

Has Digital Finance Improved the Transmission Efficiency of Monetary Policy?

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Abstract. During the period of global economic transformation and financial innovation, the effectiveness of monetary policy transmission has a significant impact on economic stability. Meanwhile, the emergence of digital finance has brought both new opportunities and difficulties. This research aims to determine the degree of digital finance development. It utilizes panel data from 296 Chinese cities spanning from 2011 to 2022. By selecting the digital inclusive financial index and M2, LPR as indicators, the double fixed effect is used for in-depth research. From the perspectives of quantity-based and price-based monetary policy, the research meticulously examines the effect of digital finance on the effectiveness of monetary policy transmission. With the degree of financial agglomeration serving as an intermediary and moderating variables like Gross Regional Product, Artificial Intelligence Level, and Total Retail Sales of Consumer Goods playing varying roles, it discovers that digital finance significantly influences the transmission efficiency of the two types of monetary policy in distinct ways. This research has contributions. First, the unique topic selection focuses on the relationship between digital finance and monetary policy transmission from a city perspective. It's crucial for the financial system. A thorough examination can provide an economic framework. Second, it adopts a multi-dimensional perspective. It divides monetary policy based on money supply and interest rates and does research at the municipal level. Third, it takes certain competencies as moderating variables and financial agglomeration as the main intermediary variable to build a research system. This offers new viewpoints. Overall, through careful data processing and modeling, this research thoroughly explores the intricate relationship between digital finance and monetary policy transmission. It also provides a solid scientific foundation for policy establishment, which is of great importance for promoting financial stability and high-quality economic development. Additionally, it contributes to the advancement of research in this field.

Keywords: Monetary Policy Transmission, Quantity-based Monetary Policy, Price-based Monetary Policy, Digital Finance, Financial Agglomeration.

1. Introduction

The financial market, economic development, and social stability are all significantly impacted by monetary policy, which is a crucial tool for national macroeconomic regulation and management. The CPC Central Committee's Political Bureau proposed the "implementation of moderately loose monetary policy" in 2024, changing the monetary policy's stance from "prudent" to "moderately loose." The Central Economic Work Conference, which took place in 2024, suggested that the monetary policy goes from "prudent" to "moderately loose" and that the two tools of structural and total monetary policy be used effectively. The effectiveness of China's monetary policy transmission mechanism has typically increased to some degree as a result of the expedited reform of interest rate embarkations. But there are still problems such as insufficient efficiency enhancement and structural imbalance that need to be solved; the improvement of the monetary policy framework is still faced with the challenge of certain deficiencies, which to a certain extent have become constraints to the sustained and healthy development of the economy (Lv et al., 2023). Financial support is indispensable for economic stability and growth, and the 14th Five-Year Plan explicitly states that new advantages in the digital economy should be developed; it listed digital finance as one of the five major articles for the construction of a strong financial state at the Central Financial Work Conference in 2023 (Zheng et al., 2024); it was clearly stated the need to coordinate and improve monetary policy frameworks at the Work Conference of the People's Bank of China in 2025 (Lv et al., 2023). The People's Bank of China's working conference made it clear that it is necessary to do a good job in coordinating the five major articles, including digital finance, and that monetary policy will play a

role in supporting the development of digital finance. The convergence characteristic that the digital economy possesses can enhance the efficiency of resource utilization (He et al., 2024).

The following sub-division will be distinguished as a quantitative monetary policy and price monetary policy in two aspects. It is based on the theory of money supply and demand, which regulates the money supply and other quantitative tools in the real economy; and interest rate parity theory, which states that the price of monetary policy is conducted with the aid of interest rates to guide the decision-making of the economic subject. Price-based monetary policy focuses on interest rates, which alter the cost of funds and direct businesses and citizens to invest and consume in accordance with the rhythm of economic activity. Quantitative monetary policy frequently modifies the money supply and other instruments to directly regulate the total amount of money, impacting the economic subject of capital reserves and the scale of investment.

The motivation of my research is to explore how digital finance impacts the effectiveness of monetary policy transmission considering financial innovation and global economic change. Based on dynamic economic theory, I use a double fixed-effects model and panel data from 296 Chinese cities during 2011 - 2022. I aim to figure out the various ways digital finance affects the amount and price of monetary policy transmission efficiency. Also, I focus on identifying the mediating role of the degree of financial agglomeration and the moderating effects of factors like the gross regional product, the degree of artificial intelligence, and the total retail sales of consumer products.

The contributions of my research are as follows. First, the contribution lies in the unique topic selection focusing on the city-based relationship between digital finance and monetary policy transmission. It focuses on the thorough examination of the inherent relationship between digital finance and the effectiveness of monetary policy transmission from a city perspective. This relationship is of critical importance for the stability and growth of the financial system, and a thorough examination of this relationship can offer a fresh framework for explaining the fundamental workings of the economy, which is vital for fostering both the long-term growth of the economy and the smooth functioning of the financial market. Encouraging sustainable economic growth and the smooth functioning of financial systems is essential.

Second, the contribution is the adoption of a multi-dimensional perspective by dividing monetary policy and broadening the research scope. For in-depth studies, this research begins with a thorough perspective, carefully splitting monetary policy into two dimensions: quantity-type and price-type. The research thoroughly examines the relationship between digital finance and the effectiveness of monetary policy transmission, beginning with the two fundamental and interconnected components of money supply as well as interest rates. It also carries out research at the municipal level, significantly broadening the scope of monetary policy research.

Third, the contribution is the establishment of a research mechanism with specific variables and a sound system for understanding the financial market. This research presents the three core competencies of urban financial market development, economic development, scientific and technological innovation, and consumption as moderating variables. It chooses the level of financial agglomeration as the primary intermediary variable and builds a logically sound research system that offers a fresh viewpoint and methodology for a thorough understanding of the inner workings of the financial market.

The remainder of the document is organized as follows: The literature review and theoretical analysis are presented in section 2, the data and variables are described in section 3, the model design is described in section 4, the empirical results are presented in section 5, the mechanistic research is described in section 6, the heterogeneity analysis is carried out in section 7, and the conclusion and recommendations are provided in section 8.

