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Digital Transformation of Commercial Banks, Monetary Policy Transmission Efficiency and SME Financing: Empirical Evidence from the Chinese Market

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Abstract

Using the data of SMEs in Chinese market from 2010 to 2021 as research samples, this paper focuses on the impact of commercial banks' digital transformation on the transmission efficiency of monetary policy to SME financing and the role of banks' risk-taking. The results show that the digital transformation of commercial banks can significantly improve the transmission efficiency of monetary policy to SME financing, and promote SMEs' bank loan supply and loan interest rate to adapt to the objectives of monetary policy regulation. Heterogeneity test shows that the impact of digital transformation of commercial banks on the transmission efficiency of monetary policy presents heterogeneity among enterprises with different property rights and growth characteristics and regions with different marketization degrees and financial development levels. Moreover, the strengthening effect on the transmission efficiency of monetary policy is more obvious in private enterprises, high-growth enterprises, enterprises in areas with higher degree of marketization and enterprises in areas with lower level of financial development. The transmission channel test shows that the strengthening effect of the digital transformation of commercial banks on the transmission efficiency of monetary policy is realized by influencing the risk-taking of banks. The findings remain robust after replacing key explanatory variables, adjusting model estimation methods, and controlling for the influence of financial development level. The research conclusions of this paper have important policy implications for promoting the digital transformation of commercial banks and improving the transmission efficiency of monetary policy, so as to promote the digital transformation of commercial banks to better alleviate SMEs' financing problems.

1. Introduction

One of the difficulties in making financial policies better help small and medium-sized enterprises is that the transmission of monetary and credit policies is not smooth. There is no doubt that the digital transformation and development of commercial banks has expanded the scope and quality of financial services, not only created a good environment conducive to the operation of commercial banks, played a positive role in digital finance in customers, capital, information and channels, but also posed a challenge to monetary policy, forcing commercial banks to change the competition pattern of traditional financial industry. It also affects the effectiveness of monetary policy (Kiyutsevskaya, 2019). Especially in the period of COVID-19, the People's Bank of China, the Banking and Insurance Regulatory Commission and other financial regulatory authorities have promoted commercial banks to give full play to their advantages of contact-free service, and continued to increase rescue efforts for small and medium-sized enterprises with the "hard power" of commercial banks' digital transformation, effectively improving the quality and efficiency of services to the real economy, which has been widely recognized by all sectors of society. Theoretically, the digital transformation of commercial banks can not only improve the accessibility and coverage of commercial banks' credit business, but also improve the identification mechanism and control mechanism of the inherent risk characteristics of small and medium-sized enterprises, making the transmission channel of monetary and credit policies more smooth (Shen & Huang, 2016; Song et al., 2020b; Zhou, 2022b). In practice, the digital transformation of commercial banks will intensify competition in the banking industry, optimize the allocation of resources in the banking industry, and make market players more responsive to monetary and credit policies, thus improving the pertinence and effectiveness of monetary and credit policies (Zhu, 2018; He et al., 2019; Yin, 2022). However, the existing research mainly focuses on the overall effect of the digital transformation of commercial banks on the effect of monetary policy. Therefore, focusing on the transmission efficiency of monetary policy, exploring the impact of commercial banks' digital transformation on the transmission efficiency of different types of monetary policy instruments and the role of banks' risk-taking can provide empirical evidence for the digital transformation of commercial banks to improve the effectiveness of monetary policy to alleviate the financing problems of small and medium-sized enterprises. It has important theoretical value and practical significance for correctly guiding the digital transformation of commercial banks and further dredging the transmission channel of monetary policy.

Literature Review

The existing research mainly focuses on the impact of digital transformation of commercial banks on the transmission of monetary policy, the impact of digital financial services on the transmission of monetary policy, and the impact of digital transformation of commercial banks on digital financial services.

The first is the impact of digital transformation development of commercial banks on monetary policy transmission. From the perspective of the impact of commercial banks' digital transformation on monetary policy objectives, the effectiveness of interest rate and money supply as intermediary targets of monetary policy are both affected to a certain extent, and the impact of interest rate index on the digital transformation of commercial banks is less than that of money supply index, indicating that the measurability and controllability of interest rate index are less affected by the digital transformation of commercial banks. This means that the interest rate index is more conducive to stabilizing prices and promoting economic growth than the money supply index (Song et al., 2020a). From the perspective of the impact of the digital transformation of commercial banks on the liquidity creation effect of monetary policy, when the development level of the digital transformation of commercial banks reaches a certain level, the digital transformation of commercial banks will significantly weaken the liquidity creation effect of monetary policy. Moreover, this effect is more significant for banks with a low proportion of semi-liquid assets and a high proportion of demand deposits, or large state-owned commercial banks, urban commercial banks and rural commercial banks (Sheng & Fan, 2020). From the perspective of the impact of the digital transformation of commercial banks on the effectiveness of monetary policy tools, with the improvement of the development degree of the digital transformation of commercial banks, the effect of price based monetary policy tools such as interest rate tends to be enhanced, while the effect of quantitative monetary policy tools such as the statutory deposit reserve ratio and open market operation tends to be weakened (Song et al., 2021). From the perspective of the transmission mechanism through which monetary policy affects households through mortgage loans, the increase in market penetration brought about by higher digital transformation of commercial banks is closely related to the transmission of more comprehensive loose monetary policy driven by higher refinancing propensity, among which the spillover of fintech loans from socially connected markets is a key determinant of the growth of fintech loans. Policies aimed at encouraging fintech loan growth, improving regional interaction and information exchange, and alleviating capacity constraints faced by traditional lenders can reduce frictions in the mortgage market and improve the efficiency of monetary policy transmission through the mortgage channel (Zhou, 2022a). From the comparison of the transmission mechanism of monetary policy through traditional banks and big technology credit institutions, the information advantage and risk management mode of technology giant lenders mainly strengthen the transmission of mone-

tary policy through large interest rate spreads, and the financial channels that obtain credit from technology giant lenders are more significant in coping with monetary policy than traditional banks. This shows that monetary policy should consider the amplification mechanism of fintech loans in the financial market, especially the technology giant lenders (Huang et al., 2022).

The second is the impact of digital financial services on monetary policy transmission. From the perspective of the impact of the digitalization of financial services on monetary policy, the use of electronic payment can enable the public to transfer their investment portfolios at a lower cost and in a more convenient way, thus improving the transmission efficiency of monetary policy, especially through the channels of credit and asset prices. This is because the decline in the cash deposit interest rate and the excess reserve ratio will lead to an increase in the money multiplier (Chucherd et al., 2018). From the perspective of the influence of electronic money on the target of monetary policy, under the impact of electronic money, the money supply and the quantity of electronic money change in the same direction, while the interest rate and the quantity of electronic money change in the opposite direction. However, the anti-interference and early warning function of money supply as an intermediary indicator of monetary policy will tend to be weakened, especially in dealing with the impact of electronic money (Yan & Lin, 2020). From the perspective of the bank asset pricing channel of monetary policy, under the superposition effect of digital finance development and interest rate deregulation, the deposits and savings diverting from Internet wealth management products will re-enter the banking system through the inter-bank market, which will strengthen banks' dependence on market-oriented funds such as inter-bank wholesale financing and certificates of deposit. As a result, the short-term market interest rate becomes an important factor affecting the cost of loan funds, which is then transmitted to the loan interest rate of the real economy and effectively promotes the transmission of three-month Shibor to the credit market (Duan & He, 2021). From the perspective of the cost transmission channel of monetary policy, the development of digital finance will strengthen the "price puzzle" generated by expansionary monetary policy on inflation, increase the dependence of external financing for enterprises' operating costs, and enhance the sensitivity of enterprises' production process to financing interest rate, thus improving the transmission effect of monetary policy and reducing the time lag of monetary policy (Zhou, 2022b). From the comparison of the transmission of digital finance through the interest rate channel and the credit channel, the amplification effect of digital finance development on the interest rate channel is stronger than the weakening effect on the credit channel (Zhan et al., 2020).

