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The impact of digital transformation on business performance of commercial banks: empirical evidence from 42 a-share listed banks in China

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Abstract. Amid the wave of financial technology, digital transformation has become an inevitable path for the development of commercial banks. However, its impact on business performance remains debated. Using panel data for 42 A-share listed banks in China from 2017 to 2021, this study empirically estimates the net effect of digital transformation. The results show that digital transformation significantly enhances banks' overall performance, with a more pronounced promotive effect for regional banks. The main conclusions remain valid after a battery of robustness checks. Based on these findings, we offer policy recommendations for differentiated digital-transformation pathways for commercial banks along three dimensions: cost reduction and efficiency enhancement, revenue diversification, and risk-control optimization.

Keywords: digital transformation, commercial banks, business performance, heterogeneity effects

1. Introduction

Currently, the world is experiencing the fourth industrial revolution, driven by emerging technologies such as artificial intelligence, big data, cloud computing, and blockchain. Digital transformation has become a key driving force for promoting highquality economic development. According to the China Digital Economy Development Report (2023) released by the China Academy of Information and Communications Technology, China's digital economy reached 50.2 trillion yuan in 2022, accounting for 41.5% of GDP. The digital economy has thus become an important pillar of national economic growth. This trend has also received strong policy support at the national level. The People's Bank of China, in its FinTech Development Plan (2022–2025), explicitly set the goal of "deepening the digital transformation of the financial industry and significantly enhancing the digital management capabilities of financial institutions", elevating the digital transformation of finance to a national strategic priority.

As the core entities of the modern financial system, the digital transformation of commercial banks is not only related to improving operational efficiency and reshaping competitiveness at the institutional level, but also bears profound strategic significance for optimizing financial resource allocation and strengthening the ability of finance to serve the real economy. In particular, in the postpandemic era, demand for contactless financial services has surged dramatically. According to the 2024 China Banking Service Report released by the China Banking Association, the total value of offcounter transactions in the banking sector reached 2626.8 trillion yuan in 2024, while the number of mobile banking individual customers soared to 3.195 billion accounts, which indicates that digital transformation has become an irreversible trend for the future development of the banking industry. A deeper investigation into its impact on the business performance of commercial banks is thus of not only significant theoretical value but also strong practical relevance for guiding the highquality development of the sector.

2. Literature review

The digital transformation of commercial banks refers to the systematic restructuring of traditional business processes through the adoption of digital technologies, thereby offering consumers more digitally integrated financial products and services in line with the requirements of the digital economy era (Du et al., 2021) [1]. This transformation also has profound strategic significance. First, Valdez (2016) shows that digital transformation enables commercial banks to develop entirely new business mindsets and operational models on the basis of technological applications [2]. Second, Mohan (2016) notes that digital

technologies create new market opportunities for commercial banks by enabling them to provide financial services to rural and remote customers, thereby overcoming the limitations of traditional service radii and expanding business boundaries [3]. In addition, Lu and Wang (2019) emphasize that commercial banks can use digital technologies to manage digital assets, thus accelerating the high-quality development of China's digital economy [4].

Despite its necessity, digital transformation poses many challenges in practice. Luo (2022) finds that the core difficulty lies in system integration: as most banks' IT systems remain fragmented, many institutions struggle to build genuinely open banking systems and urgently need to explore ecosystem-level solutions [5]. Fang and Wang (2024) further identify four major issues in China's commercial banks: from a temporal perspective, transformation began relatively late, leaving a noticeable gap with leading industries; from a cultural perspective, digital culture remains underdeveloped, lacking an atmosphere conducive to transformation; from a resource perspective, small and medium-sized banks face significant constraints in resources and technology, delaying progress; and from a risk perspective, banks' capabilities in identifying and preventing emerging digital risks require improvement [6].

