International Journal of World Economic Research
ISSN: 3080-9886 (Print), ISSN: 3080-9894 (Online) | Vol. 3, No. 3, 2026

Research on the Impact of Digital Finance on Commercial Banks' Risk-Taking

Qihao Xu

School of Business, Nanjing University of Science and Technology, Nanjing 210094, China

Abstract: With the continuous development of information technology in the new era, digital finance has become an important driving force for the high-quality development of commercial banks, but its impact on the risk-taking of commercial banks still needs to be further explored. This paper analyzes the impact of digital finance on the risk-taking of commercial banks from a theoretical perspective and, using the panel data of 38 listed banks in China from 2011 to 2022 and the Peking University Digital Financial Inclusion Index, empirically tests the impact of the development of digital finance on the risk-taking of Chinese commercial banks with a two-way fixed effects model. The results show that the development of digital finance can reduce the risk-taking of commercial banks. Based on the above conclusions, this paper puts forward corresponding policy recommendations for commercial banks.

Keywords: Digital finance, commercial banks, risk-taking, digital financial inclusion index, two-way fixed effects model.

1. Introduction

1.1. Research Background and Significance

Under the traditional operating model of Chinese commercial banks, deposit and loan business is dominant, but the mismatch between deposit and loan maturities easily exposes commercial banks to numerous risks. In addition, many enterprises find it difficult to obtain financing, and many low-income groups cannot obtain the credit lines they need because they lack qualified collateral. Traditional commercial banks are therefore confronted with such problems as narrow coverage and insufficient financing. On 11 March 2021, China issued the Outline of the 14th Five-Year Plan, which calls for establishing a modern financial framework, improving a modern financial system that is highly adaptive, competitive and inclusive, and promoting digital transformation along the two paths of digital industrialization and industrial digitalization. Accordingly, on 31 October 2023, the Central Financial Work Conference pointed out that the five major articles should be done well: technology finance, green finance, inclusive finance, pension finance and digital finance. For the first time, a central document of this term has explicitly incorporated "digital finance" into a central policy document, and its significance is becoming increasingly prominent. At present, digital finance, represented by big data, blockchain and artificial intelligence, is leading an unprecedented revolution in China's banking industry. Although digital finance, as a combination of emerging information technology and traditional finance, can technically support the reform of commercial banks, whether it will expose commercial banks to greater risks is a question worth discussing. On this basis, this paper intends to explore the impact of the continuous development of digital finance on the risk-bearing capacity of China's commercial banks from both theoretical and empirical perspectives. Through this research, it is possible to reveal how to better play its role in the risk management of commercial banks against the background of continuous development, and to put forward corresponding policy recommendations for China's commercial banks and government departments. Against the background of the vigorous development of digital finance across the country, how commercial banks can use digital finance to reduce their own risk-taking and formulate scientific and reasonable risk management policies is a question of positive theoretical and practical significance.

1.2. Research Content

This study first reviews the domestic and foreign academic literature in this field and summarizes the existing core viewpoints and research methods. Next, it introduces several key concepts concerned by this study: the digital financial inclusion index and the risk-taking of commercial banks. Subsequently, this paper discusses the impact of digital finance on the risk-taking of commercial banks from a theoretical perspective and proposes research hypotheses. On this basis, this paper selects the non-performing loan ratio as the explained variable and the Peking University Digital Financial Inclusion Index as the explanatory variable, conducts a baseline regression with a two-way fixed effects model, and adopts the Internet penetration rate as an instrumental variable to verify the robustness of the model, after which the corresponding conclusions and policy recommendations are put forward. Compared with the existing literature, this paper selects the non-performing loan ratio as the indicator measuring the risk-taking of commercial banks and selects the Internet penetration rate as the instrumental variable for the robustness test, which is innovative to a certain extent.

2. Literature Review

With the progress of the times, the development of emerging information technologies, the improvement of data collaboration and sharing capabilities and the continuous integration of financial factors, and in order to better facilitate the people, digital finance has developed rapidly, gradually changing the financial ecology and exerting a profound impact on China's traditional commercial banks. At a time when digital finance and traditional finance are increasingly integrated, commercial banks will encounter a series of challenges that cannot be underestimated in the future. In

view of this situation, this paper begins by reviewing the current literature on the impact of digital finance on the risk-bearing capacity of commercial banks.

