Research on the Regional Impact of Digital Inclusive Finance Development on the Profitability of Commercial Banks

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Abstract. Based on panel data from 42 listed commercial banks in China from 2011 to 2023, this paper empirically analyzes the impact of digital finance on the profitability of commercial banks using a two-way fixed effects model. With return on total assets (ROA) as the explained variable, the digital inclusive finance index as the core explanatory variable, and controlling for factors such as capital adequacy ratio, bank size, loan-to-deposit ratio and non-performing loan ratio. The study found that the development of digital finance has a significant negative impact on the profitability of commercial banks. For every 1-unit increase in the digital inclusive finance index, ROA drops by approximately 0.17 percent, and this effect is particularly significant in public banks and the eastern region. The capital adequacy ratio and the loan-to-deposit ratio have a positive effect on profitability, while the non-performing loan ratio significantly suppresses profitability. Heterogeneity analysis shows that state-owned banks are less sensitive to digital financial shocks, while the impact in the central and western regions fails to pass the significance test due to insufficient penetration of inclusive finance. The robustness test verified the reliability of the conclusion by replacing the explained variable (ROE) with the lag model. Based on this, it is recommended that commercial banks deepen digital transformation to optimize operational efficiency, improve capital replenishment and risk management mechanisms, and adopt differentiated strategies to address the challenges of regional and attribute heterogeneity.

Keywords: Digital finance, Profitability of commercial banks, Digital inclusive finance index, Fixed-effect model, Heterogeneity analysis

1 Introduction

Digital finance, as the product of the deep integration of digital technology and financial services, has the dual attributes of technological innovation and financial inclusion, and has gradually evolved into a variety of business forms including payment and settlement, credit financing, insurance services, and securities trading. With the deep application of technologies such as blockchain, artificial intelligence and big data, digital finance has significantly promoted the inclusiveness and accessibility of finan-

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cial services by reconfiguring transaction processes, reducing operating costs and improving the efficiency of resource allocation. However, this transformation also poses a structural impact on the profit model of traditional commercial banks: trends such as digital payment platforms diverting bank deposits, Internet credit squeezing the spread between deposits and loans, and smart investment advisors replacing traditional wealth management services are forcing commercial banks to accelerate digital transformation to cope with the challenge of shrinking profit margins.

As the core of China's financial system and a key hub for the transmission of monetary policy, the profitability of commercial banks is not only related to their market competitiveness, but also directly affects the stability of the financial system and the financing efficiency of the real economy. Especially in the context of the accelerated penetration of digital finance and the deepening of financial supply-side structural reform, systematically analyzing the mechanism of digital finance's effect on the profitability of commercial banks is not only a theoretical proposition for optimizing the allocation of financial resources, but also a practical need for preventing systemic risks and improving the financial regulatory framework. This paper focuses on the competitive and cooperative relationship between digital finance and traditional banks, aiming to reveal through empirical tests the specific paths and heterogeneous effects of digital finance on bank profitability, and to provide a scientific basis for commercial banks to formulate differentiated transformation strategies and for regulatory authorities to build an innovative and inclusive governance system.

2 Literature Review

The impact of digital finance on the profitability of commercial banks shows a significant "double-edged sword" effect. Wang Yu and Kan Bo (2021) pointed out that digital financial tools such as third-party mobile payment and P2P lending have eroded the traditional deposit and loan spread of banks, leading to a decline in profitability, and the impact on city commercial banks is stronger than that on large[1] state-owned banks. The empirical results of Hu Ling et al. (2022) show that digital finance forces banks to shift to off-balance sheet business by squeezing the revenue space of on-balance sheet business, but the profit stability of off-balance sheet business is lower, intensifying the risk[2] of profit volatility. Gao Jieqiong (2023) found through a fixed-effect model that digital finance directly compresses commercial banks' net interest income[3] by reducing deposit size, loan interest rates, and the proportion of deposit liabilities.

