. and Brain. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by 2020 Henan Province Colleges and Universities Key Young Teachers Training Project (No.2020GGJS092).

Institutional review board statement

Not applicable.

Informed consent statement

Not applicable.

Data availability statement

The data used to support the findings of this study are included within the article.

References

- Acharya, V., & Xu, Z. (2017). Financial dependence and innovation: The case of public versus private firms. *Journal of Financial Economics*, 124(2), 223–243. doi:10.1016/j.jfineco.2016.02.010.
- Aibar-Guzmán, B., García-Sánchez, I., Aibar-Guzmán, C., & Hussain, N. (2022). Sustainable product innovation in agri-food industry: Do ownership structure and capital structure matter? *Journal of Innovation and Knowledge*, 7(1) 100160. doi:10.1016/j.jik.2021.100160.
- Brown, J. R., Martinsson, G., & Petersen, B. C. (2012). Do financing constraints matter for R&D? *European Economic Review*, 56(8), 1512–1529. doi:10.1016/j.eurocorev.2012.07.007.
- Chen, X., Xie, E., & Van Essen, M. (2021). Performance feedback and firms' R&D frequency: A comparison between state-owned and private-owned enterprises in China. *Asian Business and Management*, 20(2), 221–258. doi:10.1057/s41291-019-00092-0.
- Fuster, A., Plosser, M., Schnabl, P., & Vickery, J. (2019). The role of technology in mortgage lending. *Review of Financial Studies*, 32(5), 1854–1899. doi:10.1093/rfs/hhz018.
- Guariglia, A., & Liu, P. (2014). To what extent do financing constraints affect Chinese firms' innovation activities? *International Review of Financial Analysis*, 36, 223–240. doi:10.1016/j.irfa.2014.01.005.
- Hai, H., & Li, H. (2019). More innovation, more money? Innovation performance, financial constraints, and financial performance. In *Academy of management proceedings*, Vol. 2019, No. (1), Briarcliff Manor Academy of Management. doi:10.5465/AMBPP.2019.16815abstract
- Han, H., & Gu, X. (2021). Linkage between inclusive digital finance and high-tech enterprise innovation performance: Role of debt and equity financing. *Frontiers in Psychology*, 12, 814408. doi:10.3389/fpsyg.2021.814408 –814408.
- Huang, W., Wu, Y., & Deng, L. (2021). Does banking competition stimulate regional innovation? Evidence from China. *Pacific-Basin Finance Journal*, 70, 101674. doi:10.1016/j.pacfin.2021.101674.
- Ji, X., Wang, K., Xu, H., & Li, M. (2021). Has digital financial inclusion narrowed the urban–rural income gap: The role of entrepreneurship in China. *Sustainability*, 13(15), 8292. doi:10.3390/su13158292.
- Jiang, X., Wang, X., Ren, J., & Xie, Z. (2021). The nexus between digital finance and economic development: Evidence from China. *Sustainability*, 13(13), 7289. doi:10.3390/su13137289.
- Li, J., Wu, Y., & Xiao, J. J. (2020). The impact of digital finance on household consumption: Evidence from China. *Economic Modelling*, 86, 317–326. doi:10.1016/j.econmod.2019.09.027.
- Lin, M., Prabhala, N. R., & Viswanathan, S. (2013). Judging borrowers by the company they keep: Friendship networks and information asymmetry in online peer-to-peer lending. *Management Science*, 59(1), 17–35. doi:10.1287/mnsc.1120.1560.
- Liu, X., Zhu, J., Guo, J., & Cui, C. (2021). Spatial association and explanation of china's digital financial inclusion development based on the network analysis method. *Complexity*, 2021, 1–13. doi:10.1155/2021/6649894.
- Liu, Y., Liu, C., & Zhou, M. (2021). Does digital inclusive finance promote agricultural production for rural households in China? Research based on the Chinese family database (CFD). *China Agricultural Economic Review*, 13(2), 475–494. doi:10.1108/CAER-06-2020-0141.
- Liu, Y., Luan, L., Wu, W., Zhang, Z., & Hsu, Y. (2021). Can digital financial inclusion promote China's economic growth? *International Review of Financial Analysis*, 78, 101889. doi:10.1016/j.irfa.2021.101889.
- Lu, F., Wang, Z., Toppinen, A., D'Amato, D., & Wen, Z. (2021). Managerial risk perceptions of corporate social responsibility disclosure: Evidence from the forestry sector in China. *Sustainability*, 13(12), 6811. doi:10.3390/su13126811.
- Luo, S., Zhang, Y., & Zhou, G. (2018). Financial structure and financing constraints: Evidence on small- and medium-sized enterprises in China. *Sustainability*, 10(6), 1774. doi:10.3390/su10061774.
