Research on the Impact of Digital Finance on Urban Innovation

Guo Xiao Hui[1], & Yan Wan Li[1]

[1]College of Economics, Hebei University, Baoding Hebei, 071000, China

Abstract

Innovation is the primary driving force for development and the strategic support for building a modern economic system. As an important part of implementing the innovation-driven development strategy, urban innovation is an important starting point to promote regional innovation and build an innovative country. Digital finance, as a new business form produced by the combination of digital technology and traditional finance, has a significant impact on urban innovation. Taking prefecture-level cities as the research object, this paper uses panel data model to explore the effect and mechanism of digital finance on urban innovation. The results show that: digital finance has a significant promoting effect on urban innovation, and the impact on urban innovation in different regions and different scales is obviously different; The intermediary effect analysis shows that digital finance can promote urban innovation by optimizing the supply of enterprise credit funds, expanding the scale of household consumption and improving the level of human capital. The threshold effect analysis shows that digital finance has a threshold effect on urban innovation due to its own development level, industrial structure and institutional quality. The regulatory effect analysis shows that financial regulation will weaken the promotion effect of digital finance on urban innovation to some extent. The conclusions of this study can provide reliable empirical evidence for better play the role of digital finance in promoting urban innovation capacity, and provide policy suggestions for further implementing the innovation-driven development strategy and promoting high-quality economic development.

Keywords: Digital finance Urban innovation Human capital Financial supervision

1.0 Introduction and literature

Innovation is the primary driving force for high-quality economic development, and the report to the Party's 20th National Congress pointed out that "we must accelerate the implementation of the strategy of innovation-driven development and uphold the core role of innovation in China's overall modernization drive." As an important carrier of China's regional economic development and social economic activities, the improvement of its innovation level plays a decisive role in enhancing the resilience of urban economy and improving the competitiveness of regional economy. However, at present, the overall innovation level of urban science and technology in China is not high, showing the characteristics of "strong southeast, weak northwest". Therefore, how to improve the level of urban innovation, enhance the power of urban innovation, and inject new momentum into high-quality development has become an important issue that needs to be solved urgently.

Urban innovation refers to the ability of various innovation entities within the city to carry out research and innovation based on the existing innovation elements such as talent, capital and knowledge, and then obtain knowledge and technical output. Urban innovation activities are inherently characterized by long cycle, high risk and uncertain returns, which make them need continuous and stable cash flow in various stages of technological research, achievement

transformation and application and promotion. However, the development of China's financial market is still not perfect, under the traditional financial system and historical conditions, there are widespread problems such as distortion of financial elements, imperfect transmission mechanism and low efficiency of credit resource allocation, which make it unable to provide strong support for China's innovative activities.

In recent years, with the orderly promotion of "new infrastructure", digital technologies such as "large, intelligent, material and cloud" ushered in rapid development, and the deep integration of digital technology and traditional finance made digital finance emerge. The positive interaction between digital finance and urban innovation brings new solutions to enhance the power of urban innovation, improve the level of urban innovation and narrow the gap of urban innovation. As an effective supplement to the traditional financial system, digital finance breaks the information barriers and physical restrictions of traditional finance by virtue of its efficient, strong geographical penetration and all-round accessibility, expands the financing channels of the long-tail group, effectively reduces the information asymmetry between the supply and demand of funds, and improves the allocation efficiency of credit funds. It provides inexhaustible impetus for the effective development of urban innovation activities, and creates new opportunities for our country to enter the forefront of innovative countries. Therefore, the development of digital finance is of great significance to the improvement of urban innovation level in our country.

The existing literature studies on digital finance and urban innovation mainly focus on two as pects: the impact mechanism of digital finance on urban innovation and the impact effect of d igital finance on urban innovation.First, existing studies believe that digital finance can impro ve the external financing environment of enterprises[1]、reduce financing costs for enterprises [2]and optimize the allocation of financial resources[3]to encourage enterprises to carry out rese arch and development innovation, so as to promote urban innovation with enterprise innovatio n.For example, Zhang Huihui et al.(2021)[4], using the panel data at the city level, found that d igital finance can promote the improvement of urban innovation level by improving the extern al financing environment of micro, small and medium-sized enterprises and individual practiti oners.Second, existing studies mainly believe that digital finance can improve the traditional c redit pricing model through credit transparency[5],improve risk identification ability[6],reduce adverse selection and moral hazard between financial institutions and innovation entities[7],br eak time and space constraints to promote the cross-regional flow of financial resources[8],pro mote the agglomeration of high-tech industries[9],upgrade the industrial structure[10]and suppo rt residents to engage in entrepreneurial activities[11]and other ways to promote urban innovati on.In addition, some scholars have found that the "catfish effect" of digital finance can intensi fy the competition among banks and lead to an increase in the availability of credit, which is c onducive to urban innovation[12].

From the perspective of influence and effect, there are three points of view in the existing literature: First, digital finance has a significant role in promoting urban innovation,For example, Liang Bang and Zhang Jianhua(2019)[2]、Du Chuanzhong and Zhang Yuan (2020)[8]found that the development of digital finance has a significant promoting effect on the improvement of urban innovation level by using fixed effect model based on panel data of China's prefecture level cities.Second, the specific impact of digital finance on urban innovation will show heterogeneous changes due to factors such as geographical location, innovation subjects and economic development level.Liu Maotao et al. (2021)[13], Zhang Xiaodan and Peng Geng (2021)[14], and Xu Ziyao and Zhang Lisha (2020) [15]all found that digital finance has a significant promoting effect on urban innovation, and this effect has

regional heterogeneity, specifically, the eastern region has the strongest effect, the central region has the second effect, and the western region has the weakest effect.Ren Biyun and Liu Jiaxin (2021)[16] and Zheng Wanteng and Zhao Hongyan (2021)[17]found that the innovation incentive effect of digital finance is significantly different among different innovation subjects, which is specifically manifested as "universities > scientific research institutions > enterprises". Third, the development of digital finance has a spatial spillover effect on the level of technological innovation in neighboring cities. Based on the panel data of prefecture-level cities in China, Xu Zhangxing (2021)[18]and Lv Hui He Kui (2023)[19]et al. found that digital finance has radiation effect, competition effect and trickle-down effect, so that it can stimulate the improvement of technological innovation level in the region and promote the innovation level of surrounding cities through effective ways. In general, most of the existing studies have discussed the impact of digital finance on urban innovation from the perspective of mechanism and effect, but there is a lack of analysis from other perspectives.

Based on this, this paper mainly discusses the following questions: Can digital finance promote urban innovation? How is digital finance fostering innovation in cities? Under different development levels of digital finance, is there a phased difference in the impact of digital finance on urban innovation? At the same time, will the impact of digital finance on urban innovation be significantly different depending on the location and size of the city? In addition, with the rapid development of digital finance, while enabling the operation efficiency of the capital market, digital finance also brings new financial risks such as liquidity risk, credit risk and policy risk. Therefore, strengthening financial supervision to prevent financial risks is crucial to ensure the healthy development of digital finance and play the role of digital finance in promoting urban innovation. So, what impact will financial regulation have on the innovation incentive effect of digital finance? In view of the above problems, this paper takes prefecture-level cities as the research object to analyze the effects and mechanisms of digital finance on urban innovation during 2011-2021, hoping to effectively play the enabling role of digital finance, continuously promote the improvement of urban innovation level, and thus accelerate the cultivation and formation of new quality productivity. Give play to the basic and supporting role of cities in national innovation activities.

Compared with previous literatures, the marginal contribution of this paper is mainly in the following three aspects: First, when studying the impact path of digital finance to promote urban innovation, most of the existing literatures are carried out from the perspective of financing constraints on innovative activities. This paper further explores from the social level that digital finance can reduce the opportunity cost of acquiring knowledge and skills by increasing investment in education and increasing opportunities for skill training, thus improving the level of human capital and promoting urban innovation. Second, existing studies mainly explore the impact of digital finance on urban innovation from the inclusive effect of digital finance, and pay less attention to the impact of network effects of digital finance on urban innovation. Based on the network effect of digital finance, this paper proves that the impact of digital finance on urban innovation has a "threshold effect", showing the characteristics of increasing marginal effect, which complements and enricfies the existing research. Third, existing studies rarely consider financial regulation when discussing the relationship between digital finance and urban innovation. In this paper, financial regulation is included in the research framework of "digital finance - urban innovation", which provides a new research perspective for in-depth understanding of the relationship between digital finance and urban innovation, and provides theoretical support for better exerting the positive role of digital finance on urban innovation.

2.0 The influence mechanism of digital finance to promote urban innovation

2.1.The direct impact of digital finance on urban innovation

Urban innovation refers to a series of activities in which all innovation entities within the city carry out research and innovation based on the existing resource endowment, and introduce the developed new technologies into the existing production system, thereby transforming new products, new processes and new services that can promote the economic development and social progress of the city, and then realize marketization. The successful development of urban innovation activities cannot be separated from the effective support of the financial system, but China's traditional financial system has long existed problems such as financial exclusion and structural mismatch, which seriously restricts the effective development of urban innovation activities. As an effective supplement to the traditional financial system, digital finance has gradually become an important force in China's financial supply system due to its advantages of wide coverage, low cost and low threshold, thus injecting new impetus into the development of innovative activities in China's cities.

To be specific, first, digital finance can effectively broaden the boundaries of financial services and reduce the threshold of financial services by means of digital technologies such as big data, artificial intelligence and cloud computing, thus providing strong financial support for innovative entities to carry out innovative activities, which is conducive to the improvement of urban innovation level. First of all, digital finance uses digital technology to overcome the dependence of traditional finance on physical outlets, break the restrictions of physical space and settlement time on market participants, so that it can reach more groups in a wider range and more efficiently, and help rural poor and other areas with weak financial services to carry out innovative activities[20]。Secondly, with the deep integration of digital finance and all walks of life, more and more users use digital financial platforms to pay, consume, invest and borrow, and the continuous extension of the depth of use makes digital finance provide more diversified financial products in more active financial innovation ways[21]。Low transaction costs and diversified financial products enable financial services to benefit more groups, reduce the entry threshold of financial services, improve the availability of credit funds, thus providing more financing channels for innovative entities and boosting the level of urban innovation[22].