2. Literature

2.1. Literature review

Numerous studies have maintained that monetary policy must change to keep up with technological advancements and that the growth of digital finance has an impact on both the efficiency of monetary policy and global energy stability (Stephen S. Poloz., 2021); Regarding the transmission of monetary policy, digital finance offers an effective financing channel, indicating that it may have an impact on it (Ozili et al., 2021), and it lowers the costs associated with financing corporate debt, offering indirect evidence for comprehending monetary policy transmission (Tang, et al., 2024), though the variables are unclear. Although there aren't many empirical studies, some research indicates that digital finance alters the money supply and demand pattern, which impacts the effectiveness of monetary policy and transmission channels (Li et al., 2024), however, the conventional monetary policy transmission mechanism is also under threat from the emergence of digital finance. On the one hand, digital finance may facilitate the quick transmission of monetary policy signals and improve the policy effect due to increased information transparency and improved information processing efficiency (Duan, 2021); on the other hand, based on the theories of financial disinter-mediation and increased market competition, digital finance may lead to the role of traditional financial institutions's credit inter-mediation, which would weaken and inhibit the transmission of monetary policy (Iftekhar Hasan et al., 2024; Chen et al., 2018).

Regarding the link between digital finance and monetary policy, several studies have argued that monetary policy needs to adapt to technological development and that the development of digital finance affects global energy stability and the efficiency of monetary policy (Stephen S. Poloz, 2021; Chien-ChiangLee et al., 2024; JiazhengLi et al., 2023), exploring the impact of technological development on monetary policy from an international perspective; however, studies specifically focusing on digital finance still need to be in-depth. The impact of technological development on monetary policy has been explored from an international perspective, but research specifically targeting digital finance still needs to be in-depth; some studies have also pointed out that innovations in digital finance in payments and currency issuance and repatriation can change the basis of traditional monetary policy transmission (Huang et al., 2021).

With regard to quantitative and price-based monetary policy, studies have explored the relationship between central banks and fin-tech, pointing out that fin-tech innovations affect money supply and demand and the operation of policy instruments, such as interfering with the measurement of money supply (ChristineL et al., 2018). Indirectly, it affects price-based monetary policy transmission; studies have pointed out that monetary policy uncertainty affects bank asset secularization (Huang et al., 2023), digital finance affects interest rate marketization and interferes with the transmission of interest rate channels (Zhang et al., 2023), and credit expansion alters the financial structure and affects the main body and channels of monetary policy transmission (Cornelli et al., 2022) indirectly affects price-based monetary policy transmission.

Focusing on monetary policy transmission, digital finance provides efficient channels for financing, suggesting that it may affect monetary policy transmission (Ozili et al., 2021), and digital finance reduces the cost of corporate debt financing, providing indirect evidence for understanding monetary policy transmission (Tang et al., 2024), a finding that provides indirect evidence for understanding the efficiency of monetary policy transmission due to the provides indirect evidence; the development of fintech significantly changes the structure of financial markets, which has a potential impact on the effectiveness of monetary policy transmission (Iftekhar Hasan et al., 2024), but none of the above studies have directly explored the efficiency of digital finance on the transmission of monetary policy. Some studies have begun to explore the mechanism of digital finance's impact on monetary policy transmission, arguing that the mechanism exists (Lv et al., 2023; Duan et al., 2021), but the variables are unclear and the elaboration of blocking factors is lacking. Some studies suggest that digital finance changes the pattern of money supply and demand, affecting the efficiency of monetary policy and transmission channels, but lack empirical analyses (Li et al.,

2024). In addition, several studies began to try to explore the mechanism of digital finance affecting the transmission efficiency of monetary policy, and digital finance weakened the efficiency of monetary policy during the reform of interest rate marketization and affected the policy effect through different channels (He Jian and Wei Tao, 2022; Shi Huanping and Liu Xin, 2023; Hao Xing and Guo Hongyu, 2023), but there is still bias.

For the macro and micro levels, based on the macro level, studies have concluded that digital finance promotes the high-quality development of the real economy, with spatial spillover effects (He et al., 2024; Zhang et al., 2024), and also promotes economic growth and technological innovation (Qian et al., 2020; Tang et al., 2020), and that the basis of the development of digital finance promotes the development of the real economy. Data compilation is completed (Guo et al., 2020); based on the micro level, a number of studies focus on the impact of digital finance on consumption, enterprise financing and other aspects (Yi et al., 2018; Jiang., 2024; Zhang et al., 2024; Hua et al., 2024), and the studies respectively explored the impact of digital finance on the consumption of residents, enterprise financing, The effect of monetary policy in a low interest rate environment and the transmission channel of monetary policy on stock prices. From the household perspective, research based on microdata explores digital financial literacy and household economic resilience (Si et al., 2024), and household financial literacy is affected by digital finance, which may change their behavioral response to monetary policy. Productivity (Zuo et al., 2024), indirectly affects monetary policy transmission.

The literature has several advantages. It has recognized the importance of digital finance's impact on monetary policy efficiency. It has also explored various aspects such as the financing channel provided by digital finance and its influence on money supply and demand patterns. However, there are also some disadvantages. Many studies lack in-depth research specifically focusing on digital finance. The variables in some researches are unclear and the elaboration of blocking factors is insufficient. Some studies only provide suggestions without empirical analyses. And there are biases in the exploration of the mechanism of digital finance's impact on monetary policy transmission. Based on the above, future research can improve in the following directions. Firstly, conduct more in-depth research specifically on digital finance. Secondly, clarify the variables and provide detailed elaboration of blocking factors. Thirdly, carry out more empirical analyses to support the suggestions. Finally, reduce biases in the exploration of the mechanism.

2.2. Mechanism analysis

2.2.1. Basic effects

The quantitative and price-based aspects of monetary policy have been significantly impacted by the quick emergence of digital finance. Digital finance affects the stability of the money supply by innovating the process of currency generation and circulation in terms of quantitative monetary policy. Third-party payments are widely used, which accelerates currency circulation, affects the stability of the money multiplier, increases volatility, and makes it more difficult for the central bank to formulate and implement policies. The rise of digital currency, which changed the traditional path of currency issuance and return, and its decentralization weakened the central bank's control of issuance. Digital finance increases financial market competitiveness, lowers transaction costs and information asymmetry, and boosts financial market efficiency in terms of price-based monetary policy. This increases the sensitivity of interest rates to monetary policy, allowing financial institutions to react to policy changes faster, modify lending and deposit rates, and affect market interest rates. This enhances the effectiveness of price-based monetary policy's transmission.

H1: The transmission process of price-based and quantity-based monetary policy is significantly impacted by digital finance, and the effectiveness of the method and mode of action differs significantly.