Given these challenges, scholars have not yet reached consensus on the performance outcomes of digital transformation. Supportive studies argue that digital transformation significantly enhances performance. Liu and Wang (2021) find that fintech applications help commercial banks optimize products and services, achieve precise customer targeting, expand their client base, and effectively control management costs, thus improving performance [7]. Yao (2024) further demonstrates that digital transformation can offset the competitive pressures of digital finance, helping traditional banks maintain their advantage in the digital economy [8]. However, critical perspectives also exist. Stoica et al. (2015) suppose that digital transformation does not necessarily lead to significant performance improvement [9]. Hajli et al. (2015) point out that only a limited number of firms benefit in terms of performance from digital transformation [10]. Liu et al. (2023), focusing on rural commercial banks, argue that under the dual objectives of supporting agriculture and maintaining profitability, fintech weakens their market power, thereby creating resistance to both goals and producing a "dual suppression" effect [11].

Building on these studies, this paper aims to contribute in three ways. First of all, in response to the debate on transformation effects, it develops a systematic evaluation index system to accurately measure the net impact of digital transformation on commercial banks' performance, thereby reconciling inconsistent findings. Secondly, it examines the "technology adoption–business transformation–performance output" mechanism to reveal the transmission pathways through which digital transformation affects bank performance, filling a gap in mechanism analysis. Finally, by distinguishing among state-owned large commercial banks, national joint-stock commercial banks, and regional commercial banks, it systematically investigates heterogeneity in transformation outcomes, providing a theoretical basis for differentiated transformation strategies. By constructing an analytical framework and conducting empirical tests, this study seeks to offer both theoretical support and practical reference for the digital transformation of China's banking sector.

3. Theoretical analysis and research hypotheses

3.1. The technological spillover effect of digital transformation on the business performance of commercial banks

According to Joseph Schumpeter's theory of technological innovation, innovation is the core driving force of economic development, operating primarily through the mechanism of "creative destruction" to continuously reshape industrial structures. In the digital economy era, digital technology innovations generate multidimensional spillover effects for commercial banks. These effects are reflected mainly in three aspects—cost reduction, revenue expansion, and risk management optimization—ultimately enhancing banks' business performance.

To begin with, from a cost-reduction perspective, digital transformation optimizes the cost structure of commercial banks through technology substitution. For example, the adoption of smart counters and intelligent customer service has replaced large volumes of traditional manual services. According to the China Banking Association Service Report series, between 2017 and 2023, the number of off-counter transactions in China's banking sector surged from 260.04 billion to 491.44 billion, an increase of nearly 90%. This dramatic growth illustrates the substitution effect of digital technologies on traditional counter services. From an economic perspective, this substitution generates three positive outcomes: (1) direct reductions in labor costs, (2) improved efficiency through standardized processes, and (3) 24/7 uninterrupted services that enhance customer experience.

Furthermore, with respect to revenue creation, digital transformation enables new pathways for value generation through technology empowerment. The deep application of big data and artificial intelligence allows commercial banks to build precise customer profiles, thereby facilitating personalized product recommendations and targeted marketing. For instance, at the Bank of China, the number of mobile banking users grew from 115.24 million in 2017 to 274.62 million in 2023, an increase of 138.3%. During the same period, mobile banking transaction volume skyrocketed from 10.97 trillion yuan to 54.88 trillion yuan, an increase of over 400%. This rapid growth can be attributed to three factors: (1) digital technologies have removed time and space constraints, greatly expanding service reach, (2) intelligent recommendation systems based on big data have significantly

improved product matching accuracy and conversion rates, and (3) the marginal cost of serving new customers through digital channels is extremely low, enabling substantial returns from scale expansion.

Lastly, in terms of risk management, digital transformation strengthens the risk control capabilities of commercial banks through technology enhancement. By leveraging big data–driven risk models, banks can integrate multidimensional information, including taxation, judiciary, and consumption data, to construct more accurate credit scoring systems. At the same time, AI-powered smart risk control systems employ machine learning algorithms to analyze customer transaction behaviors and cash flows, effectively mitigating information asymmetry in the pre-loan stage. Furthermore, these systems allow real-time monitoring of loan usage and borrower operations in the post-loan stage, thereby detecting potential moral hazard promptly. By covering the full loan cycle—from pre-loan approval to post-loan management—these intelligent systems reduce non-performing loan ratios and improve asset allocation efficiency.