Second, digital finance reduces transaction costs while improving the efficiency of financial services, thus providing high-quality and efficient financial services for innovative entities to carry out innovative activities, which is conducive to the improvement of urban innovation level. First of all, with the help of the Internet platform, digital finance has established an effective procedure approval and risk screening mechanism, which is conducive to financial institutions to quickly and accurately assess the solvency and business risks of innovative entities, shorten the approval process before, during and after loans, improve the efficiency of financial services, and reduce the innovation resistance of urban innovation entities[23].Secondly, the digital technology embedded in digital finance can effectively integrate the data information of different innovation subjects, break the information barriers between innovation subjects, and thus reduce the search cost and transaction cost of elements, so as to achieve the accurate matching of innovation resources. Finally, the development of online payment, cross-border payment and intelligent transaction can effectively promote the realization of mobile, convenient and affordable financial services, accelerate the concentration of financial resources to the innovation field, and further reduce the information search cost and transaction cost of innovation entities, and promote the development of urban innovation

activities.

Third, with the help of digital technology, digital finance can effectively integrate multiple data elements, actively perceive the financial needs of the public, and extend service tentacles, thus promoting the reconstruction and reconstruction of production and business models, and thus promoting urban innovation. First of all, digital finance relies on the Internet platform to integrate financial business into many areas of life, such as medical care, transportation, trade and catering, and these intertwined business ecology continue to breed new business models, thus creating new opportunities for the creation of new knowledge and the development of new technologies[24].Secondly, the massive information generated by the application of digital financial scenarios is conducive to helping innovation subjects locate their research and development direction and promoting their continuous improvement of self-innovation ability[25].Finally, the distributed business pattern spawned by digital finance has the characteristics of multi-participation, professional division of labor, information sharing and intelligent collaboration, which is conducive to cross-border exchanges and cooperation among innovation entities and the construction of collaborative innovation mechanisms[26].Based on the above analysis, this paper proposes the following hypothesis:

Hypothesis H1: Digital finance has a positive effect on urban innovation.

2.2 Indirect influence mechanism of digital finance to promote urban innovation

2.2.1.Digital finance、credit capital supply and urban innovation

Urban innovation refers to the ability of various innovation entities within the city to carry out research and innovation based on the existing innovation elements such as talent, capital and knowledge, and then obtain knowledge and technical output[27].As the micro-subject of urban innovation, enterprises cannot carry out their innovation activities successfully without a good external financing environment. For current innovative enterprises, especially for small, medium and micro enterprises, they are faced with serious financing constraints[28]。First, the technological innovation activities of enterprises are often characterized by high risk, long cycle and uncertain investment return. In order to avoid risks, traditional financial institutions are often reluctant to invest funds in such projects, especially for those "tail" groups excluded by the traditional financial system, which are difficult to obtain financial support due to insufficient collateral and poor risk bearing capacity. Eventually, its technological innovation projects failed due to insufficient research and development funds[29]。Second, the innovation activities of enterprises are confidential to a certain extent. Due to the limited information disclosed to the outside world, the ability of financial institutions to obtain corporate information is reduced to a certain extent, resulting in the information asymmetry between the supply and demand of funds, which makes financial institutions unable to carry out effective risk assessment of enterprises, inhibit the effective allocation of credit resources, and exacerbate the financing constraints of enterprises. The innovation output of enterprises comes from R&D investment. When the innovation activities of enterprises cannot obtain sustained financial support, they have to give up innovation research and development, thus curbing the improvement of urban innovation level[30].

The development of digital finance can broaden the financing channels of enterprises, improve the allocation of credit resources of enterprises, optimize the supply of credit funds of enterprises, relieve the financing constraints faced by enterprises and increase their research

and development investment, and then stimulate the internal innovation power of enterprises, and ultimately drive urban innovation with enterprise innovation[31]。First of all, with its efficient information collection and data analysis capabilities, digital finance can gather the "large, small and scattered" funds outside the traditional financial system in a low-cost and efficient way and incorporate them into the formal financial system, thus further broadening the sources of R&D funds for enterprises and easing the financing constraints faced by enterprises[32]。Secondly, the diversified financial products derived from digital finance can provide fast and convenient financing channels for enterprises' innovative activities, so as to further optimize the supply of credit funds for enterprises and facilitate enterprises' research and development and innovation[33]。At the same time, the "catfish effect" caused by digital finance intensifies the competition in the banking industry, and in order to maintain their competitive position, banks will reduce the entry threshold for enterprise innovation within the city to a certain extent, and even appropriately increase the level of risk bearing and venture investment, thereby indirectly expanding the supply of credit funds for enterprises[34]。Finally, the digital technology embedded in digital finance can collect, analyze and process enterprise information at a lower cost, which enables financial institutions to more accurately assess the profitability and innovation risk of enterprise innovation projects, reduce the information asymmetry between capital supply and demand, and enable the optimal allocation of credit resources among enterprises. Then optimize the supply of credit funds for enterprises and promote urban innovation.

Hypothesis H2a: Digital finance can improve the risk control ability of financial institutions by expanding the capital sources of enterprises, thereby optimizing the supply of credit funds of enterprises, and then easing the financing constraints of enterprises and increasing their R&D investment to promote urban innovation.

2.2.2.Digital finance、household consumption scale and urban innovation

Digital finance can expand residents' consumption scale by easing the liquidity constraint of residents and improving the convenience of settlement and payment. First, the emergence of diversified consumer credit enables digital finance to effectively alleviate the liquidity constraints of residents and expand the scale of residents' consumption[35]。For example, Internet credit products such as Ant Huabai and Jingdong Baitiao have changed the traditional concept of consumption to a great extent, enabling residents to carry out intertemporal consumption, reducing the restraint of liquidity constraints on residents' consumption, thus improving residents' immediate consumption capacity and expanding residents' consumption scale[36]。In addition, the strong geographical penetration and wide coverage of digital finance enable it to provide more convenient and personalized consumer credit and other financial services for remote areas and low-income groups, which effectively promote the expansion of regional residents' consumption scale。

Second, the online payment of digital finance has changed the traditional way of transaction, making people's consumption more convenient and fast, thus further promoting the expansion of residents' consumption scale. First of all, the emergence of payment software such as Alipay and wechat not only improves the shopping frequency of residents, but also simplifies the transaction process, improves the consumption willingness and payment intensity of residents, and thus stimulates the consumption demand of residents[37]。Secondly, the promotion of online payment tools has led to the rapid development of e-commerce, which not only expands the supply and transaction scope of commodities, but also provides residents with more choices

of commodities, thus meeting the consumer demand of urban residents for big-ticket commodities and enjoyment services, but also provides more consumption opportunities for rural residents in remote areas, releasing their consumption potential, and ultimately expanding the scale of residents' consumption[38]。Finally, the rapid development of digital finance enables the deep integration of digital technologies such as big data and cloud computing with the production process, thus promoting profound changes in the production mode and promoting the iterative upgrading of consumption quality, so as to meet the personalized and diversified consumption needs of residents and expand the scale of residents' consumption.

The expansion of residents' consumption scale has an impact on urban innovation behavior mainly from three aspects. First, economies of scale. The expansion of consumption scale will continue to share the fixed cost invested in technological innovation, and the greater the consumption demand, the lower the unit cost borne by the innovation subjec[39]。At the same time, the expansion of consumers' demand for high-quality new and old products will force innovative subjects to constantly update and transform products to maintain their competitive position in the market, thus promoting the improvement of regional innovation level[40]。Second, knowledge spillover effect. The economies of scale caused by the scale of consumption will generate many local enterprises that are compatible with the attributes of the division of labor network, and attract foreign enterprises with similar attributes of division of labor to join, thus extending and broadening the industrial chain, improving the level of industrial agglomeration, and ultimately promoting the exchange and sharing of knowledge within the industry and promoting the improvement of regional innovation level[41]。Third, the competitive effect. With the expansion of residents' consumption scale and the diversification and personalization of consumer demand, market competition will become more intense. In order to seize market share and pursue profit maximization, enterprises will continue to carry out technological innovation in order to reduce costs and gain competitive advantages, thus further promoting the improvement of urban innovation level。

Hypothesis H2b: Digital finance can promote urban innovation by expanding the scale of household consumption.

2.2.3.Digital finance、human capital and urban innovation

Urban innovation seeks to create knowledge and technological breakthroughs, which requires a high level of human capital[42]。According to endogenous growth theory, technological progress is inseparable from the creation and accumulation of knowledge, and human capital is the source of knowledge creation. Therefore, with the improvement of the level of human capital, the comprehensive quality and skill level of the labor force will also be improved accordingly, so as to better identify innovation opportunities, clarify the direction of future research and development innovation, grasp the innovation process, and promote technological innovation。At the same time, human capital plays an important role in the process of transforming innovation investment into innovation achievements. In the process of carrying out innovation activities, R&D investment is only a necessary but not sufficient condition affecting the development of innovation activities, and R&D investment must be combined with human capital to promote the improvement of innovation ability[43]。Therefore, the driving of innovation needs to be based on the concentration of talents, and areas with high human capital are often more likely to accept new knowledge and apply new technologies, so as to effectively drive the development of urban innovation activities.

Investment in education, skills training and knowledge accumulation are important ways to improve the level of human capital, and digital finance plays an important role in them. First, the root cause of the problem of "education gap" mainly lies in the lack of capital reserves and sources on which education investment depends. In this case, the inclusive performance of digital finance can cover all social groups, especially those vulnerable groups excluded by the traditional financial system. Digital finance can provide them with more opportunities to apply for education loans, thereby increasing education investment to a certain extent, promoting equality of education opportunities, and thus improving the level of human capital in the region[44]。Second, the development of digital finance provides residents and vulnerable groups with more diversified investment, credit and insurance products, which is conducive to the increase of residents' consumption of goods and services such as culture, education and entertainment。The increase in expenditure on culture and education means that residents pay more attention to their own education level and cultural level, which undoubtedly lays a solid foundation for the accumulation and improvement of regional human capital。Third, the digital technology supported by digital finance makes the communication between different subjects more convenient and efficient, which not only promotes the formation and dissemination of knowledge, but also encourages R&D personnel to quickly master new skills and stimulate new ideas through the Internet platform, thus speeding up the process of knowledge accumulation and further promoting the improvement of human capital level[45]。

Hypothesis H2c: Digital finance can promote urban innovation by improving human capital levels.