2.2.2. Mediating effects

The degree of financial agglomeration has been significantly impacted by the growth of digital finance. The conventional financial paradigm has been upended by the emergence of digital finance, and financial institutions now require more workers with digital skills. As a result, financial professionals are moving to adjacent industries, increasing the degree of financial agglomeration. Financial agglomeration regions can deeply analyze the effects of the central bank's monetary policy tools on the money supply under the quantity-based monetary policy by utilizing talent and information. For instance, they can improve the efficiency of conduction in the central bank's open market operations, accelerate the circulation of money, and accurately predict changes in the money multiplier. The human structure of the industry is altered by digital finance in price-based monetary policy, increasing the level of agglomeration. This allows the group of regional professionals to react swiftly to changes in the central bank's benchmark interest rate, improving interest rate conduction efficiency and achieving effective policy transmission.

H2: The link between digital finance and the transmission of monetary policy is mediated by the degree of financial agglomeration. The impacts of the mediating factors differ, with a larger influence on quantitative monetary policy and a smaller effect on pricing.

2.2.3. Moderating effects

This research focuses on the ability of the urban economy's financial ecological fitness, specifically the urban economic development, scientific and technological innovation, and consumption capacity of the three dimensions of the research. In the intricate pattern of deep intermingling of the financial ecology and urban economy, the impact of digital finance on the transmission efficiency of monetary policy is regulated by a variety of factors.

In terms of quantitative monetary policy, the region's industrial prosperity's high economic development capacity, the robust demand for enterprise funds, the central bank's ability to lower the quota and other operations, the local financial institutions' close cooperation with digital finance and full facilities, scientific and technological innovation in strong cities that rely on state-of-the-art technology to accurately predict the currency supply and demand, accelerate the industry chain currency circulation, and scientific and technological weakness of the city's traditional channels; the use of big data to precisely allocate funds to promote the growth of the real economy Weak consumer cities because of low consumption power hinder monetary conduction, while strong consumer cities allow the central bank to expand the money supply, digital finance to boost consumption, and aid in the quick absorption of money. According to price-based monetary policy, economically developed cities have intense financial market competition, institutions that are sensitive to interest rates, digital finance to boost competitiveness, and optimized pricing to encourage transmission. Institutions in technologically weaker cities are constrained; residents of consumer-strong cities are sensitive to changes in interest rates, and digital finance amplifies the effect; fintech companies in technologically advanced cities monitor interest rates in real-time and provide pricing advice and tools to help transmission due to technological advantages; and economically backward cities are slow to respond due to lack of competition. The complexity of the impact of these regulatory variables in various monetary policy transmissions is highlighted by the fact that residents of cities with strong consumption are sensitive to changes in interest rates and that digital finance amplifies the effect, while residents of cities with weak consumption are less effective.

H3: The transmission process of quantitative and price-based monetary policy is moderated by all the factors of the city's economic and financial ecological fitness, and the magnitude and direction of their effects vary.

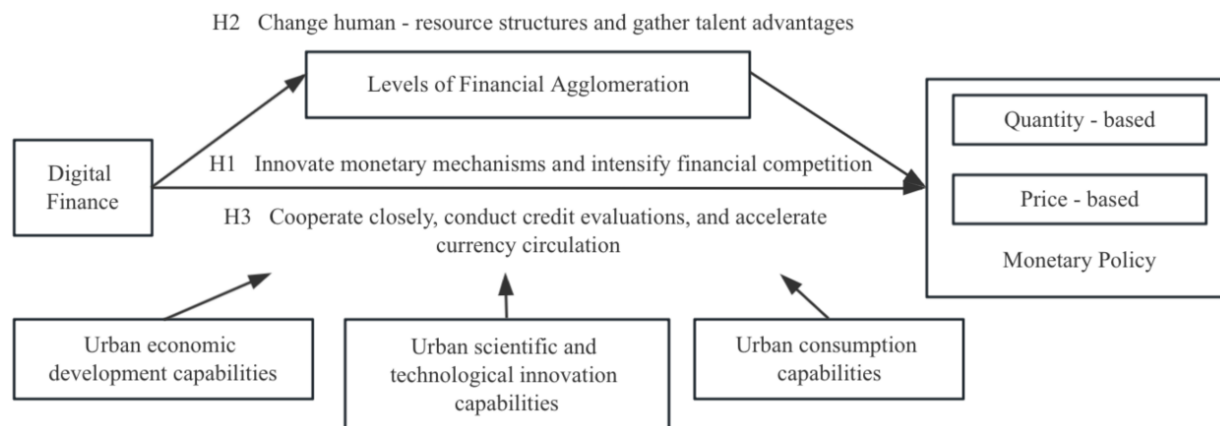


Figure 1. Theoretical analysis framework

3. Data and Variables

3.1. Data sources

This research gathers panel data from 336 Chinese municipal administrative units between 2011 and 2022. Following data cleaning, it examines data from 296 cities and carries out linear interpolation and other operations. The China Statistical Yearbook, China Urban Statistical Yearbook, and other sources are the primary sources of the data.

3.2. Variables Design

1. Explanatory variables

(1) Referring to Yang et al. (2024), the money supply is used as the money supply indicator and GDP as the weight to convert national-level M2 into city-level M2, this research is conducted at the city level and uses the money supply to illustrate quantitative monetary policy:

$$M2_{it} = \frac{GDP_{it}}{GDP_t} \times M2_t \quad (1)$$

Where $M2_{it}$ represents the M2 of the city i in year t , and GDP_{it} represents the GDP of the city i in year t ; $M2_t$ represents the M2 of our country in year t , and GDP_t represents the GDP of our country in year t .

(2) Referring to Zhou. (2023), which uses interest rates to represent price-based monetary policy, this research is carried out at the city level, based on the PPP theory and Fisher's equation analyses, using CPI as weights to transform the national-level LPR to the city level:

$$LPR_{it} = \frac{CPI_{it}}{CPI_t} \times LPR_t \quad (2)$$

Where LPR_{it} represents the LPR of the city i in year t , and CPI_{it} represents the CPI of the city i in year t ; LPR_t represents the LPR of our country in year t , and CPI_t represents the CPI of our country in year t .

2. Core explanatory variable

Digital finance manifests itself in the development of Internet finance and other related new business forms at the regional level, and its advantages of wide coverage, low cost and high efficiency show unique inclusion (Zhu et al., 2024). Given that digital inclusive finance is an important development mode of digital finance, this paper refers to the research of Liu Yong et al. (2023), Sarma (2015), Xie Gorgeous et al. (2018), and Li. (2025), and selects PKU-DIFI (Guo et al., 2020) as a proxy indicator of digital finance.