- Medase, S. K. (2020). Product innovation and employees' slack time. The moderating role of firm age and size. *Journal of Innovation and Knowledge*, 5(3), 151–174. doi:10.1016/j.jik.2019.11.001.
- Milani, S., & Neumann, R. (2022). R&D, patents, and financing constraints of the top global innovative firms. *Journal of Economic Behavior and Organization*, 196, 546–567. doi:10.1016/j.jebo.2022.02.016.
- Nitzl, C., Roldan, J. L., & Cepeda, G. (2016). Mediation analysis in partial least squares path modeling: Helping researchers discuss more sophisticated models. *Industrial Management and Data Systems*, 116(9), 1849–1864. doi:10.1108/IMDS-07-2015-0302.
- Santos-Vijande, M. L., López-Sánchez, J.Á., Loredó, E., Rudd, J., & López-Mielgo, N. (2022). Role of innovation and architectural marketing capabilities in channelling entrepreneurship into performance. *Journal of Innovation and Knowledge*, 7(2) 100174. doi:10.1016/j.jik.2022.100174.
- Seddighi, H. R., & Mathew, S. (2020). Innovation and regional development via the firm's core competence: Some recent evidence from North East England. *Journal of Innovation and Knowledge*, 5(4), 219–227. doi:10.1016/j.jik.2019.12.005.
- Su, J., Su, K., & Wang, S. (2021). Does the digital economy promote industrial structural upgrading?—A test of mediating effects based on heterogeneous technological innovation. *Sustainability*, 13(18), 10105. doi:10.3390/su131810105.
- Tang, X., Ding, S., Gao, X., & Zhao, T. (2022). Can digital finance help increase the value of strategic emerging enterprises? *Sustainable Cities and Society*, 81, 103829. doi:10.1016/j.scs.2022.103829.
- Taques, F. H., López, M. G., Basso, L. F., & Areal, N. (2021). Indicators used to measure service innovation and manufacturing innovation. *Journal of Innovation and Knowledge*, 6(1), 11–26. doi:10.1016/j.jik.2019.12.001.
- Wan, J. Y., Zhou, Q., & Xiao, Y. (2020). Digital finance, financial constraint and enterprise innovation. *Economic Review*, 1, 71–83. doi:10.19361/j.er.2020.01.05.
- Watts, L. L., Steele, L. M., & Den Hartog, D. N. (2020). Uncertainty avoidance moderates the relationship between transformational leadership and innovation: A meta-analysis. *Journal of International Business Studies*, 51(1), 138–145. doi:10.1057/s41267-019-00242-8.
- Wellalage, N. H., & Fernandez, V. (2019). Innovation and SME finance: Evidence from developing countries. *International Review of Financial Analysis*, 66, 101370. doi:10.1016/j.irfa.2019.06.009.
- Yang, L., & Zhang, Y. (2020). Digital financial inclusion and sustainable growth of small and micro enterprises—Evidence based on China's new third board market listed companies. *Sustainability*, 12(9), 3733. doi:10.3390/su12093733.
- Yao, L., & Yang, X. (2022). Can digital finance boost SME innovation by easing financing constraints? Evidence from Chinese GEM-listed companies. *PLoS one*, 17(3) e0264647. doi:10.1371/journal.pone.0264647.
- Yu, C., Wu, X., Zhang, D., Chen, S., & Zhao, J. (2021). Demand for green finance: Resolving financing constraints on green innovation in China. *Energy policy*, 153, 112255. doi:10.1016/j.enpol.2021.112255.
- Yu, N., & Wang, Y. (2021). Can digital inclusive finance narrow the Chinese urban–rural income gap? The perspective of the regional urban–rural income structure. *Sustainability*, 13(11), 6427. doi:10.3390/su13116427.
- Yu, P., & Dou, J. X. (2020). Digital inclusive finance, enterprise heterogeneity and innovation of SMEs. *Contemporary Economic and Management*, 42(12), 79–87. doi:10.13253/j.cnki.ddjgl.2020.12.011.
- Zhang, M., & Chi, D. M. (2018). Internet finance, entrepreneur heterogeneity and small and micro enterprises' innovation. *Foreign Economics & Management*, 40(09), 42–54. doi:10.16538/j.cnki.fem.2018.09.004.
- Zhao, G., Zhong, S. H., & Guo, X. X. (2021). Digital inclusive finance development, financial mismatch mitigation and enterprise innovations. *Science Research Management*, 42(4), 158–169. doi:10.19571/j.cnki.1000-2995.2021.04.017.
- Zhong, W., & Jiang, T. (2021). Can internet finance alleviate the exclusiveness of traditional finance? Evidence from Chinese P2P lending markets. *Finance Research Letters*, 40, 101731. doi:10.1016/j.frl.2020.101731.