2.2.4.Analysis of threshold effect of digital finance on urban innovation

According to Metcalfe's Law, the value of a network increases with the number of users. Digital finance is Internet-based, and its impact on urban innovation is likely to have similar characteristics. Specifically, the attributes of intelligence, informatization and networking naturally carried by digital finance enable it to exchange information across time and space at zero cost, bring more innovation subjects into the urban innovation system, and play a synergistic role between each other, thus generating innovation spillover effect[46]。When the development level of digital finance is low, due to its small service supply and narrow coverage, it cannot provide effective financial services to innovative entities, so the promotion effect of urban innovation is not obvious[47]。However, with the continuous improvement of the development level of digital finance, digital finance can provide financial services for innovative entities in a wider range and at a lower cost. At this time, the marginal cost of the innovation subject in the aspects of information acquisition, processing and analysis continues to decrease, while the innovation income continues to increase, which presents a resonance phenomenon of the continuous decline of innovation cost and the continuous increase of innovation income. In this context, more and more innovation subjects will continue to increase their demand for digital finance driven by innovation benefits, which will further deepen and broaden the penetration of digital finance in the field of urban innovation, so as to continuously strengthen the promoting role of digital finance on urban innovation, and finally make the impact of digital finance on urban innovation have threshold effect, showing an increasing trend of marginal effect[48]。

The dynamic impact of digital finance on urban innovation is not only limited by its own level of development, but also influenced by the external environment. A good external environment can provide a strong element support for the development of digital finance. Therefore, the

incentive effect of digital finance on urban innovation will change due to changes in the external environment, thus showing dynamic changes. Specifically speaking, on the one hand, the rationalization and upgrading of industrial structure can promote the capital demanders to use financial services more reasonably and efficiently, which is conducive to the concentration of financial resources to industries with potential and strength. In this case, digital finance can give full play to its advantages such as financial support, risk identification and resource allocation, and realize the effective combination of financial capital and industrial capital. Expanding the impact of digital finance on urban innovation[49]。On the other hand, the smooth development of innovation activities cannot be separated from a good external environment. When the quality of regional institutional environment is poor, the development of digital finance may lack effective supervision, making it unable to develop in a healthy and orderly way, and thus unable to exert the incentive effect of digital finance on innovation。At the same time, the rigid and even lack of fault-tolerant institutional environment is difficult to create a good development space for technological innovation. On the contrary, in an appropriate fault-tolerant and regulatory institutional environment, digital finance can better provide sustainable and stable financial support for innovation entities to improve the local innovation level and further accelerate the market value transformation of innovation achievements[50]。

Hypothesis H3a: The impact of digital finance on urban innovation has a threshold effect, showing a significant positive and increasing marginal effect.

Hypothesis H3b: With the improvement of industrial structure and institutional quality, digital finance will gradually enhance its role in promoting urban innovation.

2.2.5.Financial regulation、Digital Finance and urban innovation

The deep integration of science and technology and finance has continuously spawned new financial formats. From the perspective of the development of the financial industry, it has successively experienced the stages of digital accounting, computerization, informatization and networking. Digital finance, as a new financial model integrated by financial innovation and scientific and technological innovation, its essence and connotation still belong to the financial category. However, although digital finance has the advantages of wide coverage, low cost and high service efficiency, it can effectively make up for the shortcomings of the traditional financial system, but the risks of data loss, network fraud and transaction credit will cause serious negative impacts on the entire financial system. In July 2015, the People's Bank of China jointly issued the Guiding Opinions on Promoting the Healthy Development of Internet Finance, marking the formal inclusion of Internet finance in the scope of financial supervision in China[51]。Subsequently, the Banking and Insurance Regulatory Commission, the Financial Stability and Development Committee of The State Council and even the entire national level began to regulate related fields of digital finance from the aspects of policy formulation and regulatory implementation. Therefore, the strengthening of financial regulation is bound to affect the incentive effect of digital finance on urban innovation.

On the one hand, perfect financial supervision helps to hold the bottom line of financial risk, ensure the healthy and stable development of digital finance, and further strengthen the innovation incentive effect of digital finance[52]。First of all, the financial attributes of digital finance itself make it not free from the negative externality and extension periodicity of financial risks. Even under the superposition of digital technology and Internet platform, financial risks are likely to be transmitted to the entire financial system through a series of

"cross-infection". Improved financial supervision will effectively curb the emergence of risky behaviors such as excessive speculation and arbitrage in the field of digital finance, reasonably regulate the external financial environment, and thus provide a sound resource allocation mechanism for innovative activities[53]。 Secondly, the strengthening of financial regulation helps to overcome the endogenous vulnerability and instability of digital finance, improve the operational efficiency of digital finance, maintain the stability of the financial system, and thus ensure the sound development of urban innovation and regional economy.

Hypothesis H4a: Effective financial supervision is conducive to further exerting the incentive effect of digital finance on urban innovation.

On the other hand, due to the complex network structure, strong system correlation and deep r isk concealment characteristics of digital finance, it amplifies the deficiencies of financial sup ervision. The spatial mismatch between financial supervision and digital finance reduces the e fficiency of financial services, and thus restricts the innovation incentive effect of digital finan ce[54]。 Moreover, financial innovation and financial regulation always have different demand s, according to the political theory of financial regulation[55]Financial regulation will be influe nced by interest groups, which, in order to maximize their own interests, often urge regulators to adopt stricter regulatory measures on financial innovation through lobbying and pressure. Excessive financial regulation and policy intervention may weaken the role of the free market, lead to the reduction of financial efficiency, and thus restrict the development environment of digital finance. In turn, it increases the innovation cost and uncertainty of innovation subjects, reduces the willingness of innovation subjects to explore new technologies and new fields, an d weakens the innovation incentive effect of digital finance.

Hypothesis H4b: Excessive financial regulation will weaken the incentive effect of digital finance on urban innovation to some extent.

3.0 Research design

3.1 Model design

3.1.1.Baseline regression model

In order to test the direct impact of digital finance on urban innovation, this paper constructs the following two-way fixed effect model with reference to the studies of Jiang Changliu et al (2020)[56].and[57]

$$Innov_{i,t} = \alpha_0 + \beta_1 Index_{i,t} + \sum_{j=2}^{n} \beta_j Control_{i,t} + \theta_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

Among them, Innovi and t are the explained variables, indicating the urban innovation level of city i in the period t, which is measured by the total number of patents granted per 100 per capita in this paper; Indexi and t are the core explanatory variables, indicating the digital financial development level of city i in the period t, which is measured by the digital inclusive financial index released by Peking University. Controli, t represents the control variable that affects urban innovation, α0 is a constant term; θi and μt represent individual and time fixed effects, respectively, while εi and t represent error perturbation terms.

3.1.2.Intermediate effect model

In order to further explore the impact mechanism of digital finance on urban innovation, this paper makes reference to the studies of Wen Zhonglin and Ye Baojuan (2014) and builds the following intermediary effect model.

$$M_{i,t} = \alpha_0 + \gamma_1 Index_{i,t} + \sum_{j=1}^{n} \beta_j Control_{i,t} + \theta_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

$$Innov_{i,t} = \alpha_0 + \delta_1 Index_{i,t} + \gamma_2 M_{i,t} + \sum_{j=1}^{n} \beta_j Control_{i,t} + \theta_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

Among them, Mi and t are intermediary variables, which represent the supply of credit funds, the scale of residents' consumption and the level of human capital. Model (2) studies the impact of digital finance on intermediary variables, and model (3) studies the impact of digital finance and intermediary variables on urban innovation. The two formulas are combined with formula (1) to form Wenn's three-step method. When the model estimates that β1 is significant and γ1 and γ2 are significant, the intermediary effect exists; if δ1 is significant and |δ1|<|β1|, the intermediary effect is partially mediated; if δ1 is not significant, the intermediary effect is fully mediated. The coefficient β1 in equation (1) represents the total effect of digital finance on urban innovation, δ1 in equation (3) represents the direct effect of digital finance on urban innovation, and the product of γ1 and γ2 in equation (2) and (3) represents the indirect effect of digital finance on urban innovation

3.1.3Threshold effect model

In order to further explore whether the impact of digital finance on urban innovation is threshold effect, this paper establishes the threshold effect model with reference to Hansen's practice as follows:

$$\begin{aligned} Innov_{i,t} = {} & \alpha_0 + \beta_1 Index_{i,t} \cdot I\left(Index_{i,t} \le \delta\right) + \beta_2 Index_{i,t} \cdot I\left(Index_{i,t} > \delta\right) + \\ & \sum_{j=3}^{n} \beta_j Control_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (4)$$

Where, Innovi, t represents the city innovation level as the explained variable; Indexi, t represents the development level of digital finance, which is both an explanatory variable and a threshold variable. i is the city sample number, t is the time series number; I () is the indicative function and the threshold value. When the conditions in parentheses are met, the value is 1; when the conditions are not met, the value is 0, indicating the residual term.