2.1. Domestic Literature Review

2.1.1. The Risk-Increasing View

The risk-increasing view holds that the development of digital finance will increase the risk-taking of commercial banks. Liu and Wang (2022) took the non-performing loan ratio and the provision coverage ratio as explained variables and applied a multiple regression model, finding that the continuous application of digital finance increases the management costs of commercial banks and raises information technology risk and bank operational risk; in addition, digital finance increases the degree of business diversification of banks, thereby enlarging their risk-taking [1]. Wu and Wang (2021) used the Z-score to represent the risk-bearing capacity of commercial banks and employed static and dynamic panel data regression models to explore the impact of the development of digital finance on intensified competition among small and medium-sized commercial banks, finding that such competition further raised their level of risk-taking [2]. Mi, Xu and Tao (2019) used a t-SNE machine learning model to perform dimensionality reduction and cluster analysis, and pointed out the regional systemic contagion risk caused by the development of Internet finance, the risk of unbalanced business development and the impact on systemically important cities [3]. Qiu, Huang and Ji (2018) explored how fintech affects the liability structure of banks, arguing that banks gradually rely on interbank borrowing in their liability composition and that this "rising tide" phenomenon forces banks to rely on higher-risk assets in order to cope with the rise in liability-side costs [4].

2.1.2. The Risk-Reducing View

In current academic discussion, the risk-reducing view has been widely recognized. Yu and Wu (2021) used the Z-score to assess the risk level of commercial banks and, through the analysis of static, dynamic and generalized mixed models, confirmed the positive impact of the development of digital finance on the overall risk-bearing capacity of commercial banks, demonstrating its effectiveness in mitigating systemic financial risk [5]. He, Feng and Liu (2022) studied the deposit and loan business of commercial banks, took the non-performing loan ratio as the dependent variable and applied a two-way fixed effects model, revealing how the development of fintech enhances the risk-bearing capacity of commercial banks; they found that, as the scale of banks expands, the positive effect of fintech on their risk-bearing capacity also strengthens [6]. Gu and Gao (2022) used a multivariate regression model with the non-performing loan ratio and the risk-weighted asset ratio as dependent variables, and proved that the improvement of the risk-bearing capacity of commercial banks by digital finance is significant and heterogeneous, being most significant in state-owned banks and in urban and rural commercial banks [7]. Liu and Qin (2022) constructed a two-way fixed effects model of inclusive finance and took the non-performing loan ratio as the explained variable; they argued that improving the coverage, depth and digitalization level of digital finance can significantly reduce the bad debt ratio of banks and thereby effectively reduce risk-taking [8]. Wu, Xiang and Liu (2020) used panel data analysis, took negative return skewness as the dependent variable and explored the performance of enterprises when facing adverse factors such as the deterioration of the external environment, poor internal governance and a harsh financing environment [9]. Tang, Wu and Zhu (2020), from the perspective of serving the real economy, proposed that digital finance can effectively solve the problems of "attribute mismatch", "field mismatch" and "stage mismatch" that exist in the financial supply of traditional financial institutions, thereby helping enterprises to actively deleverage, stabilize their financial conditions and reduce the credit risk of banks [10].

2.1.3. The Two-Way Effect View

Research shows that digital finance has a complex two-way impact on the business of commercial banks and that this impact is closely related to the term of interest rates. Guo and Shen (2015) assessed the level of risk-bearing through the capital-to-asset ratio and found that, although early Internet finance could reduce the operating costs of banks in the initial stage, in the long run it may increase the risk of commercial banks because of narrowed interest margins and increased financing costs, so that a U-shaped relationship appears between digital finance and the risk of commercial banks [11]. Liu (2016) used the Z-score to quantify risk-taking and combined the non-performing loan ratio for a robustness test; through the pooled, fixed and random effects methods of static panel models, the study analyzed the influence process of Internet finance: on the one hand, through the development of Internet finance, commercial banks have broadened the channels for obtaining risk data and improved their risk management means, thereby enhancing their risk management capabilities and reducing information asymmetry and bankruptcy risk; on the other hand, through its advantages in information acquisition, channel utilization, customer service and pricing strategy, Internet finance has eroded the profits of commercial banks and reduced their returns, prompting banks to adopt higher-risk strategies and thus increasing their risk-bearing capacity [12]. The studies of Fu, Pei and Sun (2023) and of Yang and Su (2023) both point out that there is an "inverted U-shaped" non-linear relationship between the development of digital finance and credit risk [13, 14].