The third is the impact of digital transformation of commercial banks on inclusive finance and the effectiveness of monetary policy. From the impact of inclusive finance and commercial banks' digital transformation on the effectiveness of monetary policy, inclusive finance rate is the main variable that affects

household consumption behavior and enterprise investment behavior. Consumption and investment are the main variables of monetary policy transmission mechanism through interest rate channel and ultimately affect inflation rate. Although the development of digital transformation of commercial banks is not the main variable to form the level of consumption and investment, it is the key variable of the transmission mechanism of monetary policy through the channel of interest rate. Therefore, both inclusive finance and digital transformation of commercial banks will affect the effectiveness of monetary policy. In addition, the realization of inflation target within the monetary framework is largely affected by the impact of innovation in the digital transformation of commercial banks, so it is necessary for the policy authorities to effectively supervise the digital transformation of commercial banks (Saraswati et al., 2020). From the perspective of the impact of the digital transformation of commercial banks on the relationship between monetary policy and financial inclusion, the digital transformation of commercial banks provides a platform for better supervision by providing the necessary transparency in the transaction process, making monitoring and compliance easier, and ultimately reducing the incidence of corruption in the financial system. In general, not only monetary policy and digital transformation of commercial banks will have a significant positive impact on inclusive finance, but also the development of digital transformation of commercial banks will strengthen the positive relationship between monetary policy and inclusive finance. This means that the central bank's financial inclusion policy can be promoted through friendly and strategic supervision of the digital transformation of commercial banks (Joseph et al., 2021). From the perspective of the impact of digital currency on the effectiveness of monetary policy, on the one hand, electronic money facilitates the conversion of cash and other interest-bearing assets, making it easier for enterprises and individuals to hold interest-bearing assets (Wen & Zhang, 2016). On the other hand, the implementation of legal digital currency helps to reduce the flow barriers among various financial products and improve the interest rate flexibility of the market (Fang & Huang, 2020).

To sum up, although the existing literature has conducted beneficial discussions on the digital transformation development of commercial banks or the impact of digital finance on the transmission of monetary policy, as well as the role of digital transformation development of commercial banks and inclusive finance in the effectiveness of monetary policy, it has not involved the impact of digital transformation of commercial banks on the effectiveness of monetary policy. In particular, the impact of digital transformation of commercial banks on the financing transmission efficiency of different types of monetary policies to small and medium-sized enterprises is even less. Based on this, this paper attempts to make a beneficial supplement to the existing literature, using the "Peking University Digital Transformation Index of China's Commercial banks" to conduct an empirical test, focusing on the impact of commercial banks' digital

transformation on the efficiency of monetary policy to SME financing transmission and the role of banks' risk-taking. The main contributions of this paper are as follows. Different from the existing research, which mainly discusses the impact of the digital transformation development of commercial banks on the effectiveness of monetary policy from the perspectives of digital currency and electronic payment, the research conclusions of this paper are more targeted, revealing the impact of the digital transformation of commercial banks on the effectiveness of monetary policy to rescue the financing of small and medium-sized enterprises, and ensuring the unique perspective of the research question. The second is to distinguish quantitative monetary policy from price-based monetary policy and explore whether the strengthening effect of commercial banks' digital transformation on the financing transmission efficiency of monetary policy to small and medium-sized enterprises is realized through the bank risk-taking channel. The existing research rarely considers the role of bank risk-taking channel in the digital transformation of commercial banks affecting the effectiveness of monetary policy. By clarifying the transmission mechanism of commercial banks' digital transformation on the effectiveness of monetary policy and verifying the effectiveness of the risk-taking channel, this paper greatly enriches the existing research conclusions. Third, the use of panel data and frontier measurement methods improves the credibility of the research conclusions. Compared with the existing research mainly using time series data and traditional quantitative analysis methods, this paper uses panel data and dynamic model to describe and analyze the research issues in depth, and obtains scientific research conclusions, which can provide reference for strengthening the digital transformation of commercial banks and improving monetary policy regulation. The rest of this paper is arranged as follows: the second part is theoretical analysis and research hypothesis; The third part is data, model and variables; The fourth part is the empirical results and transmission channel test; Section 5 presents the main conclusions and policy implications.

2. Theoretical Analysis and Research Hypothesis

2.1. The Impact of Commercial Banks' Digital Transformation on the Transmission Efficiency of Quantitative Monetary Policy

In the process of providing money and credit to the market, commercial banks not only play an intermediary role, but also play a key role in the process of creating and distributing money and credit. From the perspective of the transmission channel of quantitative monetary policy affecting small and medium-sized enterprises, it mainly plays a role through the credit transmission channel, that is, by adjusting the deposit reserve ratio, it affects the bank credit supply decision, and then affects the credit availability of small and medium-sized enterprises (Braun, 2016; Werner, 2016; Zhan et al., 2018). The transmission process can be roughly described as follows: quantitative monetary policy (deposit reserve ratio or money supply) → loan-able funds of banks → credit availability of small and medium-sized enterprises. The digital transformation of commercial banks will

adjust their own asset and liability structure, consolidate and deepen the credit financing mode of small and medium-sized enterprises, improve the financing convenience and capital availability of small and medium-sized enterprises, and promote the improvement of the quantity and quality of credit realized by small and medium-sized enterprises on the whole. The effect mechanism of digital transformation of commercial banks on the transmission efficiency of quantitative monetary policy is mainly reflected as follows: First, the digital transformation of commercial banks will enrich the financial products and new financial products such as marketable securities of commercial banks, and increase the proportion of intermediate business and off-balance sheet business. The liabilities increased through the creation of new financial products do not need to pay deposit reserve, and can be timely converted into credit assets when the central bank tightening monetary policy. When the monetary policy is relaxed, it can choose to increase the credit assets held, so that the credit availability of small and medium-sized enterprises is weakened by the influence of contractionary monetary policy, and strengthened by the influence of expansionary monetary policy, and the stability of the credit supply level of small and medium-sized enterprises is guaranteed to a certain extent. Second, the digital transformation of commercial banks can increase the profit channels of commercial banks, expand their available assets, encourage them to carry out diversified asset allocation, and enable them to take timely measures to offset the impact of policy adjustment on their credit business when the central bank adjusts the loanable funds and credit scale limits of the banking system. When monetary policy is tightened, it can choose to convert the increased assets into credit assets, and when monetary policy is eased, it also has greater credit supply potential and ability, that is, the digital transformation of commercial banks can amplify the effect of monetary policy to rescue the financing of small and medium-sized enterprises on the whole; Third, the digital transformation of commercial banks can improve the traditional loan technology, significantly enhance the feasibility and practicality of commercial banks' mining and utilization of various soft information through digital transformation, weaken the comparative advantages of other financial institutions' fintech transformation and development, and promote commercial banks to include more tail groups that cannot get access under the traditional loan conditions into the service scope. Part of the funds originally squeezed out by the rapid development of fintech in other financial institutions should be gradually returned to the balance sheet, so as to increase the scale of bank credit supply, expand the scope of quantitative monetary policy regulation, improve the transmission efficiency of bank credit channels, and realize the credit availability of small and medium-sized enterprises (Xie & Zou, 2012; Fuster et al., 2019; Sheng et al., 2020). Accordingly, this paper puts forward research hypothesis 1.

Hypothesis 1: The digital transformation of commercial banks will improve the transmission efficiency of quantitative monetary policy, and make the bank loan and credit supply of small and medium-sized enterprises bet-

ter adapt to the target of monetary policy regulation.