Synergistically, these three dimensions of technological spillover effects reinforce one another. Cost reduction provides sustainable input capacity, revenue creation forms positive incentives, and risk optimization ensures long-term stability. This synergy drives improvements in commercial banks' business performance. Based on this reasoning, the following hypothesis is proposed:

H1: Digital transformation has a significant positive impact on the business performance of commercial banks.

3.2. Analysis of the heterogeneous effects of digital transformation in commercial banks

Due to the differentiated characteristics of China's banking system, the technological spillover effects of digital transformation manifest heterogeneously across bank types. This heterogeneity stems from structural differences in resource endowment, market positioning, and regulatory environment, which affect cost reduction, revenue creation, and risk optimization differently, thereby influencing business performance.

Firstly, regarding cost reduction, state-owned large commercial banks benefit most from economies of scale. With abundant financial resources and robust IT infrastructure, they can bear the substantial fixed costs of digital transformation while continuously lowering marginal operating costs. Their strong talent reserves and standardized business processes further enhance the substitution effect of digital channels such as smart counters and remote banking. By contrast, non–state-owned banks, with weaker capital strength and limited technological accumulation, often achieve cost savings only incrementally, reflecting gradual improvements in traditional businesses rather than systemic transformation.

Additionally, concerning revenue creation, joint-stock commercial banks demonstrate stronger technology empowerment effects. With flexible organizational structures and market-oriented strategies, these banks excel in digital product innovation and precision marketing. For example, Ping An Bank has leveraged its group's technological advantages to launch intelligent services such as the "AI Relationship Manager", while China Merchants Bank has built a digital ecosystem through its Pocket Life app, significantly enhancing customer engagement and cross-selling rates. This "light-asset, tech-driven" model allows joint-stock banks to respond quickly to market changes and build competitive advantages in areas such as wealth management and consumer finance. In contrast, state-owned large commercial banks, despite their extensive client base, often face structural rigidity that constrains their capacity for innovation.

Ultimately, with regard to risk optimization, various categories of banks manifest pronounced differentiated characteristics. State-owned large commercial banks, operating under strict prudential supervision, prioritize risk controllability, with technological applications emphasizing stability. Meanwhile, non–state-owned commercial banks, especially regional banks, benefit from differentiated regulatory policies, allowing them to tailor digital risk control practices to local economic conditions. Notably, a divergence in risk management capabilities can give rise to substantial variation in the manifestation of technological spillover effects among different bank categories.

Based on the aforementioned analysis, the following hypothesis is proposed:

H2: The impact of digital transformation on the business performance of commercial banks is heterogeneous across different bank types.

4. Empirical research design

4.1. Sample selection and data sources

This study selects panel data from 42 listed commercial banks in China's A-share market over the period 2017–2021 as the research sample. The sample includes six state-owned large commercial banks (e.g., China Construction Bank, Bank of China), nine nationwide joint-stock commercial banks (e.g., China Merchants Bank, Ping An Bank), and twenty-seven regional commercial banks (e.g., Bank of Beijing, Bank of Ningbo). The sample selection is based on the following considerations: first, the financial data of listed banks are disclosed in a complete and standardized manner, ensuring good data availability; second, these banks occupy a dominant position in China's banking industry, and their operating performance can reasonably reflect

overall industry characteristics; third, the sample covers the major types of banks, which facilitates subsequent heterogeneity analysis.

The research data are primarily obtained from two sources: (1) business performance indicators and control variables of commercial banks, collected from the National Bureau of Statistics and banks' annual reports; (2) the degree of digital transformation, measured by the Digital Transformation Index of Chinese Commercial Banks developed by Professor Xuanli Xie's team at Peking University. Widely regarded as an authoritative and representative measure, this index adopts the principal component analysis (PCA) method to comprehensively evaluate banks' digital transformation level from strategic, business, and managerial dimensions. Since the index is only updated through 2021, the study period is set as 2017–2021 to maintain data consistency. This choice ensures both timeliness and reliability of the research data.

4.2. Variable definition and descriptive statistics

4.2.1. Dependent variable: business performance of commercial banks

In measuring bank performance as the dependent variable, existing literature commonly uses return on assets (ROA) and return on equity (ROE) as proxy variables (Xiong et al., 2021) [12]. Considering that ROE may be affected by capital structure (Haw et al., 2010) [13], we adopt ROA as the benchmark measure, while ROE is used as an alternative variable in robustness checks. Higher values of both indicators represent better business performance.