3. Mediating variable

The level of financial agglomeration is a quantitative indicator that reflects the relative concentration of human resources in the financial industry in the overall employment structure of the city and reflects the aggregation of financial resources at the city level. Referring to the way of constructing financial agglomeration indicators in Zhang et al. (2017), this paper calculates the financial agglomeration level by the number of employees in the financial industry/number of employees in the unit at the end of the year.

4. Moderating variables

The city's economic and financial ecological adaptability reflects the city's ability to adapt and regulate the transmission of digital finance and monetary policy in its economic and financial ecology, covering three aspects of the city's economic development, scientific and technological innovation, and consumption capacity.

(1) Gross regional product:

Referring to Han et al. (2024), GDP is taken to represent the city's economic development capacity. The impact of digital finance on the efficiency of monetary policy transmission depends on the regional economic base, developed regions have strong corporate and financial links. And digital finance can rapidly transmit policy with the help of a sound financial system.

(2) Artificial Intelligence Level:

Referring to Yang et al. (2023), Sun et al. (2022), Hu et al. (2021), the level of AI development is taken to represent the city's scientific and technological innovation capability. Digital finance and monetary policy transmission are affected by the degree of AI empowerment. Advanced regions use AI to optimize financial services and risk control and enhance transmission.

(3) Total retail sales of consumer goods:

Referring to Zeng et al. (2024), total retail sales of consumer goods is taken to represent the consumption capacity of cities. Although digital finance affects monetary policy transmission, the effect is different in cities with different consumption capacities, and in cities with strong consumption, digital finance can further activate consumption to promote transmission.

5. Control variables

The control variables in this research include population size, education expenditure, the number of mobile phone subscribers at the end of the year, the difference between the deposit and loan balances of financial institutions at the end of the year, and the total current assets of industrial firms above the large scale.

Among them, (1) the population determines the market size and the abundance of labour resources, the consumer market is often larger in populous places and the labour force is sufficient, which affects the effect of monetary policy transmission; (2) education expenditure reflects the status of regional education investment, which affects the financial literacy of the population, and in turn affects the use of digital financial services and the perceived response to monetary policy; (3) the number of mobile phone subscribers at the end of the year reflects the degree of regional communications infrastructure coverage and the popularity of mobile technology, affecting the accessibility and frequency of use of digital financial services; (4) the difference between the deposit and loan balances of financial institutions at the end of the year is a key link in the transmission of monetary policy, and the development of digital finance will change the efficiency of financial institutions' fund allocation and the savings and loan behaviours of residents and enterprises, thus affecting the effect of the transmission of monetary policy in the credit channel; (5) the industrial enterprises above the size of a large scale occupy an important position in the economy, and digital finance can provide them with the best opportunities to improve their financial literacy. Digital finance can provide efficient financing channels and reduce costs, and monetary policy plays a role in the cost of enterprise funds.

Table 1. Variable Settings

Variable Symbol	Meaning
M2	money supply
LPR	Quoted market interest rates for loans
DF	Peking University Digital Inclusive Finance Index
FA	Level of financial agglomeration
GDP	gross regional product (GDP)
AI	level of artificial intelligence (AI)
RST	Total retail sales of consumer goods
AOP	Average annual population
EDU	Expenditure on education
MU	Number of mobile phone subscribers at year-end
FLB	Difference between deposit and loan balances of financial institutions at the end of the year
IAP	Total current assets of industrial enterprises above designated size

4. Methodology

4.1. Basic effects

The following double fixed effects model is put up to examine the connection between the degree of digital financial development and the effectiveness of monetary policy transmission:

$$EV_{i,t} = \alpha_0 + \alpha_1 DF_{i,t} + \sum \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (3)$$

Where $EV_{i,t}$ ($M2_{i,t}$ and $LPR_{i,t}$) denote the level of efficiency of monetary policy transmission in terms of quantity and price for the city i in year t , and $X_{i,t}$ is a set of control variables.

4.2. Mediating effects

Further, the research of Qiao et al. (2024) is referred to constructing a mediation effect model to analyze the specific mechanism by which digital finance affects the transmission efficiency of monetary policy:

$$EV_{i,t} = \theta_0 + \theta_1 DF_{i,t} + \sum \theta_i X_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$FA_{i,t} = \beta_0 + \beta_1 DF_{i,t} + \sum \beta_i X_{i,t} + \delta_{i,t} \quad (5)$$

$$EV_{i,t} = \gamma_0 + \gamma_1 DF_{i,t} + \gamma_2 FA_{i,t} + \sum \gamma_i X_{i,t} + \mu_{i,t} \quad (6)$$

4.3. Moderating effects

Further, an interaction term is introduced to construct a model of the moderating effect of digital finance affecting the efficiency of monetary policy transmission:

$$EV_{i,t} = \mu_0 + \mu_1 DF_{i,t} + \mu_2 Z_{i,t} DF_{i,t} + \sum \mu_i X_{i,t} + u_{i,t} \quad (7)$$

Where $Z_{i,t}$ stands for $GDP_{i,t}$, $AI_{i,t}$, $RST_{i,t}$ and the other variables are the same as above.

5. Empirical evidence

5.1. Descriptive statistics

The distribution of the money supply in each city is highly dispersed; the extreme difference is 98,520.837, and there is a significant difference in the size of the money supply between different cities, as Table 2 demonstrates. The standard deviation of M2 8,313.370 is significantly larger than the mean value of 5,585.682. In comparison to the mean value of 4.471, the LPR 1.195 standard deviation is not modest, and there is a significant degree of dispersion in the lending interest rate levels of each city. With a DF standard deviation of 76.023 compared to the mean of 192.682, the

disparity in the degree of digital finance development between cities is more pronounced, with the extreme difference being 344.046, indicating that the development level of digital finance in different cities is extremely uneven.

Table 2. Descriptive statistics of main variables

Variable	Mean	Std. dev	Min	Max
M2	5585.682	8313.370	233.423	98754.260
LPR	4.471	1.195	0.000	6.106
DF	192.682	76.023	17.020	361.066
FA	0.040	0.022	0.0003	0.225
GDP	2765.436	4021.612	133.745	44653.000
AI	5	1.847	0.000	11.293
RST	1.081	1.613	0.002	18.141

With a high GDP share, rapid growth, a variety of industries, active finance, and rich digital financial scenarios, the Yangtze River Economic Belt includes Shanghai, Suzhou, Zhejiang, and other economically developed provinces and cities. These can show how differently they affect the effectiveness of monetary policy transmission.