2.2. Impact of Digital Transformation of Commercial Banks on the Transmission Efficiency of Price-Based Monetary Policy

From the perspective of the transmission channel of price-based monetary policy affecting small and medium-sized enterprises, it mainly plays a role through the interest rate channel, that is, by adjusting the policy interest rate, it affects the money market, and then transmits to the credit market, and then affects the financing of small and medium-sized enterprises. The transmission process can be roughly described as follows: price-based monetary policy (policy interest rate) → money market interest rate → bank loan interest rate → bank loan interest rate for small and medium-sized enterprises. Among them, bank financial management is an important channel connecting the money market and the credit market, and the interest rate of market-priced financial products can respond to the market interest rate in a timely and effective manner. This is because: first, financial management funds are mainly converted from customer deposits and are affected by the implicit guarantee of banks, which has become an important supplement to bank deposit business and an important source of loanable funds; Second, financial services are not subject to interest rate control and loan-to-deposit ratio restrictions of financial regulatory authorities, and have a relatively high market-oriented attribute. Specifically, the rise in the interest rate of financial products will lead to the rise in the cost of capital on the liability side of banks, and the rate of return required by banks on financial funds will also rise accordingly. However, the investment targets of bank financial funds are usually corporate bonds and non-standardized debt financing, which means that the financing cost of the above financing methods of enterprises will rise. As a result, enterprises' financing demand for bonds and non-standardized creditor's rights decreases, and their financing demand for bank credit increases, which promotes the rise of bank loan interest rate, indicating that the larger the scale of financial services with market-oriented pricing is, the higher the degree of bank interest rate liberalization is, and the higher the transmission efficiency of policy interest rate through bank financial services is (Shen & Huang, 2016; Acharya et al., 2020; Wang, 2021). The effect mechanism of commercial banks' digital transformation on the transmission efficiency of price-based monetary policy is mainly reflected as follows: First, the digital transformation of commercial banks provides more investment opportunities for the public, encourages the public to purchase bank financial products, weakens the diversion effect of the rapid development of Internet financial products of other financial institutions on bank deposits and wealth management funds, expands the scope of interest rate liberalization exploration by commercial banks through wealth management products, and improves the transmission efficiency of interest rates on monetary policies. Second, the digital transformation of commercial banks can make the credit pricing of banks conform to the market-oriented pricing method adopted by other financial institutions, improve their comprehensive competitiveness and

service level, weaken the competition effect and crowding out effect of the rapid development of fintech of other financial institutions on commercial banks, and narrow the price disadvantage of commercial banks' loan interest rate compared with other financial institutions. Third, the digital transformation of commercial banks can promote commercial banks to use big data, cloud computing, artificial intelligence, block chain and other scientific and technological means to greatly enrich the software and hardware support and big data support of commercial banks, so as to effectively optimize their market-oriented pricing methods of loan interest rates, improve the market-oriented pricing ability of commercial banks, and promote commercial banks to accelerate the process of loan interest rate liberalization. Improve the efficiency of monetary policy interest rate transmission channel (Qiu et al., 2018; Meng et al., 2020; Duan & He, 2021). Accordingly, we put forward hypothesis 2:

Hypothesis 2: The digital transformation of commercial banks will improve the transmission efficiency of price-based monetary policy, and make the bank loan interest rate of small and medium-sized enterprises better adapt to the target of monetary policy regulation.

2.3. The Impact of Digital Transformation of Commercial Banks on the Transmission Efficiency of Quantitative Monetary Policy through Bank Risk-Taking

Theoretically, the bank's risk-taking is the key to the transmission of quantitative monetary policy. From the perspective of banks' risk-taking, the main reason for the poor transmission of credit channel of China's monetary policy lies in the insufficient sensitivity of banks' risk-taking to monetary policy adjustment, including insufficient willingness and ability to take risks. As a result, although loose monetary policy increases a large amount of loanable funds, However, due to pessimistic expectations and other reasons, it is difficult for banks to effectively play the credit creation function, which leads to the blockage of monetary policy transmission from "broad money" to "broad credit". In general, the digital transformation of commercial banks will enhance banks' risk-taking willingness and behavior through bank balance sheet and bank competition mechanism, and enhance banks' risk-taking ability through technical efficiency mechanism, thus adjusting the sensitivity of banks' risk-taking to monetary policy adjustment under loose monetary policy. Influencing the transmission effect of credit channel of monetary policy through banks' risk-taking (Wang et al., 2012; Guo & Shen, 2019; Li & Tian, 2020; Gong & Li, 2020; Yu & Zheng, 2022). From the perspective of bank balance sheet mechanism, through the digital transformation of commercial banks, not only the business boundary of the asset end is safely expanded, but also the credit support for small and medium-sized enterprises with high risks is increased compared with the traditional credit business under the condition of controllable risk-taking willingness and behavior, and the customer quality of the liability end is steadily improved. Relying on the digital transformation means of commercial banks to achieve precision marketing, im-

prove the ability to acquire customers at low cost, optimize the structure of assets and liabilities, so as to well control the non-performing loan ratio of banks and enhance the risk bearing capacity of banks. As a result, the same monetary policy adjustment under loose monetary policy will bring about a greater increase in the risk bearing willingness and risk bearing capacity of banks. Thus, the transmission effect of credit channel of monetary policy can be improved. From the perspective of bank competition mechanism, through the digital transformation of commercial banks, banks can use fintech means to identify portraits for small and medium-sized enterprises and provide customized and accurate services, diverting part of the traditional demand deposits of banks. The resulting intensified competition in the deposit market will reduce the franchise value of banks, thus increasing the risk-taking of banks. As a result, the response degree of banks' risk-taking to monetary policy adjustment is stronger under loose monetary policy than under the traditional situation, thus improving the transmission effect of monetary policy credit channel. From the perspective of technical efficiency mechanism, the digital transformation of commercial banks can lay a foundation for banks to build databases and data risk control platforms, thus strengthening the risk control efficiency of banks, reducing bank operating costs, improving bank risk monitoring and improving bank business efficiency, so that banks can improve risk tolerance and have stronger risk bearing willingness and ability. The response degree of risk-taking to monetary policy adjustment should be improved, and then the blockage of monetary policy credit channel transmission at the bank end should be unblocked. Based on this, this paper puts forward hypothesis 3:

Hypothesis 3: The impact of commercial banks' digital transformation on quantitative monetary policy can be realized through banks' risk-taking.

2.4. The Impact of Digital Transformation of Commercial Banks on the Transmission Efficiency of Price-Based Monetary Policy through Bank Risk-Taking

The digital transformation of commercial banks affects the transmission efficiency of price-based monetary policy, which requires commercial banks to be highly sensitive and adaptable to market interest rates. Theoretically, the digital transformation of commercial banks can not only optimize the market-oriented allocation of financial factors, enhance the willingness of commercial banks to issue inclusive loans, and the income generating ability of inclusive loans is stronger than the profit generating ability, but also reduce the risks brought by inclusive loans, and the effect on reducing inclusive loans for small and medium-sized enterprises is particularly obvious. Thus, commercial banks should take into account both development prevention and security when carrying out inclusive loans (Guo & Zhu, 2021). Interest rate changes will affect banks' risk-taking by affecting the asset and liability structure of commercial banks, deposit and loan spreads, maturity mismatch and other mechanisms, and the increase of market interest rate fluctuations will lead to the increase of banks'

risk-taking (Li et al., 2021). Moreover, the digital transformation of commercial banks will enhance the effect of price-based monetary policy. For example, the digital transformation of commercial banks can effectively solve the trust problem of both parties and improve the effect of interest rate allocation based on credit contracts (Macrinici et al., 2018); The digital transformation of commercial banks can lead to drastic fluctuations in money demand, which will break the stability between money supply and money demand when money supply remains unchanged in the short term (He et al., 2019). The digital transformation of commercial banks can improve the external financial environment and enhance the correlation and co-movement between loan interest rate and market interest rate by alleviating financial frictions such as information asymmetry (Song et al., 2021). Specifically, the impact mechanism of the digital transformation of commercial banks on the financing of small and medium-sized enterprises by price-based monetary policy mainly includes the scale substitution effect and network externality effect of the digital transformation of commercial banks. On the one hand, the digital transformation of commercial banks can weaken the substitution effect of other financial institutions on traditional commercial banks, alleviate the degree of financial constraints in the existing banking system, promote the willingness and ability of financial consumers originally excluded from the existing commercial banking system to purchase financial products with the help of the digital transformation of commercial banks, and improve the financial inclusion level of the commercial banking system. As a result, the sensitivity of commercial banks' deposit size and market interest rate to the interbank market interest rate is enhanced, and the effectiveness of interest-rate and other price-based monetary policy transmission is enhanced (Hannig & Jansen, 2010). On the other hand, the digital transformation of commercial banks can make full use of their network externality advantages of information technology, make original customers voluntarily purchase financial products of commercial banks, attract more financial consumers to purchase financial products of commercial banks, effectively reduce information asymmetry and operational risks, and increase the demand of commercial banks for funds in the inter-bank market. Improve the role and effect of open market operations as monetary policy, and improve the transmission mechanism and effectiveness of price-based monetary policy (Varian et al., 2013). Based on this, this paper puts forward hypothesis 4:

Hypothesis 4: The impact of commercial banks' digital transformation on price-based monetary policy can be realized through banks' risk-taking.