2.2. Foreign Literature Review

Regarding the impact of digital finance on the risk-bearing capacity of commercial banks, there are also two views abroad. Liao (2018) took the loan loss provision ratio as the explained variable and the network index as the explanatory variable, established a regression model and concluded that, in the early stage of the development of Internet finance, the loan loss provisions of commercial banks increase, which in turn leads to an increase in their risk-taking; this belongs to the risk-increasing view [15]. Berg (2020), however, believed that the combination of technology and finance can reduce information asymmetry in credit and diminish the adverse selection and moral hazard of financial institutions such as banks [16]. Malhotra and Singh (2009), through an empirical analysis of the Indian banking industry, concluded that online banking has brought great negative effects to banks; that is, the continuous development of Internet finance also helps banks to reduce their own credit risk, which is the "risk-reducing view" [17].

It can be seen from this that, in the process of the development of digital finance, domestic and foreign scholars disagree on the question of what impact digital finance has on the risk-taking of commercial banks, and there are also different views on how to measure the risk-taking of

commercial banks. However, most measurement methods use the Peking University Digital Financial Inclusion Index of Guo et al. (2020) to measure the development of digital finance [18]. In the baseline regression, the existing literature mostly uses the two-way fixed effects model, which can better control time effects and individual effects; in the robustness test, most scholars choose three methods: replacing the explained variable, replacing the explanatory variable and the instrumental variable method. In terms of conclusions, the view accepted by more scholars is that the development of digital finance can help commercial banks to reduce their risk-taking. At the same time, many domestic scholars have put forward the difficulties and problems encountered by China's commercial banks in reducing risk-taking in the course of studying the impact mechanism, and have provided many suggestions for China's commercial banks to reduce risk-taking, which has far-reaching reference significance for the continuous development of digital finance in China.

3. Related Concepts and Theoretical Analysis

3.1. Related Concepts

3.1.1. Digital Finance

Huang and Huang (2018) pointed out that digital finance, based on digital technologies such as the Internet, big data, blockchain and artificial intelligence, has innovated and optimized traditional financial services [19]. Digital finance covers many fields, including remote electronic payment, online banking, financial service outsourcing, online lending, online insurance and online funds. It not only provides financial solutions for emerging enterprises through modern technology, but also enables traditional financial institutions to improve and innovate their services through digital technology. The development goal of digital finance is to use epoch-making technology to promote the digitalization of the financial industry and to advance the digital transformation of all levels of the country. By promoting the development of the fintech industry and enhancing the integration of financial services with the real economy, it can exert a positive impact on the country's future economic growth.

3.1.2. Risk-Taking of Commercial Banks

The risk-taking of commercial banks describes the maximum capacity of commercial banks to actively accept and cope with the consequences of risks when facing them. The lower the risk-taking capacity of a commercial bank, the smaller the risk it faces. In addition, bank risk can be divided into active risk and passive risk. Active risk is usually caused by external uncontrollable factors that affect the laxity of bank lending and thus increase the potential risk of banks, although these risks have not yet actually occurred; passive risk occurs after a bank has already issued a loan, when the borrower defaults as a result of the impact of external factors. The latter kind of risk has actually occurred and can reflect the actual risk-taking level of a bank more objectively. Therefore, this paper mainly discusses the passive risk of banks.

3.2. Theoretical Analysis

Digital finance is a new form of financial service that organically combines modern information technology with traditional finance, and it helps commercial banks to reduce risk.