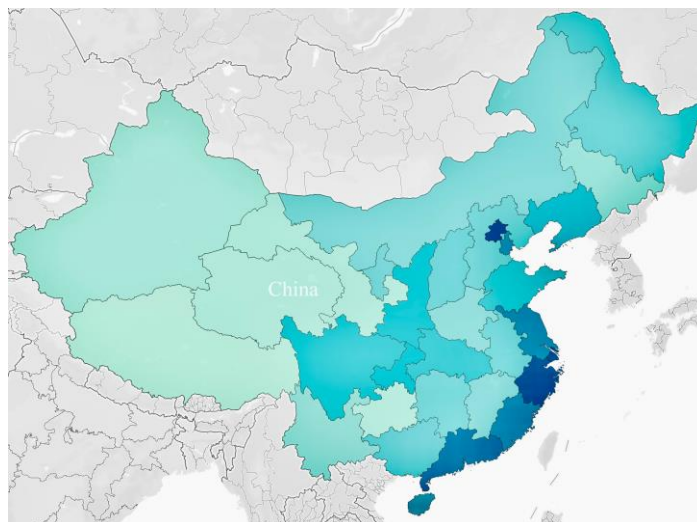


Figure 2. Provincial Digital Financial Inclusion Index 2011

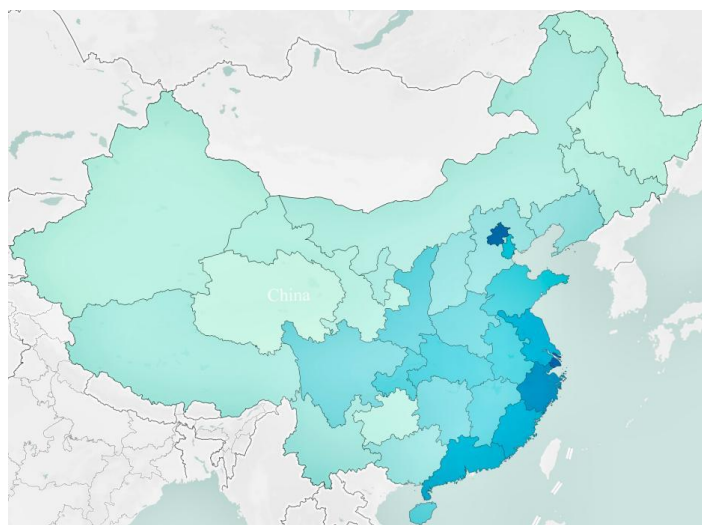


Figure 3. Provincial Digital Financial Inclusion Index 2022

The comparison shows that the degree of digital financial inclusion in China's provinces is generally on the rise. Because of their more advanced economies and thriving financial sectors, certain provinces and cities in the Yangtze River Economic Belt already had high levels of digital

financial inclusion in 2011. With the ongoing launch of new fintechs and advancements in digital financial services, the digital financial inclusion index will continue to rise until 2022, while the overall gap has been reduced as digital technologies are rolled out across the country.

5.2. Basic effects

Robust standard errors for the double fixed effects regression were chosen based on the main effects model in the model setup in order to improve the findings' dependability and lessen the influence of problems like outliers and heteroskedasticity. These results were as follows:

Table 3. Main effects regression

VARIABLES	M2	LPR
DF	26.861***	-0.010***
	-8.203	(0.000)
AOP	0.162	-0.001
	-3.019	(0.000)
EDU	0.004***	-1.197*
	-0.001	(6.528)
MU	4.314**	0.001***
	-1.954	(0.000)
FLB	8.866	-8.331
	-7.116	(5.351)
IAP	0.001***	2.289
	-1.415	(1.649)
Constant	-3,082**	6.314***
	-1,292	(0.074)
R-squared	0.891	0.669

Notes: p*** p<0.01, ** p<0.05, * p<0.1, same table as below

At the 1% level of significance, the Digital Finance (DF) coefficient for the quantitative monetary policy (M2) regression findings is 26.861***, indicating strong importance. This implies that the transmission effectiveness of quantitative monetary policy, as indicated by M2, is significantly improved by digital finance. Digital finance does have a major impact on quantitative monetary policy, which is in line with the article's main effect H1. Since digital currencies alter the route of issuance and repatriation and third-party payments impact the stability of the money multiplier, which in turn impacts the transmission efficiency of quantity-based monetary policy, the growth of digital finance may result in changes to the mechanism of money supply regulation through innovations in the mechanism of money creation and circulation. At the 1% significance level, the digital finance (DF) coefficient for the price-based monetary policy (LPR) regression findings is -0.010***, indicating strong significance. This suggests that the efficiency of price-based monetary policy transmission as assessed by LPR is significantly impacted negatively by digital finance, and H1 is true.

Monetary policy is significantly impacted by digital finance. Regarding the quantity type, digital currency alters the issuance of currency, third-party payments impact the money multiplier, heighten money supply volatility, and complicate policy. Regarding pricing, digital finance increases competition, lowers expenses, increases transmission efficiency, and improves interest rate sensitivity.

5.3. Tests of Robustness

In this research, the insurance component of the social security system is the primary intersection, monetary policy incorporates finance, and digital finance is associated with economic finance. They are used as new control variables because the number of urban workers' basic medical insurance, basic pension insurance, and unemployment insurance participants covers important influencing factors from the dimensions of employment elasticity, short-term risk buffer, consumption and saving decisions, and long-term economic stability expectations, respectively.

The inclusion of control variables can remove interference and concentrate on the fundamental relationship between digital finance and monetary policy because they reflect regional labor market security, the level of social welfare protection, the capacity to manage unemployment risk, and the behavior of financial market participants, market demand, and risk appetite of economic agents.

To improve the reliability of the results and lessen the influence of issues like outliers and heteroskedasticity on the results, the robust standard errors were chosen for the double fixed effects regression based on the main effects in the model setup after the control variables were replaced:

Table 4. Robustness test regression

VARIABLES	M2	LPR
DF	65.191***	-0.009***
	(11.882)	(0.003)
UPIPI	0.002**	-9.879
	(0.001)	(2.188)
URBMI	-0.000***	1.098
	(6.485)	(1.068)
UI	0.006***	-6.511
	(0.002)	(3.508)
Constant	-3,946***	6.114***
	(534.223)	(0.145)

The DF coefficient of digital finance, 65.191***, has a significant positive effect for quantity-based monetary policy M2, which is consistent with the main effect, according to the double fixed-effects regression based on the new control variables. The model fit is still explanatory, despite a decline from 0.891 to 0.794. The DF coefficient for price-based monetary policy LPR is -0.009***, indicating a substantial negative effect. The fit value of 0.669 is identical to the main effect. The primary effect H1 is confirmed to hold by the robustness test, which demonstrates that the initial results are trustworthy and that the direction and significance of the effect essentially stay the same once the variables are altered.