3. Research Design

3.1. Data

According to the Standard Provisions on the Classification of Small and Medium-sized Enterprises jointly issued by the Ministry of Industry and Information Technology and other four departments, the definition of the size of small

and medium-sized enterprises is divided into three types: medium, small and micro according to the employees, operating income, total assets and other indicators of enterprises, combined with the characteristics of the industry. Based on the listed companies in China from 2010 to 2021, this paper selects the data of listed companies whose "enterprise size" is medium, small and micro as the research sample, and retains the listed companies with samples for more than two consecutive years in the sample processing process. The listed companies in the financial industry, ST, listed companies in the period of ST* and listed companies with incomplete financial data are excluded. The missing data of individual samples are filled by the mean filling method and the nearest neighbor filling method, and the main continuous variables are Winsorize at 1% and 99% quantiles. Finally, 370 small and medium-sized enterprises were obtained. The micro enterprise data and most of the regional data in this paper come from Wind Information, and the basic data of the digital transformation of commercial banks come from the Institute of Digital Finance of Peking University.

3.2. Setting of Measurement Model

In order to test hypothesis 1 and hypothesis 2, this paper uses the modeling methods of Altunbas et al. (2009) and Zhan et al. (2018) to construct the following models (1) and (2) to test the impact of digital transformation of commercial banks on the transmission efficiency of quantitative monetary policy and price based monetary policy:

$$\Delta \ln loan_{i,t} = \alpha_0 + \alpha_1 QMP_{t-1} + \alpha_2 DLL_t + \alpha_3 QMP_{t-1} * DLL_t \\ + \sum \alpha_j * Controls_{i,t} + \varepsilon_{i,t} \tag{1}$$

$$RL_{i,t} = \alpha_0' + \alpha_1' PMP_{t-1} + \alpha_2' DLL_t + \alpha_3' PMP_{t-1} * DLL_t + \sum \alpha_j' * Controls_{i,j} + \varepsilon_{i,t}' \tag{2}$$

For model (1), before the introduction of commercial bank digital transformation variables, the transmission efficiency of quantitative monetary policy is α_1, and the implementation of loose quantitative monetary policy by the central bank (reducing the statutory deposit reserve ratio) will enhance the credit supply level of small and medium-sized enterprise banks, which means that there is a reverse change between quantitative monetary policy variables and small and medium-sized enterprise bank credit supply variables, so α_1 is expected to be significantly negative; After introducing the digital transformation variable of commercial banks, the transmission efficiency of quantitative monetary policy is $\alpha_1 + \alpha_3 * DLL_t$. According to hypothesis 1, the digital transformation of commercial banks will strengthen the transmission efficiency of quantitative monetary policy, which means that the estimation coefficient symbols of quantitative monetary policy variable (QMP_{t-1}) and its cross term with commercial bank digital transformation variable ($QMP_{t-1} * DLL_t$) are the same and significant, so it is expected to be significantly negative

For model (2), before introducing the digital transformation variable of commercial banks, the transmission efficiency of price based monetary policy was α_1'. The central bank's implementation of loose monetary policy (reducing the

level of interbank offered rate) will reduce the level of bank loan interest rates for small and medium-sized enterprises, which means that the price based monetary policy variable and the bank loan interest rate variable for small and medium-sized enterprises change in the same direction, so α_1' is expected to be significantly positive; After introducing the digital transformation variable of commercial banks, the transmission efficiency of price based monetary policy is $\alpha_1' + \alpha_3' * DLL_t$. According to hypothesis 2, the digital transformation of commercial banks will strengthen the transmission efficiency of price based monetary policy, which means that the estimated coefficient sign of the price based monetary policy variable (PMP_{t-1}) and its cross term with the digital transformation variable ($PMP_{t-1} * DLL_t$) of commercial banks are the same and significant, so the expected α_3' is significantly positive.

In order to test hypothesis 3 and Hypothesis 4, this paper constructs the following models (3) and (4) to test the role of bank risk taking in the process of commercial bank digital transformation affecting the transmission efficiency of quantitative monetary policy and price monetary policy:

$$
\begin{aligned}
\Delta \ln loan_{i,t} = {} & \alpha_0 + \alpha_1 MP_{t-1} + \alpha_2 DLL_t + \alpha_3 MP_{t-1} * DLL_t + \alpha_4 MP_{t-1} * Risk_{i,t} \\
& + \alpha_5 MP_{t-1} * DLL_t * Risk_{i,t} + \sum \alpha_j * Controls_{i,t} + \varepsilon_{i,t}
\end{aligned}
\tag{3}
$$

$$
\begin{aligned}
RL_{i,t} = {} & \alpha_0' + \alpha_1' MP_{t-1} + \alpha_2' DLL_t + \alpha_3' MP_{t-1} * DLL_t + \alpha_4' MP_{t-1} * Risk_{i,t} \\
& + \alpha_5' MP_{t-1} * DLL_t * Risk_{i,t} + \sum \alpha_5' * Controls_{i,t} + \varepsilon_{i,t}'
\end{aligned}
\tag{4}
$$

For model (3), in order to verify whether the impact of commercial bank digital transformation on the transmission efficiency of quantitative monetary policy is realized by affecting bank risk taking, we need to pay attention to the symbolic change of the estimation coefficient α_5 of the three variable interaction term $QMP_{t-1} * DLL_t * Risk_{i,t}$ and the size change of the $QMP_{t-1} * DLL_t$ estimation coefficient α_3. According to hypothesis 3, first of all, if α_5 is significantly negative, it shows that the sensitivity of bank risk taking to quantitative monetary policy adjustment has been enhanced; Secondly, compared with the α_3 estimation results in models (3) and (1), if the absolute value of α_3 in model (3) increases, it means that the strengthening effect of commercial bank digital transformation on the transmission efficiency of quantitative monetary policy has been further increased under the control of $QMP_{t-1} * DLL_t * Risk_{i,t}$ on the estimation results, indicating that the strengthening effect is achieved by affecting bank risk taking.

For model (4), in order to verify whether the impact of commercial bank digital transformation on the transmission efficiency of price based monetary policy is realized by affecting bank risk taking, we need to pay attention to the symbolic change of $PMP_{t-1} * DLL_t * Risk_{i,t}$ estimation coefficient α_5' of three variable interaction term and the α_3' size change of $PMP_{t-1} * DLL_t$ estimation coefficient. According to Hypothesis 4, first of all, if α_5' is significantly positive, it shows that the sensitivity of bank risk taking to price based monetary policy adjustment has been enhanced; Secondly, compared with the estimated results of

α'_3 in models (4) and (2), if the absolute value of α'_3 in model (4) increases, it means that the strengthening effect of commercial bank digital transformation on the transmission efficiency of price based monetary policy has been further increased under the control of $PMP_{t-1} * DLL_t * Risk_{i,t}$ on the estimated results, indicating that the strengthening effect is achieved by affecting bank risk taking.

3.3. Variable Definition and Description

3.3.1. Explained Variable

The first is the supply of bank credit for small and medium-sized enterprises ($\Delta \ln loan$). Following the idea of Zhan et al. (2018), the log growth rate of bank loans of small and medium-sized enterprises is selected as an alternative variable for the level of bank credit supply of small and medium-sized enterprises, and then the slope of bank credit growth of small and medium-sized enterprises on monetary policy variables is used to measure the sensitivity of bank credit supply of small and medium-sized enterprises on monetary policy, that is, as a measure of monetary policy transmission efficiency. The second is the bank loan interest rate of small and medium-sized enterprises (RL). Considering the availability of data, this paper draws lessons from the practice of Liu et al. (2018), and selects the ratio of current interest expenditure to total borrowing of small and medium-sized enterprises as an approximate measure of bank loan interest rates for small and medium-sized enterprises.