3.2.1. The Development of Digital Finance Can Improve the Credit Risk Control Level of Commercial Banks

The development of digital finance is driving the transformation and upgrading of commercial banks, especially in the field of credit risk control. Traditional loan approval and risk assessment processes have many defects, such as information asymmetry, strong subjectivity of assessment standards and inefficient operational processes. With the wide application of emerging technologies such as big data, artificial intelligence and cloud computing, commercial banks are building more intelligent and accurate credit assessment systems.

Through data mining and machine learning algorithms, banks can integrate multi-source heterogeneous data and comprehensively analyze borrowers' credit status, repayment ability and risk propensity. This assessment model based on big data can not only overcome the subjective bias of manual assessment, but also capture more subtle risk signals. At the same time, the intelligent approval process can realize automated decision-making, greatly improving efficiency and accuracy.

In addition, blockchain technology also plays an important role in fraud prevention and data privacy protection. Through encryption and distributed ledgers, banks can securely synchronize borrowers' information and reduce information asymmetry.

The development of digital finance provides commercial banks with more advanced risk management tools, which helps to improve risk identification and prevention capabilities, fundamentally reduce the non-performing loan ratio and promote the sound operation of the banking industry. Commercial banks should seize this historical opportunity, carry out comprehensive digital transformation and continuously optimize their risk management.

3.2.2. The Development of Digital Finance Helps to Alleviate the Information Asymmetry Between Commercial Banks and Individual Customers

When micro, small and medium-sized enterprises or some low-income groups want to borrow, the lack of complete credit information or of collateral that meets loan requirements gives rise to many situations in which financing is difficult and the loan amount is hard to obtain as needed. Yet this group is precisely the target group of inclusive finance, and the development of digital finance can provide it with a more relaxed and complete environment; at this point, the continuous increase in bank business also helps to improve the profitability of banks and reduce risk. In addition, with the progress of digital information technology, after issuing loans, commercial banks can use new technologies to monitor the data of borrowers; once it is found that a borrower is at risk of default, the commercial bank can promptly assess how to deal with it and effectively reduce its level of risk-taking. Moreover, the development of digital finance can also make commercial banks more sensitive to changes in the market environment and macroeconomic policies; when the market environment is poor and the economy is declining, commercial banks can appropriately adjust their lending standards to reduce default risk.

3.2.3. The Development of Digital Finance Helps to Improve the Profitability of Commercial Banks

In the process of digital transformation, commercial banks use intelligent and network-based means to improve operating efficiency. For example, through mobile payment

and electronic signing, they reduce manual service time and improve business processing efficiency, service coverage and service quality, which can increase their popularity among customers, further expand the audience and increase business scale, thereby achieving growth in operating income. In addition, the development of digital finance enables commercial banks to operate online, expand online services and optimize business processes; it reduces the number of branches of commercial banks so as to save resources and manpower; and the progress of information technology reduces business processing errors and lowers operating costs, further improving the profitability of commercial banks.

Summarizing the above, with the continuous progress of digital finance, commercial banks can enhance their risk management capabilities, reduce information asymmetry with customers, improve profitability and lower the non-performing loan ratio, thereby reducing their risk-taking. On this basis, this paper proposes the following research hypothesis:

H1: The development of digital finance helps to reduce the risk-taking of commercial banks.

4. Empirical Analysis

4.1. Data Sources

This paper selects the panel data of 38 Chinese listed banks from 2011 to 2022 as the research sample. The choice of listed banks as the research object is mainly based on three considerations. First, the annual data of listed banks are representative. According to the Analysis Report on China's Listed Banks 2023, by the end of 2022 the asset scale of listed banks had reached 265 trillion yuan, accounting for about 84% of the total assets of China's commercial banks; with a large proportion and a large capital scale, they can largely represent commercial banks. Second, the reliability of the sample data: as listed banks, the disclosure of their annual report data is subject to the review and supervision of relevant regulatory departments such as the China Banking and Insurance Regulatory Commission or of market investors, so the authenticity and completeness of the sample data are guaranteed. In addition, compared with other unlisted banks, the annual data of listed commercial banks are easier to collect and the data are complete. Since the currently published Peking University Digital Financial Inclusion Index covers the period from 2011 to 2022, this research interval is selected for a better study. The main variable data of the commercial banks in this paper all come from the CSMAR (Guotai'an) database, and a small amount of missing data is obtained from the Choice financial terminal and the annual reports of commercial banks.