6. Mechanisms Research

6.1. Examining the mediating effects mechanism

With variations in the performance of the mediating factors between price-based and quantity-based monetary policy studies, the degree of financial agglomeration thus plays a mediating function between digital finance and monetary policy transmission, and H2 is true.

Table 5. Intermediate three-stage regression

VARIABLES	(1) M2	(2) FA	(3) M2	(1) LPR	(2) FA	(3) LPR
DF	26.861***	-0.001***	26.282***	-0.009***	-0.001***	-0.009***
	-8.203	(7.055)	(7.931)	-0.003	(7.055)	(0.003)
FA			-2,351			-1.010
			(2,718)			(1.581)
AOP	0.162	-2.475	0.103	-0.001	-2.475	-0.001
	-3.019	(2.175)	(3.046)	-0.001	(2.175)	(0.001)
EDU	0.004***	3.409	0.004***	4.728	3.409	5.068
	-0.001	(2.769)	(0.001)	-5.428	(2.769)	(5.448)
MU	4.314**	-1.036	4.311**	0.000	-1.036	0.000
	-1.954	(5.086)	(1.953)	-0.000	(5.086)	(0.000)
FLB	8.866	1.111	8.886	-5.431**	1.111	-5.321**
	-7.116	(1.751)	(7.126)	-2.601	(1.751)	(2.641)
IAP	0.001***	-1.201	0.001***	-4.6110	-1.201	-5.821
	-1.415	(9.421)	(1.425)	-1.849	(9.421)	(1.879)
Constant	-3,082**	0.059***	-2,943**	6.441***	0.059***	6.501***
	-1,292	(0.010)	(1,311)	-0.296	(0.010)	(0.293)

With a coefficient of 26.861***, the first step of the regression in the quantitative monetary policy research demonstrates a considerable influence of digital finance (DF) on the transmission efficiency of the M2 measure, confirming its direct effect. With a coefficient of -0.001***, DF significantly lowers the amount of financial agglomeration (FA) in the second stage, which is in line with the reasoning of the first part of the mediation path. In the third stage, the effect is still there even though the DF coefficient 26.282*** is falling and the FA coefficient -2351 is negligible. There is no significance in the intermediate variable, which is diminishing, but the impact remains. Since the conduction path is complicated and the relationship between FA and the effectiveness of monetary policy conduction is blurred by the interaction of factors in each link, the intermediary variable is not significant. Additionally, local policies, regional economic imbalances, and other external factors interfere with the FA intermediary role, making it difficult to promote the transmission of monetary regulation. With a coefficient of -0.009*** and a steady role for control variables, the first stage of DF significantly affects the transmission efficiency as determined by LPR in the price-based monetary policy research. Similar to the quantity type, FA is adversely affected by the second stage of DF. In the third stage, the effect is still present even though the DF coefficient is -0.009*** and the FA coefficient is -1.010. Because interest rate transmission is complicated, financial institutions are impacted by a number of factors, and market expectations are dominated by the FA, it is challenging to demonstrate the mediating role of FA. As a result, the mediating variable is not significant.

The degree of financial agglomeration is greatly impacted by the growth of digital finance. As a result of its ascent, the conventional paradigm is disrupted, and the need for digital talent in institutions surges, increasing agglomeration and practitioner mobility. Financial agglomeration areas utilize the information and skill advantages in price-based and quantitative monetary policy to achieve effective policy transmission and increase the money supply and interest rate transmission efficiency, respectively.

6.2. Examining the moderating effects mechanism

In terms of quantity-based and price-based monetary policy transmission, the three regulating variables—GDP, AI, and RST—show one positive and one negative inverse regulating effect overall, and H3 is true. Urban economic development, technical innovation, and consumer capacity all influence how well digital finance transmits monetary policy in this pattern of entwining finance and the urban economy. With the aid of digital finance, the monetary supply and demand, circulation, and absorption are improved under the quantity-based policy, which is also accompanied by high economic development, robust scientific and technological innovation, and a city with strong consumption. The price-based policy is the same, and the role of each variable in different policy conduction is complex.

Table 6. Reconciliation regression

VARIABLES	(RV = GDP)		(RV=AI)		(RV=RST)	
	M2	LPR	M2	LPR	M2	LPR
DF	-1.778*** (0.171)	-0.010*** (0.000)	3.208 (6.955)	-0.006** (0.003)	5.007 (3.259)	-0.008*** (0.003)
RV*DF	0.003*** (3.695)	-0.000 (0.000)	2.834*** (0.826)	-0.001** (0.000)	7.917*** (4.968)	-1.091 (8.391)
AOP	1.442*** (0.139)	-0.000 (0.000)	-0.291 (2.749)	-0.001 (0.001)	0.541 (1.012)	-0.001 (0.001)
EDU	0.001*** (7.075)	-0.000 (0.000)	0.004*** (0.001)	8.808 (5.608)	0.001*** (0.001)	8.788 (5.698)
MU	3.242*** (0.099)	0.001*** (0.000)	3.889** (1.765)	0.000 (0.000)	-0.101 (0.581)	0.000 (0.000)
FLB	8.957* (4.957)	-0.000 (0.000)	1.155* (6.876)	-8.561** (3.551)	6.636** (3.006)	-5.131* (2.731)
IAP	4.245*** (1.606)	0.000 (0.000)	9.175*** (1.515)	1.019 (2.039)	5.405*** (1.025)	2.261 (2.009)
Constant	237.910*** (62.643)	6.305*** (0.075)	-1,807 (1,120)	6.288*** (0.269)	1,024** (403.612)	6.384*** (0.283)

The interaction term coefficient 0.003*** is significant for the city's economic development capacity, however the DF coefficient has little effect on quantitative monetary policy. Digital finance and economic principles work together in developed areas with high GDP to precisely direct funds to the real economy, efficiently encourage money supply conduction, increase conduction efficiency, and provide favorable regulatory effects. Transmission efficiency is significantly impacted negatively by the price-based monetary policy transmission's DF coefficient of -0.010***. Nevertheless, the lack of significance of the interaction term suggests that GDP control is not clear-cut. GDP regulation has essentially had no beneficial regulatory impact on the trajectory of digital finance with regard to price-based monetary policy transmission efficiency, and in developed regions with established financial markets, market competition and institutional response dominate monetary policy transmission.