3.3.2. Explanatory Variables

The first is monetary policy (MP). Drawing lessons from the practice of Zhan et al. (2018), the statutory deposit reserve ratio of financial institutions is selected as the proxy variable of quantitative monetary policy (QMP), while the 7-day interbank offered rate weighted by time is selected as the proxy variable of price monetary policy (PMP), and considering its time lag effect, it is treated as a lag period. Among them, the statutory deposit reserve ratio of financial institutions is weighted according to the deposit reserve ratio of large financial institutions and small and medium-sized financial institutions and the proportion of deposit balance in total deposits.

The second is the digital transformation of commercial banks (DLL). Considering that the credit availability of small and medium-sized enterprises is affected by the digital transformation of the whole region rather than specific commercial banks, based on the digital transformation index of commercial banks constructed by the digital finance research center of Peking University (Xie & Wang, 2022), a digital transformation index of commercial banks weighted according to the loan balance of commercial banks in various places is constructed as a proxy variable for the digital transformation of commercial banks in various places, Considering the heteroscedasticity problem, it is treated as logarithm.

Third, bank risk taking ($Risk$). In view of the fact that bank credit risk is the main risk of commercial banks, following the ideas of Wang and Wang (2014), the non-performing loan ratio of local banks is selected as the proxy variable for

bank risk bearing, and considering its time lag effect, it is treated as a lag period.

3.3.3. Control Variables

Based on existing studies (Li et al., 2021; He & Wei, 2022; Yu & Zheng, 2022), and considering the correlation between variables to minimize the impact of multicollinearity on the estimation results, the control variables selected in this paper include: enterprise scale (*SIZE*), expressed by the logarithm of total assets of enterprises; Enterprise age (*AGE*), expressed by the logarithm of the sample year minus the year of establishment of the enterprise; Return on net assets (*ROE*) of an enterprise, expressed as the ratio of net profit to net assets; The operating cash flow (*CF*) of an enterprise is expressed by the ratio of the net cash flow of operating activities of the enterprise in that year to the total assets at the beginning of the period; The asset liability ratio (*Lever*) of an enterprise is expressed as the ratio of total liabilities to total assets of the enterprise; The composition rate of current assets (*LIQ*) of enterprises is expressed by the ratio of current assets to total assets of enterprises; Equity concentration (*CRIO*) of enterprises is expressed by the shareholding ratio of the top ten shareholders of enterprises, that is, the ratio of the number of shares held by the top ten shareholders of enterprises to the total number of shares of enterprises; Regional economic development level (*GDP*), expressed in nominal GDP growth rate; Regional inflation level (*INF*) is expressed by the growth rate of consumer prices around the country.

See Table 1 for the definition and calculation of variables in this paper.

3.4. Descriptive Statistics of the Variables

Table 2 presents the descriptive statistics of variables. From the perspective of the explained variables, the average value of the bank credit supply of SMEs is greater than the median, and is significantly lower than its standard deviation, indicating that the proportion of bank loans of most SMEs in the total liabilities of enterprises is above the median, and shows great volatility; The average and median of bank loan interest rates for small and medium-sized enterprises are similar, and both are greater than their standard deviation, and the fluctuation is relatively stable on the whole. From the perspective of explanatory variables, the average and median of quantitative monetary policy are similar, and both are significantly greater than their standard deviation, which means that the adjustment of quantitative monetary policy is generally stable; The average value of price based monetary policy and bank risk-taking is greater than the median, and both are higher than their respective standard deviations, indicating that the measurement indicators of price based monetary policy and bank risk-taking in most years are above the median, and the fluctuation is relatively stable; The average value of digital transformation of commercial banks is less than the median, and is significantly higher than its standard deviation, indicating that the level of digital transformation of commercial banks in most years is below the median, and shows a fairly good volatility and stability. From the perspective of

Table 1. Variable definition and calculation description.

Variable	proxy variable	symbol	calculation method
Explained variable	Bank credit dupply for small and medium-sized enterprises	$\Delta \ln loan$	Log growth rate of corporate bank loans
	Bank loan interest rate for small and medium-sized enterprises	RL	Ratio of current loan interest expenditure to total loan amount
Explanatory variable	Quantitative monetary policy	QMP	obtained by weighted calculation according to the deposit reserve ratio and the proportion of deposit balance in total deposits of large financial institutions and small and medium-sized financial institutions
	Price based monetary policy	PMP	calculated by time weighting according to the 7-day interbank offered rate
	Digital transformation index of commercial banks	DLL	calculated according to the digital transformation index of commercial banks of Peking University and the loan balance of local commercial banks
	Bank risk taking	$Risk$	Bank non-performing loan ratio
Variable of control	Enterprise size	$SIZE$	Logarithm of total assets at the beginning of the period
	Corporate age	AGE	Take the logarithm after subtracting the year of establishment of the enterprise from the sample year
	Return on net assets	ROE	Ratio of net profit to net assets
	Operating cash flow	CF	Ratio of net cash flow from operating activities of the enterprise in the current year to total assets at the beginning of the period
	Enterprise asset liability ratio	$Lever$	Ratio of total liabilities to total assets
	Composition rate of current assets of enterprises	LIQ	Ratio of current assets to total assets of enterprises
	Enterprise equity concentration	$CRIO$	Shareholding ratio of the top ten shareholders of the enterprise
	Regional economic development level	GDP	Nominal GDP growth rate
	Regional inflation	INF	Growth rate of consumer prices around the country

Table 2. Descriptive statistics of the variables.

	mean	median	maximum	minimum	standard deviation	number of observations
$\Delta \ln loan$	0.05	0.00	2.71	−2.57	0.61	4440
RL	0.05	0.05	0.13	0.00	0.04	4440
QMP	0.16	0.16	0.20	0.11	0.03	4440
PMP	2.92	2.77	4.08	2.11	0.68	4440
DLL	3.93	4.14	5.13	−1.06	0.86	4440
$Risk$	1.37	1.20	8.75	0.00	0.89	4440
$SIZE$	2.20	2.33	5.24	−0.01	1.33	4440
AGE	2.63	2.71	3.53	0.69	0.56	4440
ROE	0.03	0.05	0.42	−1.70	0.24	4440
CF	0.03	0.02	0.34	−0.34	0.10	4440
$Lever$	0.36	0.35	0.95	0.05	0.22	4440
LIQ	0.54	0.58	0.98	0.06	0.26	4440
$CRIO$	0.46	0.47	0.99	0.21	0.21	4440
GDP	8.14	8.00	17.40	−5.00	2.82	4440
INF	2.48	2.30	6.30	0.10	1.12	4440

control variables, the average values of the size, age, composition rate of liquid assets and equity concentration of SMEs are less than the median, and are all greater than their respective standard deviations, indicating that the size, age, liquidity and equity concentration of most SMEs are below the median, and the overall fluctuation is relatively stable; The average value of SME asset liability ratio, regional economic development level and regional inflation level is greater than the median, and both are higher than their standard deviation, indicating that the asset liability ratio of most SMEs, regional economic development level and regional inflation level in most years are above the median, and show considerable stability; The average return on net assets of small and medium-sized enterprises is less than the median, and the average value of operating cash flow is greater than the median, and both are lower than their respective standard deviations, indicating that the return on net assets of most small and medium-sized enterprises is below the median, while the operating cash flow is above the median, and both show obvious volatility.

4. Empirical Results and Transmission Channel Test

4.1. Benchmark Inspection Results

Table 3 shows the benchmark test results of the impact of digital transformation of commercial banks on the transmission efficiency of monetary policy. It can be seen that the impact of the digital transformation of commercial banks on the credit supply of small and medium-sized enterprises' banks is significantly positive within the 99% confidence interval, and the impact on the loan interest rate of small and medium-sized enterprises' banks is significantly negative within the 99% confidence interval, which means that within the analysis framework of monetary policy transmission efficiency in this paper, the digital transformation of commercial banks will promote the credit supply and loan interest rate of small and medium-sized enterprises' banks to adapt to the monetary policy control objectives.