4.2.2. Core independent variable: digital transformation index

The degree of digital transformation is measured using the Digital Transformation Index of Chinese Commercial Banks (DTI) developed by Xie and Wang (2022) [14]. Based on the multidimensional characteristics of banks' digital transformation, the index constructs a comprehensive evaluation system from strategic, business, and managerial dimensions and determines the weight of each dimension through PCA. To unify measurement scales, the original index values are divided by 100. A higher index value indicates a higher level of digital transformation in a bank.

4.2.3. Control variables

To account for other potential influencing factors, we follow the research of scholars such as Teng and Lei (2024) [15], as well as Qian and Zuo (2024) [16], and selects control variables from both the macroeconomic and bank-specific levels. At the macroeconomic level, the GDP growth rate (gGDP) and the broad money supply growth rate (gM2) are included to control for the effects of economic development and monetary policy environment. At the bank-specific level, the equity multiplier (EM) and net interest margin (NIM) are included to control for the effects of financial leverage and profitability. The configuration of control variables considers both endogenous factors within bank operations and important external environmental variables, thereby helping to more accurately identify the net effect of digital transformation on bank performance.

The descriptive statistics of the main variables are shown in Table 1.

Table 1. Descriptive statistics of main variables

Variable Name	Symbol	Observations	Mean	Std. Dev.	Min	Max
Return on Assets	ROA	210	0.845	0.160	0.420	1.370
Return on Equity	ROE	210	12.15	2.589	5.760	19.76
Digital Transformation Index	DTI	210	1.113	0.350	0.122	1.844
Equity Multiplier	EM	210	13.32	1.865	9.678	20.89
Net Interest Margin	NIM	210	2.100	0.389	1.320	3.737
GDP Growth Rate	gGDP	210	5.980	2.012	2.200	8.100
Broad Money Supply Growth	gM2	210	8.820	0.721	8.100	10.10

4.3. Model specification

To examine the impact of digital transformation on the performance of commercial banks, we construct the following fixed-effects regression model based on panel data from 42 A-share listed banks during 2017–2021:

$$ROA_{i,t} = \alpha_0 + \alpha_1 DTI_{i,t} + \sum_j \alpha_j Control_{j,i,t} + \mu_i + \varepsilon_{i,t} \quad (1)$$

where i denotes bank($i = 1,2,\ldots,42$), t indexes year ($t = 2017,\ldots,2021$), and j represents the control variables. The dependent variable $ROA_{i,t}$ measures the business performance of bank i in year t. The core independent variable $DTI_{i,t}$ stands for the digital transformation index of bank i in year t. The vector of control variables $Control_{j,i,t}$ includes the equity multiplier (EM), net interest margin (NIM), GDP growth rate (gGDP), and broad money supply growth rate (gM2). μ_i identifies bank-specific fixed effects to control for time-invariant bank heterogeneity, and $\varepsilon_{i,t}$ is the random error term. The model focuses on estimating the coefficient α_1, which reflects the net effect of digital transformation on bank performance.

5. Empirical results analysis

5.1. Baseline regression results

To accurately identify the causal impact of digital transformation on the performance of commercial banks, this study first conducts a Hausman test to determine the model specification. The test yields a p-value of 0.0372, rejecting the null hypothesis at the 5% significance level, which indicates that the fixed-effects model is superior to the random-effects model. Therefore, we employ the fixed-effects estimation method for the baseline regression.

According to the baseline regression results in Table 2, in column (1) without control variables, the coefficient of digital transformation (DTI) is negative and significant only at the 10% level. However, in column (2) with all control variables included, the estimated coefficient of DTI becomes significantly positive at the 5% level, with a coefficient of 0.095, and the goodness-of-fit (R^2) of the model improves from 0.020 to 0.159. This shift underscores the necessity of integrating both macroeconomic factors (e.g., GDP and M2 growth rates) and bank-specific characteristics (e.g., the equity multiplier and net interest margin) into the regression model. Once these internal and external influences are controlled for, digital transformation is shown to significantly enhance commercial bank performance. This finding provides strong support for research hypothesis H1.