Some scholars have emphasized the positive enabling role of digital finance. Wang Bo (2024) argues that thespillover effect of technology can enable banks to optimize customer identification, improve operational efficiency and expand the scenarios of inclusive finance, providing opportunities[4] for the transformation of profit structure. Huang Zhuo and Wang Pingping (2023) pointed out that digital finance, by serving long-tail customers and promoting the development of inclusive finance, helps banks expand new business scenarios and provides an[5] opportunity for the transformation of profit models.

To sum up, this paper selects relevant financial data of 42 listed commercial banks in China from 2011 to 2023 and the Digital inclusive finance index of Peking University to systematically analyze the impact and heterogeneity of digital finance on the profitability of commercial banks. The study finds that digital finance has a significant negative impact on the profitability of commercial banks. The development of digital finance has led to a decline in the net profit of commercial banks. The impact of digital finance on the profitability of banks of different attributes and in different regions varies. Public banks and banks in the eastern region are significantly negatively affected by the digital finance index.

3 Theoretical Analysis and Research Hypotheses

Based on the theory of financial disintermediation, digital inclusive finance reconstructs the competitive landscape of financial markets by reducing transaction costs and information asymmetry. Specifically, third-party payment platforms divert commercial banks' payment and settlement business by providing efficient and convenient services, weakening their fee income; Internet credit institutions use big data risk control technology to provide low-cost credit to long-tail customers, narrowing the spread between deposits and loans of traditional banks. In addition, emerging businesses such as smart investment advisors and Internet finance have further replaced the intermediary income of banks, forcing commercial banks to offset profit losses by expanding off-balance sheet business. However, the high volatility and regulatory uncertainty of off-balance sheet business may increase the risk of profit. Based on the above, Hypothesis 1 is proposed in this paper.

H1: The development of digital inclusive finance has a significant negative impact on the profitability of commercial banks.

According to the theory of dynamic capabilities, enterprises need to integrate and restructure internal and external resources to cope with environmental changes, and dynamic capabilities determine their efficiency in adapting to technological shocks. The capital adequacy ratio (CAR) and loan-to-deposit ratio (LDR) of commercial banks, as key proxy variables of dynamic capabilities, can effectively mitigate the negative impact of digital inclusive finance. With the advantage of capital buffering, high CAR banks, on the one hand, increase their independent investment in technologies such as intelligent risk control and blockchain, reduce external dependence and improve operational efficiency; On the other hand, they dynamically adjust their business structure and expand into high value-added areas such as wealth management to hedge against the narrowing risk of traditional spreads. At the same time, high LDR banks have reduced funding costs and stabilized net interest margins by optimizing balance sheet allocation, using big data to enhance differentiated pricing capabilities for loans, and reducing reliance on high-cost retail deposits. As a result, banks with higher CAR and LDR have stronger dynamic resource integration capabilities and can more effectively transform the technology spillover of digital finance into a competitive advantage, significantly weakening its inhibitory effect on profitability. Based on that, Hypothesis 2 is proposed in this paper.

H2: Capital adequacy ratio and loan-to-deposit ratio positively regulate the negative impact of digital inclusive finance. That is, the higher the capital adequacy ratio and the loan-to-deposit ratio of a bank, the less its profitability is affected by the negative impact of digital finance

State-owned banks, thanks to policy-based financial functions such as targeted support for inclusive finance and credit for infrastructure construction, enjoy implicit credit backing and low-cost capital advantages. They can lock in quality customers through government-enterprise cooperation projects, such as "bank-tax interaction", to reduce the pressure of deposit diversion; At the same time, it can rely on policy tools such as central bank re-lending to stabilize interest spread income and weaken the competitive substitution effect of digital finance. Public banks (city commercial banks, rural commercial banks) are more dependent on local deposit and loan business due to the pressure of local operating licenses and market competition. Digital inclusive finance breaks through geographical limitations through Internet platforms and intensifies the competition for long-tail customers (such as Alipay's "Jiebei" diverting the demand for micro and small loans), leading to a contraction in deposit size and a narrowing of interest spreads. In addition, public banks have a weak ability to invest in technology, and the marginal cost of digital transformation is high, making it easy to fall into the "technology catch-up dilemma". Based on the above mechanisms, this paper proposes Hypothesis 3:

H3: There is significant attribute heterogeneity in the impact of digital inclusive finance on the profitability of commercial banks. And the impact on state-owned banks is significantly less than that on public banks.