Next, in order to further explore whether the influence of digital finance on urban innovation has threshold effect under different external environment conditions, this paper further builds the threshold model as shown below. At the same time, the industrial structure and the degree of opening to the outside world are taken as threshold variables (adj), and the following model is constructed:

$$\begin{aligned} Innov_{i,t} = {} & \alpha_0 + \beta_1 Index_{i,t} \cdot I\left(adj_{i,t} \le \delta\right) + \beta_2 Index_{i,t} \cdot I\left(adj_{i,t} > \delta\right) + \cdots + \beta_n Index_{i,t} \\ & \cdot I\left(adj \le \delta_n\right) + \beta_{n+1} Index_{i,t} \cdot I\left(adj_{i,t} > \delta_n\right) + \sum_{j=1}^{n} \gamma_j Control_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (5)$$

3.1.4.Regulatory effect model

In order to explore the impact of financial regulation on the innovation incentives of digital finance, this paper refers to Tang Song et al(2020) . and constructs a regulatory effect model to test the role of financial regulation in the process of digital finance promoting urban innovation. The model Settings are as follows:

$$Innov_{i,t} = \alpha_0 + \beta_1 Index_{i,t} + \beta_2 \left(Index_{i,t} \times \sup_{i,t} \right) + \sup_{i,t} + \sum_{j=3}^{n} \beta_j Control_{i,t} + \theta_i + \mu_t + \varepsilon_{i,t} \quad (6)$$

Among them, sup is financial supervision, this paper focuses on testing the direction and magnitude of the interaction term coefficient β2.

3.2.Variable declaration

3.2.1 Explained variables

Urban innovation(Innov):The innovation referred to in this paper is mainly technological innovation, and the existing researches mainly measure urban innovation from innovation input or innovation output. Innovation investment is mainly measured by R&D expenditure and R&D personnel investment[58],Innovation output is mainly measured by sales revenue of new products and patents. Although sales revenue of new products can directly reflect the market value of new products, it ignores the knowledge creation function of scientific and technological innovation. As the creation and transformation of new knowledge, patent contains a lot of information about technology and invention, which can better measure the innovation ability and innovation level of a region.Therefore, with reference to the studies of Bian Yuanchao et al.[59]and Zhang Ke et al.[60], this paper uses the total number of patents granted per 100 people in China to measure the level of urban innovation.

3.2.2.Explanatory variable

Digital Finance Development Level (Index) :The core explanatory variable of this paper is the development level of digital finance, and the Peking University Digital Financial Inclusion Index compiled by the Digital Finance Research Center of Peking University is used as the proxy variable. The proxy variable is compiled based on the transaction data provided by Ant Financial, which depicts the overall picture of the development of China's digital finance through a multi-dimensional in-depth analysis system. At the same time, this paper further selects the coverage breadth, use depth and digitization degree of digital finance to analyze the impact of different dimensions of digital finance on urban innovation. Considering the dimensional differences among variables, this paper refers to the practice of Xu Ziyao et al. (2020)[15] and divides the original digital finance and each dimension index by 100.

3.2.3.Intermediate variable

Supply of Credit funds (Credit). Based on the practice of Lu Fengzhi (2022)[61], this paper uses the per capita loan balance of financial institutions at the end of the year to measure the supply of credit funds. Household consumption scale (Consquan). Referring to the practice of Sun Weizeng et al. (2018)[62], this paper uses the total retail sales of consumer goods per capita in each city to measure the scale of residents' consumption in each city. Human capital (Hc).

Based on the studies of Wang Zhiyong and Li Rui (2021)[63]and He Xiaogang and Huang Yingshan (2020)[64], this paper uses the proportion of college students in the total regional population to measure the level of human capital.

3.2.4.Control variables

Due to the complex influencing factors of urban innovation, combined with China's actual situation and current research on urban innovation, and drawing on existing literature, the following variables are selected as control variables in this paper:

Economic development level (Inpgdp):The level of economic development often represents the comprehensive strength of a region, and a higher level of economic development can promote the concentration of talents and capital, create a good economic environment for innovation, which is conducive to the improvement of urban innovation level. In this paper, referring to Xu Ziyao et al. (2020)[31] per capita GDP and logarithm are adopted to measure regional economic development level.

Science and Education investment (Szi):Science and education investment can be used to support innovative research in universities and scientific research institutions, and can also be used to build research facilities such as laboratories and data centers, so as to provide strong support for the improvement of urban innovation level. In addition, the level of investment in science and education can also reflect the importance of the government to science and education. Therefore, this paper refers to Zhang Liang et al. (2021)[65] to measure the regional science and education level by using the proportion of the financial expenditure on science, technology and education in the total financial expenditure.

Industrial structure:Industrial structure reflects the proportion and composition relationship between various industries. Industrial transformation and upgrading are conducive to exchanges and cooperation between different industries, thus promoting technology crossover and knowledge sharing, and stimulating the vitality of urban innovation. Based on Li Feifei et al. (2023)[66], Meng Xiaoqian and Wu Chuanqing (2022)[67]and, this paper uses the proportion of tertiary industry added value to regional GDP to measure the level of regional industrial structure.

Infrastructure (Facility):The improvement of infrastructure can improve the development pote ntial of the region, attract more enterprises and investors to enter the region, expand the flow of information and resources in the region, and thus facilitate the further development of urba n innovation activities. In this paper, referring to Xu Ziyao et al. (2020)[15] , per capita urban r oad area is used to measure the level of urban infrastructure.

The degree of opening to the outside world: on the one hand, the continuous deepening of opening to the outside world can introduce foreign advanced knowledge and technology, and improve the innovation efficiency of innovation subjects. On the other hand, the entry of foreign markets can stimulate market vitality and force enterprises to carry out research and development innovation. Therefore, this paper refers to Dong Shugong and, Li Feifei (2023)[66], using the actual utilization of total foreign investment (converted into renminbi) in the proportion of regional gross domestic product to measure the level of regional opening up.

Institutional quality (Market):Regions with high institutional quality usually have more open, flexible and free market mechanisms, which can give full play to the role of market

mechanisms in the integration and allocation of resources, which is conducive to the development of innovative activities. Based on Liu Guangzhou et al. (2022)[20], Xie Jiazhi and, this paper adopts provincial marketization index to measure the quality of regional institutions.

Urbanization rate (Urban):Generally speaking, the improvement of urbanization rate is conducive to optimizing the population structure, improving the quality of talents, cultivating diversified and professional high-end talents, and thus stimulating the vitality of innovation. Therefore, this paper refers to Zheng Yaxin (2020)[69], Wang Liang and Liu Lingyan (2022)[70] and adopts the ratio of urbanization population to permanent resident population to measure the regional urbanization rate.

Government Ownership (Gov):The urban innovation activities cannot be carried out without the participation and support of the government. The government can support and guide the innovation activities in the market by means of policy subsidies, tax incentives or the establishment of funds, etc. Therefore, this paper takes the government factor into the model as the control variable. With reference to Zheng Puyang et al. (2023)[71], the ratio of government fiscal expenditure to fiscal revenue was used to measure regional government autonomy.

3.3.Data source

This paper takes prefecture-level cities as the research object, takes into account the availability, continuity of data, adjustment of administrative divisions and data missing, matches the initial data of digital finance with urban patent data, and builds an empirical sample of 273 cities from 2011 to 2021, with a total of 3003 sample data. Among them, the data of digital finance used in the empirical research in this paper comes from the Digital Inclusive Finance Index released by the Digital Finance Research Center of Peking University, and the patent data of prefecture-level cities comes from the China Research Data Service Platform (CNRDS). The marketization index data comes from the Marketization Index Report of China by Province, and the economic development level, industrial structure level and other control variables of prefecture-level cities come from the China City Statistical Yearbook and the Wind database. All the data have been sorted out and calculated. In this paper, interpolation method is used to complete and all continuous variables are reduced by 1%.

3.4.Descriptive statistics

The descriptive statistical results of each variable in this paper are shown in Table 1 below.

Table 1: Descriptive statistics

Varible name	Obs	Mean	Sd	Min	Median	Max
Innov	3003	0.11	0.148	0.00263	0.0485	0.778
Index	3003	1.85	0.726	0.36	1.96	3.2
Coverage	3003	1.77	0.737	0.241	1.82	3.3
Usage	3003	1.81	0.721	0.342	1.93	3.12
Digi	3003	2.19	0.825	0.229	2.53	3.23
Inpgdp	3003	4.67	0.242	4.14	4.66	5.24
Szi	3003	0.19	0.041	0.0955	0.195	0.29

Industry	3003	0.43	0.099	0.214	0.424	0.717
Facility	3003	18.04	7.305	4.3	16.6	40.6
Open	3003	0.02	0.016	0.0000736	0.0112	0.0721
Market	3003	8.33	1.651	4.26	8.43	12
Urban	3003	0.57	0.145	0.278	0.551	0.949
Gov	3003	2.86	1.679	1.00	2.36	9.56

The maximum value of urban innovation of the explained variable is 0.778, the minimum value is 0.00263, the standard deviation is 0.148, and the mean value is 0.11, indicating that the urban innovation level of different regions in China has a large gap and serious imbalance. The maximum value and minimum value of the total index of the development level of digital finance of the core explanatory variable are 3.2 and 0.36, indicating that China's digital finance has developed rapidly and has made certain achievements, but there is still an imbalance in the development of digital finance in various regions. According to the statistical results of the sub-dimensions, the mean and standard deviation of digitization degree are the largest, indicating that the development of digitization degree varies greatly in different regions, and local governments need to adopt relevant policies and regulations according to local conditions to promote the coordinated development of various regions. In addition, the descriptive statistical results of other control variables are similar to the existing research results, and the median and mean of each variable have little difference, indicating that the data structure distribution is reasonable and the data selection is reliable.

4.0 Empirical result analysis

Table 2 reports the regression results of model (1). Among them, column (1) represents the direct impact of the total digital finance index on urban innovation, and column (2), column (3) and column (4) represent the direct impact of the sub-dimension of digital finance, namely coverage breadth, depth of use and digitization degree, on urban innovation.