4.2. Variable Selection

4.2.1. Explained Variable

In this study, the explained variable selected is the risk-taking of commercial banks. At present, the indicators commonly used to measure this variable include the non-performing loan ratio, the Z-score and the ratio of risk-weighted assets to total assets. Although the Z-score is an effective tool for assessing the bankruptcy risk of banks, it does not comprehensively reflect the overall operating risk of commercial banks, so its value in measuring actual risk-taking is limited; the risk-weighted asset ratio can measure the risk-taking of commercial banks relatively comprehensively, but because some banks do not fully disclose this indicator, data collection is difficult, so it is not adopted; the non-performing loan ratio is a direct manifestation of the credit risk of commercial banks, and a rise in the non-performing loan ratio means that commercial banks face greater risk. For the above reasons, this paper chooses the non-performing loan ratio as the main indicator for measuring the risk-taking of commercial banks.

4.2.2. Explanatory Variable

This study uses the total Peking University Digital Financial Inclusion Index (Index) as the main explanatory variable [18]. This index is a comprehensive indicator for measuring the development level of digital inclusive finance in a country or region; it evaluates the penetration rate and accessibility of digital financial services in meeting public financial needs by analyzing indicators in multiple dimensions. The Peking University Digital Financial Inclusion Index (2011–2022) used in this paper was compiled by the Institute of Digital Finance of Peking University on the basis of the big data user information of Ant Financial, covering 31 provinces (autonomous regions), 337 cities and more than 1,700 county-level administrative units in China. This index is further divided into three main components, namely coverage breadth, usage depth and support degree, together with their respective sub-industries or business indicators, comprehensively reflecting the development trend of digital finance in China. In view of the comprehensiveness and integrity of the Peking University Digital Financial Inclusion Index, this paper chooses only this indicator as the core explanatory variable.

4.2.3. Control Variables

This paper selects the following five indicators as control variables: the total assets of commercial banks represent the operating scale of commercial banks, but because the total assets of commercial banks are too large, the logarithm is taken to make the data smoother (Asset); the provision coverage ratio (PCR) can reflect the ability of commercial banks to guard against loan risk; the capital risk asset ratio (CAR) can reflect the extent to which commercial banks can rely on their own capital to absorb losses when facing risks; the net interest margin (NIM) indicates the profitability of commercial banks; and the cost-to-income ratio (CIR) reflects the management ability of commercial banks.

4.2.4. Instrumental Variable

Because digital finance develops to different degrees in different regions, that is, the digital financial inclusion index is affected by the local level of information technology, and the Internet penetration rate can indicate the degree of digital development of a region — since the in-depth development of digital financial services depends on the information coverage capacity of each region — the digital financial inclusion index is correlated to some extent with the Internet penetration rate. To solve the potential endogeneity problem, this paper selects the Internet penetration rate as the instrumental variable of the digital financial inclusion index of each prefecture-level city, denoted as Index_iv.

Table 1. Variable Selection and Definition

Variable type	Variable name	Symbol	Definition
Explained variable	Risk-taking	Risk taking	Non-performing loan ratio
Explanatory variable	Digital financial inclusion index	Index	Calculated by Peking University, covering the coverage breadth, usage depth and digitalization degree of digital finance
Control variable	Bank size	Asset	Logarithm of total bank assets
Control variable	Provision coverage ratio	PCR	Loan loss provisions / non-performing loans
Control variable	Capital risk asset ratio	CAR	Net capital / risk-weighted assets
Control variable	Net interest margin	NIM	Net interest income / average interest-earning assets
Control variable	Cost-to-income ratio	CIR	Operating expenses / operating income
Instrumental variable	Internet penetration rate	Index_iv	Internet broadband subscribers per 100 people