As the forefront of China's digital finance development, the eastern region has a high proportion of investment in digital finance technology, but the payback period is long, and short-term costs squeeze commercial banks' profits, falling into an "input-loss" cycle. In the competition, Internet giants gather with private banks; Retail credit, due to low platform prices, Eastern banks have reduced risk control, and both spreads and asset quality have declined. In terms of technical risks, complex architectures (distributed systems, etc.) cause frequent failures (such as blockchain clearing disruptions) and data security incidents, and repair costs are much higher than those in the Midwest, raising operating costs. In terms of regulation, the eastern region, as a frontier of innovation, faces stricter capital provisions, business concentration restrictions, and increased costs for compliance transformation. Under the influence of these factors, banks in the east should be more affected by the negative impact of digital finance than those in the west. Based on this, Hypothesis 4 is proposed in this paper.

H4: There is significant regional heterogeneity in the impact of digital inclusive finance on profitability. The impact on banks in the eastern region is significantly higher than that on banks in the central and western regions.

4 Research Design

4.1 Data Sources

This paper takes 42 listed commercial banks in China from 2011 to 2023 as samples. The bank financial data and stock indicators, etc. are sourced from the CSMAR and Wind databases. The digital inclusive finance index is derived from the provincial digital inclusive finance index compiled by Guo Feng et[6] al. from the Digital Finance Research Center of Peking University. Some missing values are filled in by interpolation method. To ensure the reliability of the sample selection, the data are processed as follows: logarithm of the variable of total assets of banks; Exclude samples with severe data deficiency; Undertail all consecutive variables by 1 percent or less. After precisely matching the enterprise database, 6,492 observations were finally obtained.

4.2 Variable Settings

4.2.1 Explained Variable.

Return on assets (ROA) is an important indicator for measuring corporate profitability. In this paper, Hu Yi et[7] al. And Xing Tiancai et[8] al. Selected ROA as an indicator for measuring the profitability of commercial banks and return on equity (ROE) as an auxiliary indicator for robustness tests. ROA (Net profit/average total assets) directly reflects a bank's ability to generate profits from total assets, emphasizing management's control over asset allocation and operational efficiency[9]. In digital finance research, ROA is often used to assess the direct impact[10] of technology input on asset returns. ROE (Net profit/net assets) represents the return on shareholders' equity. When analyzing the impact of inclusive finance, ROE can reveal the transmission path[11] of digital finance to earnings through capital restructuring, such as increasing debt or compressing equity.

4.2.2 Explanatory Variables and Control Variables.

The Digital Inclusive Finance Index (DiF), which reflects the overall development level of digital financial services in a region, is used to capture the direct impact of digital technologies such as mobile payments and big data risk control on the profitability of commercial banks, particularly through competitive effects, cost structure and business model transformation[12]. This paper selects the Digital inclusive finance index as the core explanatory variable to analyze its impact on the profitability of commercial banks.

The capital adequacy ratio (CAR) controls the differences in the capital strength of banks and avoids the estimation bias of profitability due to different capital levels. Bank size (LnSize, logarithm of total assets) controls the impact of scale effects on earnings and distinguishes the heterogeneous effects[13] of digital finance on banks of different sizes. The loan-to-deposit ratio (LDR) controls the structure of a bank's balance sheet, eliminating the direct interference[14] of capital allocation efficiency on earnings. The non-performing loan ratio (NPL) controls the differences in asset quality

and avoids the confusion[15] of risk exposure to the effects of digital finance. The definitions of the above variables are shown in Table 1.

Table 1. Definitions of Key variables.