Table 2: Baseline regression result

	(1) *Innov*	(2) *Innov*	(3) *Innov*	(4) *Innov*
Index	0.2968***			
	(9.72)			
Coverage		0.0813***		
		(3.00)		
Usage			0.2018***	
			(8.20)	
Digi				0.0740***
				(8.02)
Inpgdp	-0.0884***	-0.0354	-0.0530**	-0.0301
	(-3.41)	(-1.31)	(-2.06)	(-1.14)
szi	0.3696***	0.4653***	0.3691***	0.4092***
	(3.44)	(3.88)	(3.57)	(3.71)
Industry	-0.2232***	-0.2456***	-0.2349***	-0.2489***
	(-4.01)	(-4.00)	(-4.09)	(-4.22)
Facility	-0.0019***	-0.0022***	-0.0018***	-0.0020***
	(-3.03)	(-3.25)	(-2.95)	(-3.12)
Open	-0.4088*	-0.4220	-0.3120	-0.3666

	(-1.68)	(-1.63)	(-1.29)	(-1.51)
Market	0.0107***	0.0088**	0.0083**	0.0100***
	(2.96)	(2.28)	(2.30)	(2.79)
Urban	-0.2070	-0.2232*	-0.1260	-0.1993
	(-1.65)	(-1.66)	(-1.06)	(-1.49)
Gov	-0.0042**	-0.0055**	-0.0064***	-0.0049**
	(-2.13)	(-2.43)	(-3.06)	(-2.32)
Cons	0.3686***	0.2626*	0.2337*	0.2293
	(2.70)	(1.79)	(1.70)	(1.59)
N	3003	3003	3003	3003
R^2	0.5811	0.5418	0.5783	0.5668
Individual effect	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes

Note: The coefficient in brackets is t value, ***, **, * respectively indicate that it is significant at the level of 1%, 5% and 10%. If no special explanation is given, the following table is the same.

According to the regression results in column (1), the regression coefficient of the total digital finance index is significantly positive at the 1% confidence level, indicating that digital finance can promote urban innovation and verify the hypothesis H1 in this paper, which is consistent with the research of Xu Ziyao et al. (2020) and Nie Xiuhua et al. (2021). According to the regression results of column (2), column (3) and column (4), the estimated coefficients of coverage breadth, use depth and digitization degree of digital finance are 0.0813, 0.2018 and 0.0740 respectively, and all of them are significantly positive at 1% confidence level. It shows that the expansion of the coverage breadth, the deepening of the use depth and the improvement of the digital degree can promote urban innovation. Further analysis shows that the "inclusive and inclusive" concept of digital finance has alleviated the unbalanced and inadequate development of traditional finance to a certain extent, enabling it not only to meet the financing needs of technologically innovative enterprises, but also to provide high-quality and efficient financial services for urban innovation activities.

4.1.Endogenetic analysis

Endogeneity is a problem that cannot be ignored in the empirical research. The main causes of endogeneity are reverse causality and missing variables. First of all, digital finance is based on the wide application of digital technology, which has a significant driving effect on technological innovation, but with the improvement of urban innovation level, innovation based on digital technology such as big data and cloud computing will in turn help the development of digital finance, that is, there may be reverse causality problem. Secondly, there are many factors affecting the level of urban innovation. Although this paper has selected relevant influencing factors as control variables, there are still some factors that have not been taken into account, and there is the problem of missing variables. In order to solve the endogeneity problem, this paper adopts the method of instrumental variables and selects three instrumental variables to analyze the endogeneity problem.

Firstly, in this paper, Zhang Xun et al. (2019)[72]and Huang Manyu and Wang Haoyang (2023)[73]use the spherical distance from each city to Hangzhou as an instrumental variable. As we all know, digital finance originated in Hangzhou, and the development level of digital finance in different cities has a certain relationship with the distance from Hangzhou, while the relationship between urban innovation and the spherical distance from each city to Hangzhou is not obvious. Therefore, the spherical distance from each city to Hangzhou meets the requirements of instrumental variables. Considering that the geographical distance variable does not change with time, while digital finance is a variable that changes with time, this paper

takes the interaction term (Iv) of the spherical distance from each city to Hangzhou and the mean value of the digital financial development index at the national level (except the city) as the new instrumental variable.

Secondly, referring to the methods of Zhao Tao et al. (2020)[74], this paper adopts the Internet penetration rate (hlw) of prefecture-level cities as an instrumental variable. Digital finance takes the Internet as the carrier, and its various businesses such as payment, investment and credit cannot be carried out without the Internet, while the direct relationship between Internet penetration and urban innovation is not significant. Therefore, the urban Internet penetration rate meets the requirements of the use of instrumental variables.

Finally, with reference to the studies of Guo Yutang and Luo Pinliang (2016)[75], this paper selected the one-phase lag value of digital finance (L.Index) as the instrumental variable. Because the development situation of digital finance in this period is related to the previous development situation, but the relationship between the previous development situation and the current urban innovation level is not obvious, it should be exogenous, so the value of digital finance lagging in one period can be used as an effective instrumental variable.

As can be seen from Table 3, columns (1) and (2) show the regression results that take the interaction term (Iv) of the spherical distance from each city to Hangzhou and the mean value of the digital financial development index at the national level (except the city) as the instrumental variable. Column (2) shows that the instrumental variable of geographic distance is significantly negatively correlated with digital finance, which means that the farther away from the digital financial development center, the better the distance. The lower the level of digital financial development. Columns (3) and (4) show the regression results with the Internet penetration rate of prefectures as the instrumental variable, and columns (5) and (6) show the regression results with the value of digital finance lag one stage as the instrumental variable. The F-value of the first stage is all greater than 10, indicating that there is no weak instrumental variable problem, and after the regression using the instrumental variable, The promotion effect of digital finance on urban innovation is still significant, which indicates that the conclusion of this study is reliable and robust.

Table 3: Endogeneity test results

	(1) *first stage*	(2) *second stage*	(3) *first stage*	(4) *second stage*	(5) *first stage*	(6) *second stage*
Variables	*Index*	*Innov*	*Index*	*Innov*	*Index*	*Innov*
Index		0.778***		1.043**		0.708***
		(0.063)		(0.409)		(0.055)
Iv	-0.000543***					
	(0.000)					
Hlw			0.001***			
			(0.000)			
L.index					0.499***	
					(0.024)	
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
N	3,003	3,003	3003	3003	2730	2730
R^2		0.468		0.309		0.474
Stage one F number	242.57		11.11		415.64	

Note: In brackets, clustering robust standard error, ***, ** and * are statistically significant at 1%, 5% and 10%, respectively.

4.2.Robustness test

On the basis of the previous research results, this paper will further explore the robustness of digital finance on the regression results of urban innovation in the following ways.

First of all, replace the explained variables. Since invention patents are generally formed in the process of technology creation and new product research and development, they occupy a large proportion in the number of patents granted, which can better represent the level of urban innovation. Therefore, in this paper, referring to Bian Yuanchao and Wu Lihua (2019), the index to measure urban innovation level was further replaced by the total amount of patent authorization per 100 per capita to the total amount of invention patent authorization per 100 per capita for regression analysis, as shown in Table 4 below.

Table 4: Replace the explained variable

	(1) *Innov*	(2) *Innov*	(3) *Innov*	(4) *Innov*
Index	0.0409***			
	(8.67)			
Coverage		0.0121***		
		(3.06)		
Usage			0.0221***	
			(5.84)	
Digi				0.0116***
				(8.44)
Cons	0.0570***	0.0431*	0.0372*	0.0384*
	(2.79)	(1.95)	(1.77)	(1.83)
Control variable	Yes	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
N	3003	3003	3003	3003
R^2	0.3998	0.3584	0.3810	0.3934

Secondly, compared with other cities, central cities have more advantages in infrastructure, economic development and human resources, etc. Therefore, this paper uses the previous literature to process special samples, and further excludes provincial capital cities and municipalities directly under the central government samples for regression analysis, as shown in Table 5 below.

Table 5: Excluding provincial capitals and municipalities

	(1) *Innov*	(2) *Innov*	(3) *Innov*	(4) *Innov*
Index	0.2736***			
	(8.70)			
Coverage		0.1076***		
		(4.18)		
Usage			0.1692***	
			(7.12)	
Digi				0.0596***
				(6.62)
Cons	0.2497*	0.1824	0.1226	0.1159
	(1.93)	(1.32)	(0.93)	(0.84)
Control variable	Yes	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes

Time effect	Yes	Yes	Yes	Yes
N	2763	2763	2763	2763
R^2	0.5507	0.5134	0.5403	0.5291

The regression results are shown in Table 4 and Table 5. Both the regression coefficients of the total digital financial index and its primary index are significantly positive at the 1% confidence level, and are consistent with the research conclusions obtained by the benchmark regression. The regression results of its control variables have also not changed greatly, so the research results in this paper can be regarded as relatively robust.

4.3.Heterogeneity analysis

4.3.1.Heterogeneity analysis based on urban location

Table 6 shows the empirical regression results of the eastern, western and eastern samples. It can be seen from Table 6 that the estimated coefficients of digital finance for the eastern, central and western regions are significantly positive at the 1% level, indicating that digital finance can promote urban innovation in different regions, which reflects the "inclusive" and "inclusive" characteristics of digital finance. The estimated coefficients were 0.3167, 0.1226 and 0.0679, respectively. It shows that the driving effect of digital finance on urban innovation is strongest in the eastern region, followed by the central region, and finally the western region. The reason for this difference may be that the eastern region, as the "leader" of China's economic development, has a higher degree of urbanization, a relatively perfect industrial structure, and a higher level of digital financial development, which can provide enterprises and individuals with more low-cost and efficient financial services, so as to better play the driving role of digital finance on urban innovation. Secondly, compared with the eastern region, the application of digital finance in the central region is relatively small, but in recent years, with the strong support of the government for digital finance, digital finance has developed rapidly, which helps the central region to cultivate emerging industries, attract high-quality talents, and promote the transformation and upgrading of the regional economy and innovative development. In the western region, due to the problems of backward economic development, imperfect infrastructure and lack of talents, it is faced with a huge "digital divide", which further limits the driving role of digital finance on urban innovation.