4.3. Model Specification

When analyzing the panel data of the sample commercial banks, this paper refers to the research results of He (2022), Liu (2022) and others [6, 8]. Because the data of the same bank in different years may be autocorrelated, it is necessary to control the individual and time dimensions. Therefore, this study adopts the two-way fixed effects model, a method widely used in panel data analysis. By controlling fixed effects, this model allows the simultaneous analysis of the interactive influence between different time points and different individuals, aiming to accurately estimate the causal relationship in panel data and to effectively avoid the bias caused by omitted variables and endogeneity problems. The baseline regression model established in this paper is as follows:

$$Risktaking_{i,t} = \alpha + \beta Index_{i,t} + \gamma Controls + \delta_i + \theta_t + \varepsilon_{i,t} \quad (1)$$

In the above equation, $Risktaking_{i,t}$ is the explained variable, representing the risk-taking of bank i in period t; $Index_{i,t}$ represents the digital financial inclusion index of bank i in period t; and Controls represents a series of control variables of commercial banks. The individual and time fixed effects of commercial banks are denoted by δ_i and θ_t respectively, and $\varepsilon_{i,t}$ represents the unobservable random disturbance term. The explanatory variable, the Peking University Digital Financial Inclusion Index, is measured by the index of the prefecture-level city in which each sample commercial bank is registered.

This paper first uses the Hausman test to test the model. When P is greater than 0.05, the random effects model is adopted; when P is less than 0.05, the null hypothesis is rejected and the fixed effects model is adopted. The P value of the test in this paper is less than 0.05, which proves the feasibility of the selected model.

In addition, as regards the variables used in the study, when multiple variables are involved in the multiple linear regression, the various indicators of commercial banks may affect each other and show autocorrelation because the research data all come from commercial banks, so a multicollinearity test should be carried out first and then the baseline regression of the two-way fixed effects model. This study uses the variance inflation factor (VIF) to evaluate the degree of collinearity in the data. The VIF measures the ratio of the variance of the regression coefficient estimate to the variance between independent variables when a non-linear association exists between the independent variables; when its mean value is less than 1.5, there is no multicollinearity. After the VIF test in this study, the mean value is 1.37, which is less than 1.5 according to the collinearity test.

Table 2. Collinearity Test

Variable	VIF	1/VIF
index	1.850	0.542
nim	1.480	0.676
cir	1.360	0.734
asset	1.190	0.841
pcr	1.170	0.854
car	1.160	0.863
Mean VIF	1.370	—

4.4. Descriptive Statistics

To exclude the influence of outliers, this paper winsorizes the continuous variables at the 1% and 99% levels; the processed data are shown in Table 3. Table 3 reports the descriptive statistics of the variables studied in the sample data. Although the non-performing loan ratio, which measures the level of risk-taking, fluctuates less than the other data, the maximum and minimum values still reveal certain differences in the risk-taking of different commercial banks; the mean value of the Peking University Digital Financial Inclusion Index is 236.2, its minimum value is 73.48 and its maximum value is 351.5. The gap between the maximum and the minimum is large and the standard deviation is also large, which shows that the development of digital finance in different regions of China differs greatly. As for the total asset scale of commercial banks, since all the banks selected in this paper are listed banks with sufficient financing funds and this variable has been logarithmized, the standard deviation is small, although there are still certain differences among different commercial banks. Judged by their mean values, both the provision coverage ratio and the capital risk asset ratio have reached the operating standards for commercial banks required by the Basel Accords, namely a capital risk asset ratio above 8% and a provision coverage ratio of no less than 150%, and thus generally meet the regulatory requirements. The mean values of the net interest margin and the cost-to-income ratio, which measure profitability, also meet the standards well, and the data are relatively stable.

Table 3. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Risk taking	1.339	0.451	0.260	2.470
Index	236.2	80.08	73.48	351.5
Asset	12.00	0.787	10.75	13.52
PCR	272.8	101.6	139.4	563.5
CAR	13.45	1.655	9.880	18.45
NIM	2.309	0.391	1.540	3.260
CIR	0.457	0.147	0.119	0.776