The interaction term AI*DF coefficient 2.834*** and the DF coefficient 3.208 for the city's ability for scientific and technical innovation are not significant for the quantity-based monetary policy. Financial institutions can precisely evaluate the credit risk of businesses in regions with high levels of artificial intelligence, serving a positive regulatory role, expediting the flow of money in the real economy and allocating monetary funds in a reasonable manner. The transmission of price-type monetary policy has a DF coefficient of -0.006**, which has a negative impact on transmission efficiency. In technologically advanced areas, artificial intelligence assists financial institutions in real-time interest rate monitoring, pricing guidance, altering the interest rate conduction channel, and bolstering the negative regulation of digital finance (interaction term coefficient -0.001**).

When quantitative monetary policy is implemented, the DF coefficient of 5.007 is not significant for urban consumption capacity, and the interaction term RST*DF coefficient is 7.917***.

In regions with high RST and high consumption, digital finance boosts consumption through an active consumer market, speeds up money circulation in the consumer sector, and facilitates the faster inflow of new funds from the central bank into the real economy's consumption sector. This positively regulates the efficiency of quantitative monetary policy conduction, while the DF coefficient of -0.008*** significantly reduces the efficiency of conduction in price-based monetary policy. It is unclear how the RST on digital finance influences price-type monetary policy conduction efficiency regulation because the interaction term coefficient is not significant. Consumption of strong regions, even when inhabitants' interest rate sensitivity is increased by digital finance. However, the supply and demand in the financial markets as well as institutional pricing strategies primarily influence price adjustment; the interaction between RST and digital finance did not substantially alter the conduction path.

6.3. Endogenous type test

In order to address the potential endogeneity issue, referring to the studies by Hong. (2022) and Ding et al. (2022), the spherical distance between each city and Hangzhou, the capital city of Zhejiang Province (where Ant China Service is headquartered), is adopted as the tool variable for digital finance, and the geographic distance can be regarded as exogenous.

2SLS model setup:

$$DF_{i,t} = \delta_0 + \delta_1 Dis_i + \sum \delta_i X_{i,t} + \lambda_i + \varepsilon_{i,t} \quad (8)$$

$$M2_{i,t} = \alpha_0 + \alpha_1 \widehat{DF}_{i,t} + \sum \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (9)$$

$$LPR_{i,t} = \alpha_0 + \alpha_1 \widehat{DF}_{i,t} + \sum \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (10)$$

Where D_i represents the instrumental variable described above, i.e., the spherical distance of each city from Hangzhou (Dis); λ_i represents individual fixed effects, and the other variables are as above.

Table 7. Endogeneity test regression

	(1)	(2-1)	(2-2)
VARIABLES	DF	FA	LPR
Dis	-0.015*** (0.002)	22.442*** (4.302)	0.011*** (0.004)
AOP	-0.112*** (0.007)	0.773 (0.471)	0.002*** (0.000)
EDU	8.105*** (4.076)	0.002*** (0.000)	-1.896*** (3.297)
MU	0.010* (0.006)	4.188*** (0.425)	0.001** (0.000)
FLB	-6.257*** (3.378)	3.876 (4.106)	1.288*** (2.629)
IAP	-5.517*** (9.258)	0.000*** (5.436)	1.508*** (2.629)
Constant	208.511*** (3.449)	-4,597*** (800.620)	2.219*** (0.700)

According to the regression results, Dis has a significant impact on DF in the first stage (coefficient of -0.015***), and geographic distance can reflect digital financial differences. In the second stage, the quantitative monetary policy transmission efficiency has a DF coefficient of 22.442***, despite the fact that the coefficient has changed, the positive effect is still significant, indicating that endogeneity has not altered the fundamental trend. After addressing endogeneity, the price monetary policy transmission efficiency has a DF coefficient of 0.0113***, which is inverse to the main effect and is caused by the complexity of endogeneity factors.

7. Heterogeneity Analysis

7.1. Regional Heterogeneity Analysis

The Yangtze River Economic Belt (YE) was selected as the measure:

$$YE = \begin{cases} 0, & \text{if not belong to the Yangtze River Economic Belt.} \\ 1, & \text{if else} \end{cases}$$

$$M2_{i,t} = \alpha_0 + \alpha_1 DF_{i,t} + \alpha_2 YE + \sum \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (11)$$

$$LPR_{i,t} = \alpha_0 + \alpha_1 DF_{i,t} + \alpha_2 YE + \sum \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (12)$$

Table 8. Regression of regional heterogeneity

	YE=0	YE=1	YE=0	YE=1
VARIABLES	M2	M2	LPR	LPR
DF	2.349*** (0.396)	2.038*** (0.501)	-0.010*** (0.000)	-0.011*** (0.000)
AOP	0.265 (0.426)	-3.576*** (0.456)	-0.000 (0.000)	-0.000 (0.000)
EDU	0.004*** (0.000)	0.005*** (0.000)	-6.328 (8.058)	-2.317** (1.137)
MU	1.886*** (0.246)	2.448*** (0.385)	0.001*** (0.000)	0.001*** (0.000)
FLB	2.536** (1.286)	7.416*** (1.456)	-1.059 (6.721)	-7.251 (9.001)
IAP	9.315*** (4.046)	0.001*** (4.376)	1.589 (2.149)	3.499 (2.429)
Constant	-951.724*** (175.320)	-332.301 (243.503)	6.269*** (0.102)	6.375*** (0.109)

The DF coefficient for quantity-based monetary policy is 2.038*** inside the Yangtze River Economic Belt and 2.349*** outside. The impact is slightly lower inside the belt because of a significant marginal impact during the start-up phase of digital finance outside the belt, and the rate of increase is slower because of maturing synergies inside the belt. The DF coefficient for price-based monetary policy is -0.010*** inside the Yangtze River Economic Zone and -0.011*** outside of it; the difference between inside and outside the zone is less pronounced, and as digital finance advances, the geographic gap is progressively closing.