Table 6: Heterogeneity test results based on urban location

	(1) The east	(2) The Middle part	(3) The west
	Innov	*Innov*	*Innov*
Index	0.3167***	0.1226***	0.0679***
	(3.40)	(3.55)	(2.83)
Cons	1.1300**	-0.3741**	0.3025***
	(2.46)	(-2.01)	(2.84)
Control variable	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
N	924	858	836
R^2	0.6847	0.7611	0.6828

4.3.2.Heterogeneity analysis based on city size

As can be seen from Table 7, the digital finance coefficient of megacities, medium-sized cities and small cities is not significant, while the digital finance coefficient of megacities and big cities is significantly positive at 1% level. This suggests that the contribution of digital finance to urban innovation is not evident in cities that are too large or too small. This may be due to the fact that megacities have a good external environment, relatively complete financial system, and lower degree of distortion of financial elements compared with other cities. Traditional financial institutions can provide good financial services and financing channels for the development of innovative activities. At this time, the driving effect of digital finance on urban innovation is limited. However, in small and medium-sized cities, economic development and infrastructure are relatively backward, and there is a relative shortage of digital financial talents, which cannot effectively play the driving role of digital finance on urban innovation.

Table 7: Heterogeneity test results based on city size

	(1) megacity	(2) megalopolis	(3) Big city	(4) Medium sized city	(5) Small city
	Innov	*Innov*	*Innov*	*Innov*	*Innov*
Index	0.2205	0.3825***	0.2051***	0.0390	0.1789
	(0.95)	(5.15)	(7.52)	(0.80)	(2.76)
Cons	1.9078**	0.7832**	0.0150	-0.1887	-1.4229
	(2.21)	(2.19)	(0.17)	(-1.12)	(-0.98)
Control variable	Yes	Yes	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes
N	160	776	1970	75	22
R^2	0.8522	0.6462	0.6066	0.7252	0.9995

4.5.Regression analysis of intermediate effects

4.5.1.Analysis of the intermediary effect based on the supply of credit funds

Table 8 reports the regression results with the supply of credit funds as the intermediate variable. From the regression results, the digital finance regression coefficient in column (3) is smaller than the estimated result in column (1), and the credit fund supply coefficient in the estimated result in column (2) is significantly positive at 1% level and the digital finance coefficient in column (2) is also significantly positive at 1% level, indicating that the intermediary effect is a partial intermediary effect.

The above results suggest that digital finance can promote the level of urban innovation by optimizing the supply of corporate credit, assuming that H2a is validated. Further analysis shows that the original intention of digital finance is to use digital technology to integrate with traditional finance, provide more inclusive, efficient and convenient financial services for vulnerable groups such as "agriculture, rural areas and farmers" and small, medium and micro enterprises, expand the scope of financial services, increase effective financial supply, so as to

make up for the deficiency of traditional financial services and help the high-quality development of the real economy. In other words, through the development of digital finance, local enterprises can expand the supply of credit funds to a certain extent, provide financial support for research and development activities in urban innovation, increase their research and development capital investment, so as to alleviate the innovation financing constraints of small and medium-sized enterprises in the region and promote the improvement of urban innovation level.

Table 8: The results of intermediate effect test based on the supply of credit funds

	(1)	(2)	(3)
	Innov	*Credit*	*Innov*
Index	0.2968***	9.0326***	0.1915***
	(9.72)	(8.26)	(7.09)
Credit			0.0117***
			(7.30)
Cons	0.3686***	16.9461***	0.1712
	(2.70)	(3.60)	(1.38)
Control variable	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
N	3003	3003	3003
R^2	0.5811	0.6074	0.6670

4.5.2.Analysis of the intermediary effect based on the scale of household consumption

Table 9 reports the regression results with household consumption scale as the intermediary variable. Column (2) in the table is the regression result of residents' consumption scale based on digital finance as the core explanatory variable, and column (3) is the regression result of adding an intermediary variable, namely residents' consumption scale, to the benchmark regression. Its digital finance coefficient and residents' consumption scale coefficient are both significantly positive at the 1% level, and the digital finance coefficient of column (3) is smaller than 0.2968 in column (1).

Table 9: Test results of mediating effect based on the scale of household consumption

	(1)	(2)	(3)
	Innov	*Consquan*	*Innov*
Index	0.2968***	2.0313***	0.2403***
	(9.72)	(9.80)	(7.71)
Consquan			0.0278***
			(4.02)
Cons	0.3686***	-9.9481***	0.6451***
	(2.70)	(-9.97)	(4.34)
Control variable	Yes	Yes	Yes

Individual effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
N	3003	3003	3003
R^2	0.5811	0.6873	0.5991

It shows that the scale of household consumption plays a part of the intermediary effect, thus verifying the hypothesis H2b in this paper. Further analysis shows that, first of all, the emergence of digital finance, on the one hand, broadens the channels for residents to obtain credit products, alleviates the liquidity constraints of residents, on the other hand, facilitates the payment of residents, fundamentally realizes a profound change in the previous transaction mode, and expands the consumption scale of residents. Secondly, the deep integration of digital finance and all walks of life has promoted the reconstruction and upgrading of production modes, making residents pay more attention to the quality of consumption. In turn, the expansion of consumption scale will force innovation subjects to carry out research and innovation in order to obtain greater competitive advantages, thus driving the improvement of urban innovation level.

4.5.3. Analysis of intermediary effect based on human capital

Table 10 reports the regression results with human capital level as the intermediate variable. Column (2) is the regression result of digital finance as the core explanatory variable to the intermediary variable human capital level, and column (3) is the regression result of adding the intermediary variable, namely human capital level, to the benchmark regression. Its digital finance coefficient and human capital level coefficient are both significantly positive at the 1% level, and its digital finance coefficient is less than 0.2968 in column (1). This shows that the mediation effect is partial mediation effect, thus verifying the hypothesis H2b in this paper.Further analysis shows that digital finance provides more education loans and training opportunities to social labor with its advantages of wide coverage and low threshold, thus reducing the opportunity cost of labor to acquire knowledge and skills and accelerating the accumulation of human capital. The improvement of human capital level can not only effectively exert its own skills advantages, learn relevant knowledge and skills from previous innovation activities, scientifically grasp the future direction of the innovation process, but also effectively promote the communication and exchange of intellectual capital such as knowledge, skills and experience in different fields, so as to promote the generation of new knowledge and the creation of new technologies, and contribute to the promotion of urban innovation.

Table 10: The test results of intermediary effect based on human capital level

	(1)	(2)	(3)
	Innov	*Hc*	*Innov*
Index	0.2968***	0.0049*	0.2920***
	(9.72)	(1.65)	(9.77)
Hc			0.9769*
			(1.79)
Cons	0.3686***	0.0196	0.3494***
	(2.70)	(1.62)	(2.63)
Control variable	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
N	3003	3003	3003
R^2	0.5811	0.1905	0.5842

4.5.4. Mediation effect analysis based on Bootstrap method

It can be intuitively seen from the above regression results that no matter the supply of credit funds is used as the intermediary variable or the scale of consumer consumption and the level of human capital is used as the intermediary variable, the regression results of the three stages are significant. However, considering the low statistical test effectiveness of the step-to-step regression coefficient method, the existence of intermediary effect still cannot be completely determined. Therefore, the Bootstrap method of deviation correction was adopted in this paper for further verification, and the results are shown in Table 11 below.

Table 11: The results of bootstrap test of mediation effect

Intermediate variable	Effect	Coefficient	S.d	zvalue	floor(95%)	Upper limit (95%)
Creditfund supply	Mediating effect	0.105***	0.0163	6.43	0.0731	0.1373
	Direct effect	0.192***	0.0217	8.79	0.1488	0.2342
Household consumption scale	Mediating effect	0.0565***	0.0098	5.73	0.0371	0.0757
	Direct effect	0.2403***	0.0243	9.87	0.1926	0.288
Human capital level	Mediating effect	0.00523*	0.0025	2.01	0.000136	0.0103
	Direct effect	0.2846***	0.0218	13.03	0.2417	0.3273

According to the Bootstrap test results in Table 11, all intermediary variables do not include 0 in the 95% confidence interval, and the coefficients of both the intermediary effect and the direct effect are significantly less than 0, indicating that the intermediary effect of the supply of credit funds and the scale of consumer consumption of human capital is significant.

4.6.Threshold effect regression analysis

In order to explore whether the impact of digital finance on urban innovation has threshold effect under different development levels of digital finance and external environmental conditions, this paper refers to Hansen (1996)[76]and takes digital finance's own development level, industrial structure and institutional quality as threshold variables to conduct threshold existence test. The test results are shown in Table 12 below.

Table 12: Threshold existence test results

	Threshold number	*F* value	*P value*	Critical value 10%	Critical value 5%	Critical value 1%	*BS degree*
Index	Single threshold	1220.62	0.0000	100.69	109.61	120.33	300
	Double threshold	466.65	0.0000	18.50	22.78	30.61	300
	Triple threshold	172.87	0.7033	409.76	433.48	500.49	300
Industry	Single threshold	250.18	0.0000	59.33	69.23	94.13	300
	Double threshold	54.96	0.0433	45.71	52.87	72.54	300
	Triple threshold	30.08	0.7733	70.77	78.75	100.20	300
Market	Single	760.78	0.0000	82.43	87.95	124.00	300

threshold						
Double threshold	214.80	0.0000	57.87	66.11	93.76	300
Triple threshold	86.56	0.6567	205.22	231.18	255.29	300

Table 12 reflects the test results that take digital finance's own development level, industrial structure and institutional quality as threshold variables. It can be seen that the development level, industrial structure and institutional quality of digital finance have passed the double threshold test, indicating that the double threshold model should be adopted for regression analysis. In order to overcome the possible heteroscedasticity, this paper adopts the robust standard deviation method to estimate the regression using the threshold model. The regression results are shown in Table 13.