Variable types	Variable name	Variable symbol	Definition and Measurement
Explained variable	Return on total assets	ROA	Net profit/average total assets, a measure of how efficiently a bank uses total assets to generate profits
	Return on net assets	ROE	Net profit/net assets, measuring return on shareholders' equity, affected by leverage
Core explanatory variable	Digital inclusive finance index	DiF	Peking University's provincial digital inclusive finance index covers three dimensions: breadth of coverage, depth of use, and degree of digitalization
Control variables	Capital adequacy ratio	CAR	Net capital/risk-weighted assets, a measure of a bank's risk resilience
	Bank size	LnSize	The natural logarithm of total assets reflects a bank's economies of scale or diseconomies of scale effect
	Loan-to-deposit ratio	LDR	Total loans/total deposits, measuring the efficiency of capital allocation
	Non-performing loan ratio	NPL	Non-performing loan balance/total loan balance reflecting asset quality risk

4.3 Model Building

Based on the unbalanced panel data of 42 listed commercial banks in China from 2011 to 2023, this paper examines the impact of digital finance on the profitability resilience of commercial banks using the Two-way fixed effect model (Two-way FE). The specific model is set as follows:

$$ROA_{it} = \beta_0 + \beta_1 \mathrm{DiF} + \beta_2 \mathrm{CAR}_{it} + \beta_3 \mathrm{LnSize}_{it} + \beta_4 \mathrm{LDR}_{it} + \beta_5 \mathrm{NPL}_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

Where, ROA is the return on total assets; DiF is the digital inclusive finance index; The capital adequacy ratio CAR is the capital adequacy ratio, LnSize is the bank size (logarithm), LDR is the loan-to-deposit ratio, and NPL is the non-performing loan ratio; β0 is a constant term; β1, β2, β,3 β,4 β are5 the coefficients of each variable

respectively. μi andt γ respectively represent the enterprise fixed effect and the year fixed effect, which, on the basis of controlling the inherent differences among individual enterprises, absorb the common shock that changes over time, thus ensuring that β1 can accurately capture the causal impact of the data trading platform on enterprise resilience;ε_{it} Represent the error term.

5 Empirical Analysis

5.1 Descriptive Statistics

Table 2. Descriptive statistical results of the main variables.

	Return on total assets	Digital Inclusive Finance Index	Capital adequacy ratio	Total asset size (logarithmic)	Loan-to-deposit ratio	Non-performing loan ratio
count	540	540	540	540	540	540
mean	0.9622	290.6257	13.5055	9.2139	73.3703	1.2614
std	0.2514	117.3463	1.662	1.7545	14.5514	0.4226
min	0.4413	18.47	10.4112	6.363	33.1217	0.3839
25%	0.7788	206.2275	12.3275	7.7378	65.0975	0.9375
50%	0.9358	297.6882	13.32	8.9646	72.1353	1.25
75%	1.1123	388.2098	14.4475	10.6479	81.3454	1.52
max	1.647	473.8341	18.4383	12.7466	109.791	2.4283

As shown in Table 2 above, the descriptive statistics of the main variables are presented. The sample data covers 540 observations from 42 commercial banks from 2011 to 2023. The statistical characteristics of the core variables are as follows: The average return on total assets (ROA) is 0.96%, and the standard deviation is 0.25%, reflecting that the overall profitability of commercial banks is relatively stable, but there are certain differences among individuals. The average value of the Digital Inclusive Finance Index (DiF) is 290.63, with a wide range (18.47-473.83), indicating significant differences in the development level of digital finance among provinces. The average capital adequacy ratio (CAR) was 13.51%, in line with regulatory requirements (>10.5%), but some banks were close to the lower limit (min=10.41%), and capital replenishment pressure needs to be watched. The average loan-to-deposit ratio (LDR) was 73.37%, with some banks having an excessively high loan-to-deposit ratio (max=109.79%) and potentially facing liquidity risks.

5.2 Analysis of Regression Results

The table shows comparisons of regression results from different models, and the results show that the fixed-effect model (FE) is superior: FE has the highest R^2 (0.665), and the coefficient directions and significance of key variables (such as NPL, LDR) are consistent, indicating that the model has stronger explanatory power after

controlling for individual heterogeneity. As shown below in Table 3, the regression results of different models are presented.

Table 3. Comparison of regression results from different models.