Table 2. Baseline regression results

	(1)	(2)
	ROA	ROA
DTI	-0.051*	0.095**
	(0.028)	(0.042)
EM		-0.006
		(0.006)
NIM		-0.010
		(0.023)
gGDP		-0.010**
		(0.005)
gM2		-0.075***
		(0.017)
_cons	0.902***	1.565***
	(0.032)	(0.195)
Individual Fixed Effects	YES	YES
N	210	210
r2	0.020	0.159

*Note: *, *, and *** denote significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses. The same notation applies to subsequent tables.

5.2. Heterogeneity test

Given the structural stratification within the commercial banking system, different types of banks vary significantly in resource access, business positioning, and regulatory environments, which may lead to heterogeneous outcomes of digital transformation. To test this hypothesis, the full sample is divided into three subsamples based on ownership type and operating scale: state-owned large commercial banks, joint-stock commercial banks, and regional commercial banks. The effects of digital transformation on the performance of each category are then examined separately.

The regression results in Table 3 reveal clear heterogeneity in the impact of digital transformation (DTI) across the three types of banks. The DTI coefficient is not statistically significant for state-owned banks and joint-stock banks, but it is significantly positive at the 1% level for regional commercial banks with a coefficient of 0.160, which indicates that the performance-enhancing effects of digital transformation are mainly concentrated among regional banks. This finding may be attributed to the advantages of regional banks in organizational agility and local adaptability, which enable them to respond more quickly to local financial needs. Through digital technologies, regional banks can streamline service processes, reduce operating costs, and expand their customer base, thereby improving operational performance. For example, Chengdu Rural Commercial Bank launched the "Grain e-Loan" product to serve local agricultural businesses, leveraging digital technology to effectively reach rural clients and significantly enhance service efficiency and coverage. In contrast, state-owned and joint-stock banks face constraints from large organizational structures, complex business systems, and strict compliance requirements. Their digital transformation often entails higher coordination costs and institutional rigidity, and the benefits of digital investment may be diluted by existing business structures, resulting in insignificant short-term marginal effects.

Nevertheless, while the short-term performance impact of digital transformation on large banks may be limited, its long-term strategic imperative remains undeniable. With their strong capital base and technological capabilities, state-owned and joint-stock banks have the potential to achieve deeper digital transformation, with benefits expected to unfold over a longer time horizon. Conversely, regional banks prioritize the scenario-based deployment of digital tools and client acquisition, which leads to quicker and more visible short-term performance improvements. Consequently, the findings validate research hypothesis H2.

Table 3. Heterogeneity test results

	(1)	(2)	(3)	(4)
	Full Sample	State-owned Banks	Joint-stock Banks	Regional Banks
DTI	0.095**	-0.056	0.044	0.160***
	(0.042)	(0.042)	(0.121)	(0.059)
EM	-0.006	-0.033***	0.001	-0.008
	(0.006)	(0.008)	(0.024)	(0.007)
NIM	-0.010	-0.009	0.057	0.011
	(0.023)	(0.035)	(0.086)	(0.028)
gGDP	-0.010**	-0.011**	-0.014	-0.011*
	(0.005)	(0.005)	(0.011)	(0.006)
gM2	-0.075***	-0.074***	-0.103**	-0.079***
	(0.017)	(0.018)	(0.041)	(0.023)
_cons	1.565***	2.141***	1.631**	1.521***
	(0.195)	(0.249)	(0.646)	(0.248)
N	210	30	45	135
r2	0.159	0.717	0.277	0.144

5.3. Robustness test

In order to verify the reliability of the baseline regression results, this study further conducts robustness tests. Following established research practices, the test employs a variable substitution method, replacing the dependent variable ROA with ROE to examine whether the estimated results of the core explanatory variable—digital transformation (DTI)—remain robust. Since ROE and ROA are complementary measures of bank profitability, with ROE placing greater emphasis on shareholder return, this substitution allows us to test the impact of digital transformation on bank performance from a different perspective. Meanwhile, the sample period remains consistent with that of the baseline model (2017–2021).