4.5. Analysis of Empirical Results

4.5.1. Baseline Regression Results

Table 4 shows the regression results of the individual fixed effects and the two-way fixed effects. Columns (1) and (2) report the results of the individual fixed effects regression, in which, at the 1% significance level, each one-unit increase in the digital financial inclusion index significantly reduces the risk-taking of commercial banks by 0.004 units. Columns (3) and (4) present the results of the two-way fixed effects regression. Before the control variables are introduced, an increase in the digital financial inclusion index significantly reduces the non-performing loan ratio of the sample commercial banks at the 5% significance level; that is, for each one-unit increase, the non-performing loan ratio decreases by 0.0094 units. In column (4), after the control variables are introduced, the results show that the digital financial inclusion index has a significant impact on the non-performing loan ratio of commercial banks, declining significantly at the 1% significance level; for each one-unit increase in the digital financial inclusion index, the non-performing loan ratio decreases by 0.0039 units. This further verifies the positive impact of the development of digital finance on reducing the risk-taking of commercial banks. In addition, among the control variables, the provision coverage ratio and the capital risk asset ratio can also significantly reduce the risk-taking of commercial banks at the 1% level, and the net interest margin can significantly reduce the risk-taking of commercial banks at the 5% level, which is consistent with the findings of the existing literature. An increase in the provision coverage ratio means that commercial banks have made more adequate provisions for loan losses and hold more sufficient funds to resist risk; increases in the capital risk asset ratio and the net interest margin give commercial banks stronger profitability, and the growth of profits also enables commercial banks to resist risk. R2 is 0.6969 and 0.9173 in the two cases respectively, indicating that the sample data fit the two-way fixed effects model well. In summary, on the whole, the continuous development of digital finance can reduce the risk-taking of commercial banks, and H1 is therefore verified.

Table 4. Baseline Regression Results

Variable	Individual fixed effects		Two-way fixed effects	
	(1)	(2)	(3)	(4)
index	-0.004*** (0.000)	-0.004*** (0.000)	-0.0094** (0.0039)	-0.0039*** (0.0013)
asset		-0.024 (0.105)		-0.0191 (0.1232)
pcr		-0.003*** (0.000)		-0.0031*** (0.0001)
car		-0.024*** (0.006)		-0.0211*** (0.0077)
nim		-0.065** (0.030)		-0.0741** (0.0360)
cir		0.073 (0.061)		0.0706 (0.0550)
_cons	2.422*** (0.098)	3.899*** (1.381)	3.5526*** (0.9264)	3.7547** (1.6093)
Time fixed effects	No	No	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes
Observations	456	456	456	456
R^2	0.5843	0.9152	0.6969	0.9173
F	15.4260	103.3500	5.7176	130.360

Note: standard errors are reported in parentheses; ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

4.5.2. Robustness Test

To further verify the reliability of the argument of this paper, a robustness test is carried out. Referring to the relevant literature, this paper uses the Internet penetration rate as the instrumental variable of the digital financial inclusion index (Index_iv) [20]. At the same time, this paper applies the two-stage least squares (2SLS) method to ensure the validity of the instrumental variable. Since the sample size of the selected instrumental variable is consistent with that of the core explanatory variable, appropriate identification is achieved, which satisfies the condition for the two-stage least squares method to test the feasibility of the instrumental variable.

Column (1) of Table 5 shows the regression results of the first stage of the two-stage least squares method, in which the Internet penetration rate significantly raises the digital financial inclusion index of the corresponding region at the 1% significance level; for each one-unit increase, the digital financial inclusion index increases by 3.0032 units. This shows that the Internet penetration rate is an effective instrumental variable. With the development of technology and the popularization of the Internet, people's mastery of network technology and their frequency of use are increasing, which promotes the improvement of the digitalization level. Correspondingly, the coverage and the service objects of digital inclusive financial services are also expanding and the types of services are increasing, which helps commercial banks to expand their business scope, improve business processing efficiency and service quality, form a virtuous circle, reduce operating costs, improve profitability and ultimately reduce the risk-taking of banks.

As shown in column (2) of Table 5, the development of digital finance significantly reduces the risk-taking of commercial banks at the 1% significance level; for each one-unit increase in the digital financial inclusion index, the risk-taking of commercial banks decreases by 0.0045 units. The

regression results of the two-stage least squares method verify the validity of the baseline regression. In addition, a weak instrumental variable test is carried out on the instrumental variable, and its F value is 82.4, far higher than 10, which rejects the hypothesis of a weak instrumental variable. This further proves the reliability of the instrumental variable method and once again confirms the H1 hypothesis of this paper: the development of digital finance helps to reduce the risk-taking of commercial banks.