From the perspective of the transmission efficiency of the digital transformation of commercial banks on the quantitative monetary policy, the impact of the quantitative monetary policy on the credit supply of small and medium-sized enterprises' banks is significantly negative within the 95% confidence interval, and the impact of the cross term of the quantitative monetary policy and the digital transformation of commercial banks on the credit supply of small and medium-sized enterprises' banks is significantly negative within the 99% confidence interval (Table 3, column 1), which confirms the transmission mechanism of the quantitative monetary policy, That is, the reduction of the statutory deposit reserve ratio by the central bank will significantly improve the level of bank credit supply for SMEs, and the digital transformation of commercial banks will significantly strengthen the transmission efficiency of quantitative monetary policy to SME financing. Hypothesis 1 is verified.

From the perspective of the transmission efficiency of the digital transformation of commercial banks on the price based monetary policy, the impact of the

Table 3. Test results of the impact of digital transformation of commercial banks on the transmission efficiency of monetary policy.

	1. Quantitative monetary policy transmission	2. Price monetary policy transmission
MP(−1)	−7.725**	0.005**
	(−2.29)	(2.51)
DLL	0.460***	−0.008***
	(3.31)	(−4.61)
MP(−1)*DLL	−2.109***	0.002***
	(−2.81)	(2.77)
Constant term	1.177*	−0.030***
	(1.76)	(−5.16)
Variable of control	control	control
Year fixed effect	control	control
Industry fixed effects	control	control
Adjusted R^2	0.032	0.277
Total number of panel observations	4070	4070

Note: t value is in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

price based monetary policy on the bank loan interest rate of small and medium-sized enterprises is significantly positive within the 95% confidence interval, and the impact of the cross term of the price based monetary policy and the digital transformation of commercial banks on the bank loan interest rate of small and medium-sized enterprises is significantly positive within the 99% confidence interval (Table 3, column 2), which confirms the transmission mechanism of the price based monetary policy, That is, the reduction of interbank offered rate by the central bank will significantly reduce the bank loan interest rate of small and medium-sized enterprises, and the digital transformation of commercial banks will significantly strengthen the transmission efficiency of price based monetary policy to the financing of small and medium-sized enterprises. Hypothesis 2 is verified.

4.2. Heterogeneity Test Results

This paper uses the existing domestic studies such as He and Wei (2022) for reference to test the heterogeneity from four aspects: first, the nature of enterprise property rights, which divides the research sample into state-owned enterprises and private enterprises; Second, the growth of enterprises. According to the year-on-year growth rate of operating revenue, the sub samples with the year-on-year growth rate of operating revenue higher than the 75% quantile and lower than the 25% quantile are defined as high growth enterprises and low growth enterprises respectively; The third is the degree of regional marketization. According to the "total score of marketization process" index of China's provincial

marketization index database, sub samples with a total score of marketization process higher than 75% and lower than 25% are defined as enterprises in regions with higher degree of marketization and enterprises in regions with lower degree of marketization; Fourth, the level of regional financial development. According to the ratio of local and foreign currency loan balances to GDP, the subsample with the ratio of local and foreign currency loan balances to GDP higher than the 75% quantile and the subsample with the ratio lower than the 25% quantile are defined as enterprises in regions with high financial development level and enterprises in regions with low growth financial development level. Table 4 and Table 5 show the results of the enterprise heterogeneity test and the regional heterogeneity test of the impact of the digital transformation of commercial banks on the transmission efficiency of monetary policy. It can be seen that the impact of the digital transformation of commercial banks on the credit supply of small and medium-sized enterprises' banks is significantly positive at least within the 90% confidence interval, and the impact on the loan interest rate of small and medium-sized enterprises' banks is also significantly negative at least within the 90% confidence interval, which means that the digital transformation of commercial banks will promote the credit supply and loan interest rate of small and medium-sized enterprises' banks to adapt to the monetary policy control objectives.

Table 4. Heterogeneity test results of commercial bank digital transformation on monetary policy transmission efficiency (enterprise heterogeneity).

	Nature of property rights				Growth			
	Quantitative monetary policy transmission		Price based monetary policy transmission		Quantitative monetary policy transmission		Price based monetary policy transmission	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	State owned enterprises	Private enterprises	State owned enterprises	Private enterprises	High growth enterprise	Low growth enterprises	High growth enterprise	Low growth enterprise
MP(−1)	−6.133**	−12.022***	0.012*	0.022***	−13.432*	−0.786***	0.024***	0.005**
	(−2.07)	(−5.81)	(1.65)	(3.85)	(−1.72)	(−5.16)	(2.67)	(2.09)
DLL	0.390***	0.629***	−0.008***	−0.011***	0.756**	0.142**	−0.017*	−0.005**
	(3.54)	(6.77)	(−2.83)	(−3.16)	(2.30)	(2.23)	(−1.69)	(−2.11)
MP(−1)*DLL	−1.830***	−2.917***	0.003	0.008**	−3.395**	−0.555*	0.006**	0.001**
	(−2.60)	(−5.58)	(1.61)	(2.45)	(−1.99)	(−1.78)	(2.28)	(2.48)
Constant term	0.764	1.815***	−0.013***	−0.052**	0.516	−0.637	0.010	−0.096**
	(1.50)	(3.08)	(−0.26)	(−2.24)	(0.29)	(−0.32)	(0.24)	(−2.01)
Variable of control	control	control	control	control	control	control	control	control
Year fixed effect	control	control	control	control	control	control	control	control
Industry fixed effects	control	control	control	control	control	control	control	control
Adjusted R^2	0.101	0.018	0.310	0.398	0.120	0.049	0.247	0.305
Total number of panel observations	924	3146	924	3146	1017	1086	1017	1086

Note: t value is in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5. Heterogeneity test results of commercial bank digital transformation on monetary policy transmission efficiency (regional heterogeneity).

	Degree of Marketization				Financial development level			
	Quantitative monetary policy transmission		Price based monetary policy transmission		Quantitative monetary policy transmission		Price based monetary policy transmission	
	(1) High degree of Regional Marketization	(2) Low degree of Regional Marketization	(3) High degree of Regional Marketization	(4) Low degree of Regional Marketization	(5) High level of regional financial development	(6) Low level of regional financial development	(7) High level of regional financial development	(8) Low level of regional financial development
MP(−1)	−13.991** (−2.40)	−1.318*** (−4.71)	0.008*** (4.69)	0.006*** (4.01)	−12.914* (−1.80)	−18.467* (−1.67)	0.008*** (5.65)	0.022*** (5.39)
DLL	0.506* (1.95)	0.372** (2.00)	−0.015** (−2.32)	−0.009*** (−2.73)	0.670* (1.68)	0.808* (1.81)	−0.006** (−2.37)	−0.011*** (−3.46)
MP(−1)*DLL	−3.441*** (−3.18)	−1.610* (−1.75)	0.008*** (5.30)	0.002** (2.25)	−2.929* (−1.78)	−4.658** (−1.98)	0.001** (2.55)	0.005*** (2.78)
Constant term	1.984 (1.34)	1.483 (1.40)	−0.042*** (−4.04)	−0.052* (−1.79)	1.975 (1.46)	3.469* (1.72)	−0.023*** (−0.42)	−0.020* (−1.92)
Variable of control	control	control	control	control	control	control	control	control
Year fixed effect	control	control	control	control	control	control	control	control
Industry fixed effects	control	control	control	control	control	control	control	control
Adjusted R²	0.048	0.030	0.297	0.417	0.067	0.041	0.260	0.420
Total number of panel observations	1058	1009	1058	1009	1054	870	1054	870

Note: t value is in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

From the perspective of the nature of enterprise property rights, both the effect of monetary policy and the strengthening effect of digital transformation of commercial banks on monetary policy are stronger in the sample of private enterprises (columns 1 - 4 of Table 4), indicating that compared with state-owned enterprises, the effectiveness of digital transformation of commercial banks in improving the transmission efficiency of monetary policy is more obvious in private enterprises. This is because, compared with the state-owned enterprises with rich bank credit resources, the central bank's easing of monetary policy has a greater role in improving the credit availability of private enterprises, and the digital transformation of commercial banks, with its unique inclusiveness and long tail effect, can further unblock the transmission channel of monetary policy financing to private enterprises, and further enhance the transmission efficiency of monetary policy financing to private enterprises.