Variables	Mixed OLS	Fixed effects (FE)	Random effects (RE)
Digital inclusive finance index	-0.0017 (p=0.000)	-0.0009 (p=0.000)	-0.0014 (p=0.000)
Capital adequacy ratio	0.042 (p=0.000)	0.002 (p=0.658)	0.012 (p=0.009)
Total asset size (logarithm)	0.014 (p=0.005)	-0.084 (p=0.015)	0.006 (p=0.538)
Loan-to-deposit ratio	0.0034 (p=0.000)	0.0018 (p=0.018)	0.0022 (p=0.003)
Non-performing loan ratio	-0.152 (p=0.000)	-0.206 (p=0.000)	-0.196 (p=0.000)

Table 4. Regression results of the fixed-effect model.

Variables	Coefficients	Standard error	T-statistic	P value	95% confidence interval (lower bound)	95% confidence interval (upper bound)
const	0.6981	0.081	8.669	0.000	0.540	0.856
Digital inclusive finance index	-0.0017	8.69e-05	-19.440	0.000	-0.002	-0.002
Capital adequacy ratio	0.0424	0.005	8.817	0.000	0.033	0.052
Total asset size (logarithmic)	0.0135	0.005	2.846	0.005	0.004	0.023
Loan-to-deposit ratio	0.0034	0.001	5.164	0.000	0.002	0.005
Non-performing loan ratio	-0.1515	0.019	-8.112	0.000	-0.188	-0.115

As shown in Table 4 above, the regression results of the fixed effects model are presented. The regression results based on the fixed effects model showed that the Digital Inclusive finance Index (DiF) had a significant negative impact on the return on total assets (ROA) of commercial banks (coefficient =-0.0017, p=0.000), indicating that for every 1-unit increase in digital inclusive finance, ROA decreased by approximately 0.17 per cent. This result is in line with Hypothesis 1 mentioned above. The coefficient of the capital adequacy ratio (CAR) was 0.0424 (p=0.000), indicating a 4.24% increase in ROA for every 1% increase in the capital adequacy ratio. The loan-to-deposit ratio (LDR) coefficient was 0.0034 (p=0.000), indicating that every 1% increase in the loan-to-deposit ratio corresponds to a 0.34% increase in ROA. This result is in line with Hypothesis 2 mentioned above. The coefficient of the asset size

(LnSize) is 0.0135 (p=0.005), indicating that the economies of scale effect are significant, but the magnitude of the effect is small. The negative impact of the non-performing loan ratio (NPL) was most prominent (coefficient =-0.1515, p=0.000). For every 1% increase in the non-performing loan ratio, ROA dropped significantly by 15.15 per cent, highlighting the core position of asset quality management.

5.3 Robustness Test

Robustness tests were conducted on the model, with ROE replacing the explained variable ROA. Based on the results of the robustness test, the impact of the Digital Inclusive Finance Index (DiF) on the profitability of commercial banks showed high robustness across different model Settings. In the benchmark model (ROA), the coefficient of DiF is -0.0009 (p=9.93e-08), indicating that for every 1-unit increase in digital inclusive finance, ROA decreases by approximately 0.09%, and the model has strong explanatory power (R^2=0.665). In the alternative dependent variable (ROE) model, the negative impact of DiF expanded significantly, with a coefficient of -0.0198 (p=5.33e-15), indicating that inclusive finance may have a stronger inhibitory effect on return on equity by adjusting the capital structure, such as increasing liabilities or reducing return on equity. At the same time, the explanatory power of the model increased further (R^2=0.827). In the lagging explanatory variable model, the coefficient of DiF remained -0.0009 (p=5.41e-08), consistent with the benchmark model, verifying the persistence of the negative effects, and the explanatory power of the model decreased only slightly after a one-period lag (R^2=0.661), indicating that the results were adaptive to the time dynamic effect. Although the lag model lost some samples due to data lag (observations were reduced from 540 to 498), the sample size still met the requirement of a large sample, and the conclusion was reliable.