7.2. Analysis of heterogeneity at time points

In August 2019, the People's Bank of China (PBOC) released the Fintech Development Plan, the first high-level policy for the fintech sector that directs financial institutions to logically deploy their fintech businesses, with 2019 as the dividing line and the introduction of the dummy variable D:

$$D = \begin{cases} 0, & \text{if } year < 2019 \\ 1, & \text{if } else \end{cases}$$

$$M2_{i,t} = \alpha_0 + \alpha_1 DF_{i,t} + \alpha_2 D + \alpha_3 D \times DF_{i,t} + \sum \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (13)$$

$$LPR_{i,t} = \alpha_0 + \alpha_1 DF_{i,t} + \alpha_2 D + \alpha_3 D \times DF_{i,t} + \sum \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (14)$$

Table 9. Regression of point-in-time heterogeneity

	D=0	D=1	D=0	D=1
VARIABLES	M2	M2	LPR	LPR
DF	2.610*** (0.325)	13.744*** (1.108)	-0.010*** (0.000)	-0.009*** (0.001)
AOP	-0.411 (0.264)	0.426 (0.556)	-0.000 (0.000)	5.745 (0.000)
EDU	0.004*** (0.000)	0.003*** (0.000)	-2.187** (1.067)	-1.787* (1.067)
MU	1.217*** (0.193)	4.674*** (0.438)	0.001*** (0.000)	0.001*** (0.000)
FLB	3.547 (1.326)	6.336*** (1.486)	-1.169 (1.039)	-4.371 (6.941)
IAP	0.000*** (3.576)	0.000*** (3.936)	2.149 (2.739)	3.229 (1.969)
Constant	-551.200*** (120.400)	-4,293*** (347.200)	6.308*** (0.089)	5.821*** (0.216)

The DF coefficient of 2.610*** in quantity-based monetary policy is significant prior to implementation and rises significantly to 13.744*** following implementation. The policy's positive impact is further enhanced by the financial institutions' response and business adjustments, which fortify its transmission. For example, increasing research and development of digital currencies improves the accuracy of monetary investment. Regarding price-based monetary policy, the DF coefficient of -0.010*** was significantly negative prior to the policy's implementation and decreased in absolute value to -0.009*** after it was put into place. This suggests that the policy strengthens financial institution management, lessens the negative effects of digital finance, and makes the digital financial adjustment of interest rates more reasonable while also reducing the inhibitory effect.

8. Conclusion

8.1. Summary conclusions

The effectiveness of monetary policy transmission is essential for stable economic growth in light of significant changes in the global economy and financial innovations, and the emergence of digital

finance has resulted in new ramifications. Using panel data from 296 Chinese cities between 2011 and 2022, this research investigates how digital finance affects the effectiveness of monetary policy transmission. The research concludes:

(1) Main effect: The effectiveness of price-based and quantitative monetary policy transmission is greatly and differently impacted by digital finance. Because it innovates the process of money production and circulation, digital finance has a big positive influence on the transmission efficiency as measured by M2, but it has a significant negative impact on the transmission efficiency as assessed by LPR, which results from altering the way interest rates are transmitted and boosting competition in the banking sector. (2) Mediating effect: Although complicated circumstances disrupt the transmission channel during the transmission process of quantity-type and price-type monetary policy, the mediating effect persists overall. (3) Moderating effect: Although GDP, AI, and RST have distinct functions, they all have an adverse influence on price-based monetary policy and a favorable effect on quantity-based monetary policy. (4) Heterogeneity analysis: the impact of DF on M2 varies somewhat between regions inside and outside the Yangtze River Economic Belt, whereas the impact on LPR varies less and the geographic gap steadily closes as digital finance advances; in terms of time, the policy's implementation mitigates the negative effects of DF in price-based monetary policy and amplifies its beneficial effects in quantitative monetary policy.

8.2. Recommendations

Regionally specific policies ought to be put into effect by policymakers. Financial institutions are urged to further integrate and innovate digital financial applications and traditional finance in areas with high financial market maturity and leading digital financial development. Examples of these include conducting joint credit business, streamlining credit procedures and risk assessment models, and improving the effectiveness of financial resource allocation and the positive transmission effect of monetary policy. In areas that are lagging behind in financial development, financial institutions should invest more in building digital financial infrastructures and implementing preferential policies to draw in fintech companies. Increase investment in building digital financial infrastructure in areas with underdeveloped financial systems, implement preferential policies to draw in fintech companies, encourage the spread of digital financial services, close the regional divide, and improve the transmission balance of monetary policy. Simultaneously, when developing price-based monetary policy, improve the mechanism for interest rate market formation, create a reference system for benchmark interest rates, and increase the efficiency and transparency of interest rate transmission; when developing quantitative monetary policy, modify the money supply target and regulatory tools in accordance with the growth of digital finance.

Financial institutions should make more investments in digital talent training and technology research and development in order to actively follow the growth trend of digital finance. Hire and develop professionals with expertise in artificial intelligence and data analysis, form fintech teams to improve digital operations and innovation capabilities, and consistently invest in the creation of cutting-edge fintech application systems. To ensure sound operations and effective transmission of monetary policy intentions, in the price-based monetary policy environment, monitor interest rate dynamics in real-time, analyze the impact of interest rates on the balance sheet, adjust interest rates promptly, optimize risk management strategies, and increase sensitivity and responsiveness to the monetary policy interest rate signals. In the quantitative monetary policy environment, big data and artificial intelligence accurately predict the money multiplier and corporate capital demand and optimize credit allocation. To guarantee stable operations and efficient communication of monetary policy objectives, increase the sensitivity and reactivity to monetary policy interest rate signals.

Businesses should aggressively utilize the benefits of digital finance to secure financial resources, while also being mindful of the geographical and temporal variations in the dissemination of monetary policy and digital finance. In areas with more advanced digital finance and favorable policy periods, they should improve their collaboration with financial institutions, increase the number of financing channels and lower financing costs through the use of digital financial platforms, optimize

capital allocation, boost their capacity for innovation and production efficiency, and increase their competitiveness in the market. In areas where digital finance is developing at a rather slow pace, policymakers should actively work to advance policy support, raise their own degree of digitalization, and get ready to receive assistance from digital financial services. To better adapt to changes in the monetary policy environment and achieve sustainable development, digital finance will actively approach the direction of policy support in areas where its development is comparatively lagging behind. It will also improve its level of digitalization and get ready to receive support for digital financial services.

This research has flaws despite efforts. The model can't fully capture economic and financial changes. Data limitations affect trend reflection and comprehensiveness. Also, variable selection may exclude emerging fintech.

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