From the perspective of enterprise growth, both the effect of monetary policy and the strengthening effect of digital transformation of commercial banks

on monetary policy are stronger in the sample of high growth enterprises (Table 4, columns 5 - 8), indicating that compared with low growth enterprises, the effectiveness of digital transformation of commercial banks to improve the transmission efficiency of monetary policy is more significant in high growth enterprises. The possible explanation is that, compared with low growth enterprises, high growth enterprises have the internal incentive to adjust the capital structure and expand financing in order to expand production and operation when the central bank relaxes monetary policy, and the digital transformation of commercial banks can deeply tap the intrinsic value of enterprises through financial technology, provide practical financing facilities for high growth enterprises, and make the transmission efficiency of monetary policy to high growth enterprises' financing more efficient.

From the perspective of the degree of Regional Marketization, both the effect of monetary policy and the strengthening effect of digital transformation of commercial banks on monetary policy are stronger in the samples of regions with higher degree of Regional Marketization (columns 1 - 4 of Table 5), indicating that the effectiveness of digital transformation of commercial banks in improving the transmission efficiency of monetary policy is more obvious in regions with higher degree of marketization. This is because the government reduces its intervention in economic activities, creates a good environment for financial market competition and diversified financing of enterprises, helps to enhance the sensitivity of enterprise financing to monetary policy, and promotes commercial banks to alleviate the problems of financing risk premium and rising financing costs caused by monetary policy adjustment for enterprises through digital means, so as to make the transmission efficiency of monetary policy more efficient.

From the perspective of regional financial development level, both the effect of monetary policy and the strengthening effect of digital transformation of commercial banks on monetary policy are stronger in the samples of regions with lower regional financial development level (column 5 - 8 of Table 5), indicating that the effectiveness of digital transformation of commercial banks to improve the transmission efficiency of monetary policy to enterprise financing is more significant in regions with lower financial development level. The possible explanation is that compared with areas rich in financial resources, the central bank's easing of monetary policy has a more significant effect on improving the credit availability of SMEs in areas lacking financial resources, and the digital transformation of commercial banks can promote commercial banks to break through the space and time constraints of the traditional network layout, broaden the information depth of commercial banks' understanding of the real financial situation of enterprises, and enhance the penetration, accuracy and effectiveness of financial resources, Make the transmission efficiency of monetary policy to the financing of small and medium-sized enterprises in areas with low financial development level stronger.

4.3. Transmission Channel Test Results

Table 6 shows the transmission channel test results of the impact of digital transformation of commercial banks on the transmission efficiency of monetary policy. It can be seen that the estimated results are consistent with the research hypothesis of hypothesis 3 and Hypothesis 4 that the digital transformation of commercial banks is to strengthen the transmission efficiency of monetary policy by changing the bank's risk-taking (the results of column 1 and column 3 of Table 6 are the same as those of Table 3, and are given here together with the new output content for comparative analysis).

For the transmission of quantitative monetary policy, the estimated coefficient of $QMP_{t-1} * DLL_t * Risk_{i,t}$ is significantly negative within the 95% confidence interval (column 2 of Table 6), and its sign is consistent with the estimated coefficient of QMP_{t-1}, indicating that under normal conditions, the increase of bank risk-taking will improve the transmission efficiency of quantitative monetary policy; Comparing the estimated coefficient of $QMP_{t-1} * DLL_t$ in column 2 of Table 6 with that in column 1 of Table 6, the absolute value of the estimated coefficient of $QMP_{t-1} * DLL_t$ increased significantly after controlling the $QMP_{t-1} * DLL_t * Risk_{i,t}$ item, indicating that after considering the bank risk-taking, the strengthening effect of the digital transformation of commercial

Table 6. Estimation results of the heterogeneity of the synergistic effect of deposit insurance system and bank information disclosure on bank risk-taking.

	(1) Quantitative monetary policy transmission	(2) Quantitative monetary policy transmission	(3) Price monetary policy transmission	(4) Price monetary policy transmission
MP(−1)	−7.725** (−2.29)	−8.871*** (−2.68)	0.005** (2.51)	0.008** (2.36)
DLL	0.460*** (3.31)	0.527*** (3.77)	−0.008*** (−4.61)	−0.004* (−1.80)
MP(−1)*DLL	−2.109*** (−2.81)	−2.452*** (−3.16)	0.002*** (2.77)	0.005** (2.08)
MP(−1)*RISK		−0.643*** (−4.72)		0.002* (1.84)
MP(−1)*DLL*RISK		−0.115** (−2.56)		0.001** (2.19)
Constant term	1.177* (1.76)	1.513** (2.34)	−0.030*** (−5.16)	−0.067*** (−3.30)
Variable of control	control	control	control	control
Year fixed effect	control	control	control	control
Industry fixed effects	control	control	control	control
Adjusted R^2	0.032	0.033	0.277	0.371
Total number of panel observations	4070	4070	4070	4070

Note: t value is in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

banks on the transmission efficiency of quantitative monetary policy has been further enhanced, that is, the digital transformation of commercial banks strengthens the transmission efficiency of quantitative monetary policy financing to small and medium-sized enterprises by effectively changing the bank risk-taking. Hypothesis 3 is verified.

For the transmission of price based monetary policy, the estimated coefficient of $PMP_{t-1} * DLL_t * Risk_{i,t}$ is significantly positive within the 95% confidence interval (column 4 of Table 6), and its sign is also consistent with the estimated coefficient of PMP_{t-1}, indicating that under normal conditions, the increase of bank risk-taking will improve the transmission efficiency of price based monetary policy; Comparing the estimated coefficient of $PMP_{t-1} * DLL_t$ in column 4 of Table 6 with that in column 3 of Table 6, the absolute value of the estimated coefficient of $PMP_{t-1} * DLL_t$ increases significantly after controlling the $PMP_{t-1} * DLL_t * Risk_{i,t}$ item, which also shows that the strengthening effect of the digital transformation of commercial banks on the transmission efficiency of price based monetary policy has been further expanded after considering the bank risk taking, That is, the digital transformation of commercial banks strengthens the transmission efficiency of price based monetary policy to SME financing by effectively changing the bank's risk-taking. Hypothesis 4 is verified.

4.4. Robustness Test

4.4.1. Replace Key Explanatory Variables
The credit business sub index in the "Peking University Digital inclusive finance index" is used to measure the digital transformation of commercial banks. The higher the credit business sub index of commercial banks, the higher the level of digital transformation of commercial banks. Table 7 shows the estimated results of the digital transformation indicators of replacement commercial banks, and the basic conclusions remain stable.

4.4.2. Adjust the Model Estimation Method
The generalized moment estimation (GMM) method for dynamic panel systems is used to solve the OLS estimation bias caused by endogenous problems. Table 8 shows the estimation results of the alternative model estimation method. When sargan test and autocorrelation test both show that the model passes the over identification test and sequence autocorrelation test, the basic conclusion remains robust.

4.4.3. Control the Level of Financial Development
Considering that the improvement of the transmission efficiency of monetary policy financing to SMEs is affected by the level of regional financial development, the level of regional financial development (the ratio of local and foreign currency loan balances to GDP) is added to the control variable. Table 9 shows the estimated results of controlling the level of financial development, and the basic conclusions remain robust.

Table 7. Robustness test results of replacing key explanatory variables.