5.4 Heterogeneity Test

5.4.1 Heterogeneity Analysis of Company Attributes.

Public banks are significantly negatively affected by the inclusive finance index: The development of inclusive finance may increase the competitive pressure or operating costs of public banks (such as the higher marginal cost of serving micro and small enterprises), leading to a decline in profitability. State-owned banks have no significant impact: State-owned banks may be less sensitive to inclusive finance due to policy support, scale advantages or stronger risk-bearing capacity. This result is in line with Hypothesis 3 mentioned above.

5.4.2 Regional Heterogeneity Analysis.

The negative impact of inclusive finance in the eastern region is significant: The financial market maturity in the eastern region is high, and inclusive finance may accelerate industry competition and compress profit margins; Or the high digital penetration rate leads to higher costs.The impact in the Midwest is not significant: it may be due to low coverage of inclusive finance, lagging policy implementation, or finan-

cial institutions offsetting the negative effects through differentiated services such as rural finance. This result is in line with Hypothesis 4 of the above. The regression results of firm characteristics and regional heterogeneity analysis are shown below in Table 5.

Table 5. Regression results of company attributes and regional heterogeneity analysis.

Variables	ROA			
	(1)	(2)	(3)	(4)
	Group by enterprise attributes		Group by region	
	State-owned banks	Public banks	Eastern Region	Midwestern Region
Index	0.000088 (p=0.653)	-0.0021 (p=0.000)	-0.0012 (p=0.000)	-0.00066 (p=0.165)
R^2	0.720	0.674	0.631	0.817
Number of observations	333	207	436	104

6 Conclusions and Recommendations

6.1 Conclusions

Based on the unbalanced panel data of 42 listed commercial banks in China from 2011 to 2023, this paper systematically examines the impact of digital finance on the profitability of commercial banks and the heterogeneity effect through a two-way fixed effects model, and concludes as follows:

Digital finance has a significant inhibitory effect on the profitability of commercial banks. For every 1-unit increase in the digital inclusive finance index, the return on total assets (ROA) of commercial banks drops by approximately 0.17 per cent. This negative effect is particularly prominent in public banks and the eastern region. The study supports the "competitive substitution effect" hypothesis that digital finance weakens traditional banks' net profit and profit stability by diverting deposits, narrowing the spread between deposits and loans, and forcing off-balance sheet business expansion.

Capital structure and asset quality play a key moderating role in profitability. The increase in capital adequacy ratio (CAR) and loan-to-deposit ratio (LDR) significantly boosts ROA, indicating that adequate capital reserves and efficient balance sheet allocation are important foundations for banks to withstand digital financial shocks; The negative impact of the non-performing loan ratio (NPL) was the most significant (coefficient -0.1515), highlighting the core position of asset quality management in profitability.

The heterogeneity effect was significant. State-owned banks are less sensitive to digital finance due to policy support and scale advantages, while public banks are significantly less profitable due to increased competitive pressure; The eastern region failed to pass the significance test due to the high penetration rate of digital finance and

the compression of profit margins caused by intensified market competition, while the central and western regions failed to pass the significance test due to the lagging development of inclusive finance.

6.2 Recommendations

This article suggests that commercial banks deepen digital transformation, optimize profit models, strengthen capital replenishment and risk management mechanisms, improve capital planning, and replenish core capital by issuing perpetual bonds, preferred stocks, etc. At the same time, use digital technology to optimize credit risk assessment models, dynamically monitor non-performing loans, and reduce the impact of asset quality fluctuations on profits. Implement a differentiated development strategy. In response to regional and attribute heterogeneity, banks in the eastern region can focus on high value-added businesses (such as cross-border finance and green finance), and public banks need to enhance customer stickiness through differentiated services for micro and small enterprises and inclusive finance; The central and western regions should accelerate the layout of digital infrastructure and leverage policy dividends to unlock the potential of inclusive finance. Improve the regulatory coordination framework, suggest that regulatory authorities balance innovation incentives with risk prevention and control, formulate differentiated regulatory rules for competition between digital finance and traditional banks to avoid "regulatory arbitrage" exacerbating market imbalances, and promote the construction of data sharing platforms to reduce the cost of information asymmetry.

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