Table 13: Threshold effect regression results

	Dynamic effect estimation	Adjustment effect estimation	
	(1)	(2)	(3)
	Innov	*Innov*	*Innov*
Index(*Index*<2.496)	0.0410***		
	(5.59)		
Index(2.496<*Index*<2.989)	0.0655***		
	(7.76)		
Index(*Index*>2.989)	0.1130***		
	(12.30)		
Index(*Industry*<0.451)		0.0491***	
		(5.28)	
Index(0.451<*Industry*<0.578)		0.0593***	
		(6.56)	
Index(*Industry*>0.578)		0.0943***	
		(8.95)	
Index(*Market*<9.21)			0.0006***
			(7.43)
Index(9.21<*Market*<10.58)			0.0008***
			(9.32)
Index(*Market*>10.58)			0.0012***
			(12.13)
Cons	0.0531	-0.2921**	0.0579
	(0.49)	(-2.25)	(0.52)
Control variable	Yes	Yes	Yes
N	3003	3003	3003
R^2	0.6632	0.4946	0.5960

Column (1) is the regression result of the threshold effect model based on the development level of digital finance itself as the threshold variable. The results show that the estimated coefficient of digital finance is significantly positive in each threshold interval, indicating that the impact of digital finance on urban innovation has a threshold effect, showing a trend of increasing marginal effect. Specifically, when the threshold is lower than 2.496, the estimated coefficient of digital finance is 0.0410; when the threshold is between [2.496 and 2.989], the estimated coefficient of digital finance is 0.0655; when the threshold is higher than 2.989, the estimated coefficient of digital finance is 0.1130. It is not difficult to find that with the improvement of the development level of digital finance, the driving effect of digital finance on urban innovation has evolved from weak to strong, which verifies the hypothesis H3a in this paper.

The dynamic impact of digital finance on urban innovation will not only be affected by its own level of development, but also by changes in the external environment. Columns (2) and (3) in Table 13 are regression results of industrial structure and institutional quality as threshold variables, respectively. The results show that when the industrial structure level exceeds 0.451, the estimated coefficient of digital finance is 0.0491; when the threshold value is [0.451, 0.578], the coefficient of digital finance increases to 0.0593; when the threshold value exceeds 0.578, the estimated coefficient of digital finance further increases to 0.0943. It can be seen that its promoting effect on urban innovation continues to increase and presents a significant feature of increasing marginal effect, which verifies the hypothesis H3b in this paper. Similarly, when the institutional quality threshold value is lower than 9.21, the estimated coefficient of digital finance is 0.0006; when the threshold value is [9.21, 10.58], the estimated coefficient of digital finance is 0.0008; when the threshold value is higher than 10.58, the estimated coefficient of digital finance is 0.0012. It can be seen that under the condition of continuous improvement of industrial structure and institutional quality, digital finance also has a positive and increasing marginal effect in promoting urban innovation, which verifies the hypothesis H3c in this paper.

4.7.Regression analysis of adjustment effect

In order to explore the specific impact of financial regulation on the innovation incentive effect of digital finance, this paper referred to the research of Wang Ren et al. (2019)[77], adopted regional regulatory expenditure/financial industry added value as the final proxy variable of financial regulation, and grouped financial regulation by intensity (bounded by 50% quantile). The regression results are shown in Table 14 below.

Table 14: Regression results of regulatory effects of financial supervision

	(1) Strong financial regulation	(2) Weak financial regulation	(3)	(4)	(5)
	Innov	*Innov*	*Innov*	*Innov*	*Innov*
Index	0.2273***	0.2678***	0.2927***		
	(6.60)	(6.09)	(9.80)		
Index×sup			-0.9281***		
			(-4.37)		
Coverage				0.0971***	
				(3.64)	
Coverage×sup				-1.0075***	
				(-4.82)	
Usage					0.2003***
					(8.25)
Usage×sup					-0.8745***
					(-4.35)
sup			1.4757***	1.5295***	1.2110***
			(3.52)	(3.90)	(3.24)
Cons	0.3266***	0.6130***	0.4568***	0.3783**	0.3303**
	(3.02)	(2.63)	(3.28)	(2.55)	(2.37)
Control variable	Yes	Yes	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes
N	1495	1508	3003	3003	3003

As can be seen from Table 17, the results of columns (1) and (2) show that the incentive effect of digital finance on urban innovation is more obvious in the weak financial supervision range, and the interaction coefficient of column (3) is significantly negative at the 1% level. In order to further verify the robustness of this result, In this paper, the subdivision index of digital finance, namely coverage breadth and use depth, is used to replace the total index of digital finance. The results are shown in columns (4) and (5), and the interaction coefficient is still significantly negative at 1% level, indicating that the result is still robust, which verifies the hypothesis H5b in this paper, indicating that financial regulation will weaken the promotion effect of digital finance on urban innovation to a certain extent. Excessive financial regulation is not conducive to the incentive effect of digital finance on urban innovation.

Further analysis shows that the spatial mismatch between financial regulatory system and digital financial model will weaken the incentive effect of digital finance on urban innovation (Wang Zhixin et al., 2022)[78]. Specifically, under the central-local decentralization of financial supervision system, local governments will promote the rapid development of digital finance in a more tolerant way in order to play the driving role of digital finance in urban innovation. However, with the intensification of financial supervision and even beyond a certain range, more and more digital financial cross-domain business platforms will choose to carry out relevant activities in areas with relatively loose supervision in order to avoid strict supervision, resulting in regulatory failures or regulatory loopholes and other problems, which reduce the efficiency of financial services, and then increase the innovation cost and time investment of innovation entities, and inhibit urban innovation. Therefore, we should deal with the relationship between financial regulation and digital financial development, further improve the financial supervision system, steadily promote the healthy and stable development of digital finance, and give full play to the enabling role of digital finance in urban innovation.

5.0 Conclusion and suggestion

Taking 273 prefecture-level cities in China as research objects, this paper uses panel data model to analyze the influence mechanism and effect of digital finance on urban innovation during 2011-2021. The research results show that: First, digital finance has a significant positive promoting effect on urban innovation, and the impact on urban innovation in different regions and different scales is significantly different. The conclusion is still valid after endogeneity analysis and robustness test. Second, digital finance mainly promotes urban innovation by optimizing the supply of enterprise credit funds, expanding the scale of household consumption, and improving the level of human capital. Third, due to its own development level, industrial structure and institutional quality, the impact of digital finance on urban innovation has a threshold effect; Fourth, to some extent, financial regulation will weaken the role of digital finance in promoting urban innovation, and excessive financial regulation is not conducive to the incentive effect of digital finance on urban innovation.

Based on the above conclusions, this paper puts forward the following suggestions: First, improve the digital financial infrastructure system. Steadily promote the construction of digital financial infrastructure, give full play to the enabling role of digital finance in urban innovation, and fully release the production potential of innovative entities. Second, strengthen the path dependence of digital finance to promote urban innovation. Strengthen the accumulation of human capital, increase the investment in all kinds of education funds, and strive to build a large scale, reasonable structure, high skills, excellent learning style of scientific and technological innovation personnel team, to build a solid foundation for urban innovation. At the same time, accelerate the reform of financial institutions, encourage financial institutions

to continue to innovate and promote differentiated, scenario-based and intelligent financial products according to the different development stages of innovative entities, and strengthen the supply of credit funds for innovative entities. And give full play to the advantages of digital finance in third-party payment, cross-border payment and application scenarios, optimize the consumption environment, release the consumption potential of residents, and force urban innovation. The third is to build a digital financial supervision system to stimulate the innovation incentive effect of digital finance. Adhere to the principle of substance over form, explore the establishment of a cross-departmental, cross-market, cross-regional digital financial business risk consultation mechanism, classify legal and compliance new things into routine supervision as soon as possible, and eliminate gaps and gaps in institutional supervision. At the same time, the "regulatory sandbox" mechanism should be established to give emerging things in the field of digital finance sufficient "trial and error" space, set flexible regulatory boundaries, solve the contradiction between strong supervision and inclusive development, and give full play to the incentive role of digital finance on urban innovation.

References

[1] 王敏,李兆伟.数字普惠金融与企业创新：理论逻辑与实证检验[J].管理学刊,2023,36(01):102-119.
[2] 梁榜,张建华.数字普惠金融发展能激励创新吗?——来自中国城市和中小企业的证据[J].当代经济科学,2019,41(05):74-86.
[3] 崔耕瑞.数字金融与产业高质量发展[J].西南民族大学学报(人文社会科学版),2022,43(02):136-144.
[4] 张慧慧,张云,荆睿.普惠金融数字化如何影响城市创新力——来自地级市面板数据的证据[J].金融理论与实践,2021(09):62-69.
[5] Duarte J ,Siegel S ,Young L .Trust and Credit: The Role of Appearance in Peer-to-peer Lending[J].The Review of Financial Studies,2012,25(8):2455-2483.
[6] Norden L, Buston C S, Wagner W. Financial innovation and bank behavior: Evidence from credit marketsyl. journal of Economic Dynamics and Control,2014,(43):130-145.
[7] Demertzis M, Merler S, Wolff G B. Capital markets union and the fintech opportunityly[J].Journal of Financial Regulation,2018,(4):157-165.
[8] 杜传忠,张远.“新基建”背景下数字金融的区域创新效应[J].财经科学,2020(05):30-42.
[9] 任娇,赵荣荣,任建辉.数字金融、高技术产业集聚与区域创新绩效[J].统计与决策,2023,39(05):86-91.
[10] 宋宝琳,张航,宋凤轩.数字金融对城市创新水平与质量的影响效应研究——基于我国 284 个地级市面板数据的实证分析[J].系统科学与数学,2023,43(01):199-214.
[11] 谢绚丽,沈艳,张皓星等.数字金融能促进创业吗?——来自中国的证据[J].经济学(季刊),2018,17(04):1557-1580.
[12] 潘爽,叶德珠,叶显.数字金融普惠了吗——来自城市创新的经验证据[J].经济学家,2021(03):101-111.
[13] 刘毛桃,何启志,彭承亮.数字普惠金融促进了城市的创新创业吗？——来自 283 个城市的经验证据[J].武汉金融,2021(07):35-43+52.
[14] 张晓丹,彭耿.数字普惠金融发展与区域创新能力——基于 282 个城市数据的非线性影响研究[J].技术经济与管理研究,2021(10):32-36.
[15] 徐子尧,张莉沙,刘益志.数字普惠金融提升了区域创新能力吗[J].财经科学,2020(11):17-28.
[16] 任碧云,刘佳鑫.数字普惠金融发展与区域创新水平提升——基于内部供给与外部需求视角的分析[J].西南民族大学学报(人文社会科学版),2021,42(02):99-111.
[17] 郑万腾,赵红岩.数字金融发展能驱动区域技术创新收敛吗?——来自中国 284 个城市的经验证据[J].当代经济科学,2021,43(06):99-111.
[18] 徐章星.数字普惠金融发展促进了城市创新吗?——基于空间溢出和门槛特征的实证分析[J].南方金融,2021(02):53-66.
[19] 吕慧,许可,宋子源.有形与无形之手能否协同激发城市创新活力——基于中国 275 个城市数据的分析[J].科技进步与对策,2023,40(06):59-68.