The regression results reported in column (2) of Table 4 show that the coefficient of DTI is 1.385 and highly significant at the 1% level, indicating that for every unit increase in digital transformation, banks' ROE increases by an average of 1.385 units. This result is fully consistent with the baseline regression, where DTI significantly improves ROA, suggesting that the core conclusion does not hinge on the specific performance measure used. These findings demonstrate that even after substituting the dependent variable, the positive effect of digital transformation on commercial bank performance remains robust. Thus, the main empirical conclusions of this study are not affected by the choice of performance indicator, lending strong credibility to the results.

Table 4. Robustness test results

	(1)	(2)
	ROA	ROE
DTI	0.095**	1.385***
	(0.042)	(0.512)
EM	-0.006	0.493***
	(0.006)	(0.089)
NIM	-0.010	0.965**
	(0.023)	(0.420)
gGDP	-0.010**	-0.162
	(0.005)	(0.127)
gM2	-0.075***	-1.472***
	(0.017)	(0.381)
_cons	1.565***	15.964***
	(0.195)	(4.395)
N	210	210
r2	0.159	0.250

6. Conclusion and policy recommendations

With the accelerated integration of artificial intelligence, big data, cloud computing, and blockchain into the financial sector, the digital transformation of commercial banks has become a key pathway for reshaping industry competition, enhancing service efficiency, and achieving sustainable development. Drawing on technological innovation theory, this study systematically analyzes the spillover mechanisms of digital transformation on bank performance from three dimensions—cost control, revenue diversification, and risk management optimization—and accordingly proposes research hypothesis H1. Furthermore, considering the structural heterogeneity among banks in terms of resource endowment, market positioning, and regulatory environment, hypothesis H2 is developed to capture potential asymmetries in the spillover effects.

Empirical analysis based on panel data of 42 listed commercial banks in China from 2017 to 2021 yields the following findings. First, digital transformation significantly improves banks' operating performance, confirming the positive technological spillover effect predicted by H1. Second, the effect is heterogeneous, with regional commercial banks benefiting more strongly, thus supporting H2. In addition, the robustness check using ROE instead of ROA as the dependent variable confirms the consistency of the main conclusion, underscoring the reliability of the results.

Based on these findings, and particularly the identified technological spillover mechanisms, the following policy recommendations are proposed:

The primary objective is to strengthen technology integration and organizational adaptation, thereby unlocking operational efficiencies and cost savings. Commercial banks should systematically promote the deep integration of emerging technologies with core business processes, with a focus on automation in operations, intelligent risk modeling, and precision in customer services. Large state-owned and joint-stock banks should address the coordination costs arising from system complexity and institutional rigidity by establishing fintech subsidiaries or co-developing industry-wide cloud platforms to enhance resource sharing and technology diffusion. Regional commercial banks, in turn, should prioritize localized application scenarios and develop lightweight digital solutions to achieve cost-effective service penetration and improved customer experience.

A second strategic imperative involves building a diversified income structure through digital innovation to drive sustainable profitability. To realize the revenue-side spillover effects of digital transformation, banks must move beyond a cost-cutting mindset and actively cultivate new profit growth drivers. On one hand, leveraging big data analytics and user profiling, banks can uncover latent customer needs and design scenario-based and personalized digital financial products to strengthen cross-selling. On the other hand, by developing open banking platforms and establishing API-enabled partnerships with third parties such as tech firms, government services, and supply chain enterprises, banks can embed themselves in broader ecosystems to generate intermediary income and traffic-driven revenues.

The final priority is to enhance intelligent risk governance frameworks to secure the foundation for long-term, resilient development. Digital transformation enables banks to enhance risk identification, measurement, and mitigation capabilities, thereby securing long-term performance improvements. Banks should integrate internal and external data resources to establish unified intelligent risk management platforms covering credit, market, and operational risks, with functions for real-time monitoring, dynamic early warning, and automated interception. Additionally, investment in financial infrastructure should be

intensified. Large banks are advised to take the lead in building industry-level data-sharing platforms—such as credit information exchange and anti-fraud databases—to help regional banks overcome data constraints and fully benefit from technological spillovers in risk control, thereby achieving synergies between performance enhancement and prudent risk management.

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