	(1) Quantitative monetary policy transmission	(2) Quantitative monetary policy transmission	(3) Price monetary policy transmission	(4) Price monetary policy transmission
MP(−1)	−8.478* (−1.66)	−16.783** (−2.15)	0.013* (1.65)	0.019*** (2.92)
DLL	0.356** (2.24)	0.702** (2.47)	−0.012*** (−2.80)	−0.014*** (−3.22)
MP(−1)*DLL	−1.869*** (−1.84)	−3.449** (−2.30)	0.003* (1.65)	0.004*** (3.02)
MP(−1)*RISK		−1.408*** (−6.81)		0.005** (2.10)
MP(−1)*DLL*RISK		−0.231** (−2.06)		0.009*** (7.04)
Constant term	1.443* (1.80)	3.462** (2.18)	−0.061*** (−3.18)	−0.069*** (−3.46)
Variable of control	control	control	control	control
Year fixed effect	control	control	control	control
Industry fixed effects	control	control	control	control
Adjusted R^2	0.023	0.031	0.246	0.248
Total number of panel observations	4070	4070	4070	4070

Note: t value is in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 8. Robustness test results of adjustment model estimation method.

	(1) Quantitative monetary policy transmission	(2) Quantitative monetary policy transmission	(3) Price monetary policy transmission	(4) Price monetary policy transmission
MP(−1)	−14.480*** (−4.56)	−15.026*** (−4.88)	0.019** (2.36)	0.022*** (3.94)
DLL	0.712*** (4.91)	0.716*** (4.98)	−0.014*** (−3.03)	−0.034** (−2.06)
MP(−1)*DLL	−3.407*** (−4.67)	−3.571*** (−5.15)	0.004* (1.71)	0.006*** (2.95)
MP(−1)*RISK		−0.961*** (−9.15)		0.032* (1.68)
MP(−1)*DLL*RISK		−0.098*** (−2.68)		0.007* (1.67)
Variable of control	control	control	control	control
Year fixed effect	control	control	control	control
Industry fixed effects	control	control	control	control
Sargan Statistics (P value)	0.397	0.414	0.212	0.297
AR (1) (P value)	0.000	0.000	0.000	0.000
AR (2) (P value)	0.585	0.582	0.495	0.758
Number of observations	3700	3700	3700	3700

Note: t value is in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 9. Robustness test results of controlling the level of financial development.

	(1) Quantitative monetary policy transmission	(2) Quantitative monetary policy transmission	(3) Price monetary policy transmission	(4) Price monetary policy transmission
MP(−1)	−8.331***	−9.017***	0.008**	0.013*
	(−2.71)	(−2.75)	(2.43)	(1.67)
DLL	0.455**	0.519***	−0.004*	−0.025***
	(3.47)	(3.72)	(−1.71)	(−3.66)
MP(−1)*DLL	−2.161***	−2.395***	0.002**	0.004*
	(−3.13)	(−3.05)	(2.18)	(1.94)
MP(−1)*RISK		−0.723***		0.005**
		(−5.50)		(2.41)
MP(−1)*DLL*RISK		−0.176**		0.001**
		(−2.03)		(2.55)
Constant term	1.471**	1.777***	−0.054**	−0.061*
	(1.80)	(2.76)	(−2.49)	(−1.93)
Variable of control	control	control	control	control
Year fixed effect	control	control	control	control
Industry fixed effects	control	control	control	control
Adjusted R^2	0.033	0.033	0.327	0.386
Total number of panel observations	4070	4070	4070	4070

Note: t value is in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5. Conclusion

Using the data of small and medium-sized enterprises in the Chinese market from 2010 to 2021 as the research sample, we focus on the impact of digital transformation of commercial banks on the transmission efficiency of monetary policy to small and medium-sized enterprises' financing and the role of bank risk-taking. The results show that the digital transformation of commercial banks can significantly improve the transmission efficiency of monetary policy to SME financing, and promote SME bank loan supply and loan interest rate to adapt to the monetary policy control objectives. The heterogeneity test found that the impact of digital transformation of commercial banks on the transmission efficiency of monetary policy was heterogeneous among enterprises with different property rights, growth and regions with different degrees of marketization and financial development, and the strengthening effect on the transmission efficiency of monetary policy should be more obvious in private enterprises, high growth enterprises, regions with higher degrees of marketization and regions with lower levels of financial development. The transmission channel test shows that the strengthening effect of the digital transformation of commercial banks on the transmission efficiency of monetary policy is achieved by affecting the bank's risk-taking. The research conclusion of this paper remains robust after replacing key explanatory variables, adjusting model estimation methods and

controlling the impact of financial development level. This paper enriches and expands the empirical research on the transmission efficiency of monetary policy, reveals the impact of the digital transformation of commercial banks on the transmission efficiency of different types of monetary policy to SME financing, and discusses the important role of bank risk-taking in it. This provides new empirical evidence for further promoting the digital transformation of commercial banks, improving the transmission efficiency of monetary policy by adjusting and improving bank risk-taking, and then promoting the changes of bank loan supply and loan interest rate of small and medium-sized enterprises to adapt to the regulatory objectives of monetary policy.

The research conclusion of this paper has important enlightenment significance for promoting the digital transformation of commercial banks and improving the transmission efficiency of monetary policy to SME financing, and then promoting the digital transformation of commercial banks to better alleviate the financing problems of SMEs. First, we will continue to improve the monetary policy framework and mechanism. Closely combined with the current situation of China's monetary policy regulation and transformation, we should take measures to actively respond to the impact of the digital transformation of commercial banks on the monetary policy framework mechanism. We should not only give full play to the important regulatory role of quantitative monetary policy, broaden the regulatory scope of quantitative monetary policy, create more structural monetary policy tools directly reaching small and medium-sized enterprises, and guide commercial banks to continue to deepen the digital transformation for small and medium-sized enterprises, To maintain the reasonable growth and steady pace of credit supply for small and medium-sized enterprises, we should also pay more attention to the regulation of price based monetary policy, continue to deepen the market-oriented reform of interest rates, improve the flexibility and toughness of market interest rates to respond to a series of external shocks such as the digital transformation of commercial banks, explore and launch targeted price based monetary policy tools for the digital transformation of commercial banks, and smooth the transmission path of the central bank's policy interest rate to financing for small and medium-sized enterprises, improve the efficiency of price based monetary policy tools to lead the financing cost of SMEs, especially the change of loan interest rate, and realize the continuous improvement of SME financing and the continuous reduction of financing cost. The second is to play an important role in the smooth transmission of monetary policy through the digital transformation of commercial banks. Under the monetary policy credit transmission and interest rate transmission mechanism with commercial banks as the core, promoting the digital transformation of commercial banks will help to improve the level and level of financial technology empowerment from within the commercial banking system. At the same time, from outside the commercial banking system, it will shorten the gap with other financial institutions in the level of financial technology application, and even

surpass or far exceed the level of financial technology application of other financial institutions. On the whole, it can promote the improvement of the transmission efficiency of monetary policy. Therefore, it is suggested to accelerate the deep integration of commercial banks and modern financial technology, focus on accelerating the in-depth research and development of financial technology such as blockchain and big data, and strive to build a multi-dimensional scene application system conducive to the implementation of SME quality review and accurate portrait, so as to improve the implementation environment of monetary policy, It will provide more convenience for the flexible, moderate, accurate regulation and rapid and effective transmission of monetary policy, making the transmission of monetary policy more forward-looking and targeted. Third, price stability and financial stability should be taken as the policy objectives of monetary policy regulation at the same time. Whether implementing quantitative monetary policy regulation or price monetary policy regulation, we should maintain the bank's risk-taking within a reasonable range. We should neither actively weaken the monetary policy regulation in order to reduce the bank's risk-taking, nor cause the bank's risk-taking to rise significantly in order to pursue economic growth excessively. Therefore, we need to address the strategic risks, compliance risks, and A series of risks, such as liquidity risk, operational risk and information technology risk, improve the professionalism, unity, penetrability and foresight of financial regulation, promote the sharing of information between banks, governments and enterprises, reduce transaction costs and related risks, and better provide convenient ways for SME financing, so as to achieve the overall stability of financial operation, controllable risk and sustainable and high-quality development of the real economy.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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