[20] 刘广州,刘婧.数字金融赋能绿色创新的理论与实证——来自地级市的经验证据[J].武汉金融,2022(09):50-60.
[21] Pierrakis Y, Collins L. Crowd funding: A New innovative Model of Providing Funding to Projects and Businesses [J].journal of Economic Perspectives,2014,31(1)45-65.
[22] 郑素兰,刘婧涵,姚婷.数字金融对绿色技术创新的影响及机制研究[J].经济问题,2024(02):41-47+63.
[23] 张勋,万广华,张佳佳等.数字经济、普惠金融与包容性增长[J].经济研究,2019,54(08):71-86.
[24] Teece. D j. Business models, business strategy and innovation[J].Long Range Planning,2010,43(2-3):172-194.
[25] Gomber P. Koch j A, Siering M.Digital inance and Fin Tech: Curent research and future research directions[J].journal of Business Economics,2017.87(5):537-580.
[26] 郑万腾,赵红岩.数字金融发展能驱动区域技术创新收敛吗?——来自中国 284 个城市的经验证据[J].当代经济科学,2021,43(06):99-111.
[27] 柳卸林,胡志坚.中国区域创新能力的分布与成因[J].科学研究,2002(05):550-556.
[28] 汪伟和潘孝挺,2015,《金融要素扭曲与企业创新活动》,《统计研究》第 5 期,第 26~31 页.
[29] 曾雅婷,邢晶晶,李宾.数字金融发展对新创企业成长的影响——融资约束和研发投入的链式中介效应与异质性分析[J].西部论坛,2022,32(06):20-36.
[30] 马红,李小萍.数字金融与企业创新风险——基于制度背景因素的再检验[J].财会月刊,2022(14):62-71.
[31] 徐子尧,张莉沙,刘益志.数字普惠金融提升了区域创新能力吗[J].财经科学,2020(11):17-28.
[32] 唐松,伍旭川,祝佳.数字金融与企业技术创新——结构特征、机制识别与金融监管下的效应差异[J].管理世界,2020,36(05):52-66+9.
[33] Pierrakis Y, Collins L. Crowd funding: A New innovative Model of Providing Funding to Projects and Businesses [J].journal of Economic Perspectives,2014,31(1)45-65.
[34] 董春风,司登奎.数字普惠金融改善城市技术创新“低端锁定”困境了吗？[J].上海财经大学学报,2022,24(04):62-77.
[35] 董云飞,李倩,张璞.我国普惠金融发展对农村居民消费升级的影响分析[J].商业经济研究,2019(20):135-139.
[36] 傅秋子,黄益平.数字金融对农村金融需求的异质性影响——来自中国家庭金融调查与北京大学数字普惠金融指数的证据[J].金融研究,2018(11):68-84.
[37] 江红莉,蒋鹏程.数字普惠金融的居民消费水平提升和结构优化效应研究[J].现代财经(天津财经大学学报),2020,40(10):18-32.
[38] 陈晓,王森.数字普惠金融对居民消费的影响及传导机制研究——基于生命周期模式的分析[J].价格理论与实践,2022(02):156-159+202.
[39] 金晓彤,黄蕊.技术进步与消费需求的互动机制研究——基于供给侧改革视域下的要素配置分析[J].经济学家,2017(02):50-57.
[40] 范红忠.有效需求规模假说、研发投入与国家自主创新能力[J].经济研究,2007(03):33-44.
[41] 冯伟,徐康宁,邵军.基于本土市场规模的产业创新机制及实证研究[J].中国软科学,2014(01):55-67.
[42] 汪亚楠,徐枫,郑乐凯.数字金融能驱动城市创新吗？[J].证券市场导报,2020(07):9-19.
[43] 李建强,赵西亮,张昀彬.教育扩招、人力资本与企业创新[J].中国经济问题,2019(03):81-94.
[44] 李汉瑾,张淑婷,公茂刚.数字普惠金融对家庭教育投资的影响分析[J].征信,2022,40(07):74-80.
[45] 姜松,周鑫悦.数字普惠金融对经济高质量发展的影响研究[J].金融论坛,2021,26(08):39-49.
[46] 韩先锋,宋文飞,李勃昕等.数字金融赋能绿色创新的异质非线性调节效应[J].中国人口·资源与环境,2022,32(10):65-76.
[47] 曾建中,李银珍,刘桂东.数字普惠金融赋能乡村产业兴旺的作用机理和空间效应研究——基于县域空间动态面板数据的实证检验[J].国际金融研究,2023(04):39-49.
[48] 顾江寒,柴华奇.数字金融的绿色创新影响效应[J].软科学,2022,36(09):51-56.
[49] 王修华,杨彦宁.数字金融能够降低城市发展差距吗[J].经济学动态,2023(02):88-105.
[50] 史宇鹏,顾全林.知识产权保护、异质性企业与创新:来自中国制造业的证据[J].金融研究,2013(08):136-149.
[51] 黄锐,赖晓冰,唐松.金融科技如何影响企业融资约束？——动态效应、异质性特征与宏微观机制检验[J].国际金融研究,2020(06):25-33.

[52] 石光乾,寇娅雯.互联网众筹融资监管标准的多维度构建[J].广西社会科学,2022(05):9-18.
[53] 孙友晋,王思轩.数字金融的技术治理：风险、挑战与监管机制创新——以基于区块链的非中心结算体系为例[J].电子政务,2020(11):99-107.
[54] 韩贺洋,周全,韩俊华.数字经济时代数字金融“双风险”演变机制分析[J].科学管理研究,2023,41(03):98-106.
[55] Becker, Gary, et al. A theory of competition among pressure groups for political influence[J].Quarterly Journal of Economics,1983,98(3):371-400.
[56] 蒋长流,江成涛.数字普惠金融能否促进地区经济高质量发展?——基于 258 个城市的经验证据[J].湖南科技大学学报(社会科学版),2020,23(03):75-84
[57] 聂秀华,吴青.数字金融的创新激励效应——基于传导机制新视角[J].华东经济管理,2022,36(08):34-50.
[58] 白俊红,蒋伏心.协同创新、空间关联与区域创新绩效[J].经济研究,2015,50(07):174-187.
[59] 卞元超,吴利华,白俊红.高铁开通是否促进了区域创新?[J].金融研究,2019(06):132-149.
[60] 张可.产业集聚与区域创新的双向影响机制及检验——基于行业异质性视角的考察[J].审计与经济研究,2019,34(04):94-105.
[61] 陆凤芝,徐鹏,李仲武.数字普惠金融与城市创新创业质量[J].武汉大学学报(哲学社会科学版),2022,75(05):35-48.
[62] 孙伟增,吴建峰,郑思齐.区位导向性产业政策的消费带动效应——以开发区政策为例的实证研究[J].中国社会科学,2018(12): 48-68,200.
[63] 王智勇,李瑞.人力资本、技术创新与地区经济增长[J].上海经济研究,2021(07):55-68.
[64] 何小钢,黄莹珊,朱国悦.高质量人力资本与中国城市创新能力——来自高校扩招政策的证据[J].当代财经,2022(10):15-27.
[65] 张梁,相广平,马永凡.数字金融对区域创新差距的影响机理分析[J].改革,2021(05):88-101.
[66] 李菲菲,刘宇星,黄解宇.地方政府债务、数字金融与企业创新——基于创新异质性视角[J].管理现代化,2023,43(03):28-36.
[67] 孟晓倩,吴传清.数字金融对区域创新生态影响研究[J].中国软科学,2022(09):161-171.
[68] 谢家智,张馨月.双向直接投资、知识溢出效应与创新链协同发展——基于工业行业数据的实证研究[J].科技进步与对策,2023,40(22):33-42.
[69] 郑雅心.数字普惠金融是否可以提高区域创新产出?——基于我国省际面板数据的实证研究[J].经济问题,2020(10):53-61.
[70] 王亮,刘凌燕.数字普惠金融与区域创新的交互影响及空间溢出——基于空间联立方程和异质性 SDM 的实证检验[J].金融发展研究,2022(09):26-35.
[71] 郑浦阳,杨鑫垚,卢泓宇等.数字普惠金融与城市创新：理论逻辑与实证检验[J].统计与决策,2023,39(12):143-148.
[72] 张勋,万广华,张佳佳等.数字经济、普惠金融与包容性增长[J].经济研究,2019,54(08):71-86.
[73] 黄漫宇,王浩昉.数字金融与中国统一大市场建设——来自 255 个地级及以上城市的经验证据[J].金融论坛,2023,28(12):67-78.
[74] 赵涛,张智,梁上坤.数字经济、创业活跃度与高质量发展——来自中国城市的经验证据[J].管理世界,2020,36(10):65-76.
[75] 郭家堂,骆品亮.互联网对中国全要素生产率有促进作用吗?[J].管理世界,2016(10):34-49.
[76] Hansen B E. Threshold effects in non-dynamic panels: Estimation, testing, and inference[J].Journal of Econometrics,1999, 93(2):345-368.
[77] 王韧,张奇佳,何强.金融监管会损害金融效率吗[J].金融经济学研究,2019,34(06):93-104.
[78] 王智新,韩承斌,朱文卿.数字金融发展对出口技术复杂度的影响研究[J].世界经济研究,2022(08):26-42+135-1