Table 5. Robustness Test Results

Variable	2SLS first stage	2SLS second stage
	Index	Risk taking
index		-0.0045*** (0.0003)
Index_iv	3.0032*** (0.3382)	
asset	-23.8507*** (5.6066)	-0.0134 (0.0108)
pcr	-0.0083 (0.0313)	-0.0032*** (0.0001)
car	8.5533*** (1.4728)	-0.0122*** (0.0042)
nim	-63.6942*** (7.7111)	-0.0425 (0.0319)
cir	-150.8565*** (17.1691)	0.0273 (0.0772)
_cons	436.2741*** (59.1481)	3.6855*** (0.2068)
Observations	456	456
R^2	0.5520	0.8988

Note: standard errors are reported in parentheses; ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

5. Countermeasures and Suggestions

Based on the existing literature and the realistic background, this paper puts forward the following suggestions at three levels for the government and commercial banks in the context of today's society:

5.1. Government Level

The government should vigorously support the development of technologies related to digital finance, subsidize and incentivize relevant scientific and technological institutions and commercial banks through fiscal policy, improve the construction of digital financial infrastructure, stimulate the creative and innovative vitality of digital finance and provide a guarantee for commercial banks on the road to deep integration with digital finance. At the same time, the mass media should be used to publicize to ordinary people the arrival of digital finance and its convenience and universality, so that they recognize the importance and accessibility of digital finance, user demand is stimulated, and commercial banks gain more business opportunities on the user-demand side.

5.2. Financial Regulation Level

Relevant financial regulatory agencies should strengthen the supervision of commercial banks in digital transformation and innovative development. Regulators should supervise their major projects: in the process of continuous technological reform and development of commercial banks, and with the continuous progress of information technology, problems such as the leakage of users' private data, failures of the data analysis and operation systems of commercial banks and the digital divide will arise, causing negative impacts on users' information security, users' asset security and the smooth operation of the financial system. Regulators should also keep pace with the development of digital finance, digitally upgrade the regulatory technology of financial regulatory agencies, detect improper operations and unexpected problems of commercial banks in a timely manner, and escort commercial banks on the road to digital transformation.

5.3. Commercial Bank Level

Commercial banks should seize the opportunities of the times, actively seek cooperation with emerging Internet technology companies, and develop operating systems, analysis systems and management systems suitable for their own banks in order to promote digital transformation and improve their profitability. The traditional business mode of commercial banks is passive service, requiring users to go to the branches of commercial banks to handle deposit and loan business by themselves; in the context of digital finance, commercial banks can retain a certain number of branches to facilitate users' cash deposits and withdrawals while vigorously developing online business, optimizing business processes, improving work efficiency and facilitating ordinary people, which constitutes active service. In the case of active service, commercial banks should regard themselves as the "party B", earnestly listen to the various needs of users and provide differentiated and all-round services for different customers, so as to better cater to users' needs and expand a wider business scope; at the same time, they should humbly accept users' service feedback, analyze their own strengths and weaknesses, give play to their unique advantages and form their own service characteristics.

For unlisted small and medium-sized banks, the government should increase support, relax their financing policies, reduce their financing costs and facilitate their development. At the same time, the government should act as the "leader", helping small and medium-sized banks to cooperate with relevant scientific and technological institutions and to keep up with the pace of digital transformation in the new era so as to reduce their risk-taking.

6. Conclusions

This paper examines the impact of the development of digital finance on the risk-taking of commercial banks. Based on the theoretical analysis of three directions — the credit risk control level of commercial banks, the information asymmetry between commercial banks and their customers, and the profitability of commercial banks — it presents the combined impact of the digital financial inclusion index and the Internet penetration rate on the risk-taking of commercial banks. Using panel data from 2011 to 2022, this paper verifies that the data are suitable for the two-way fixed effects model and do not suffer from multicollinearity, carries out the baseline regression of the two-way fixed effects model and uses the instrumental variable method for the robustness test, and finally draws the conclusion: the continuous development of digital finance can reduce the risk-taking of commercial banks.

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