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Research on the Impact of Commercial Banks' Digitalization Level on Their Operational Performance

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Abstract

This article takes the digitalization level of commercial banks as the research object to explore the impact of the improvement of commercial banks' digitalization level on their operational performance. The article uses the "Peking University Commercial Bank Digital Transformation Index" from the Digital Finance Research Center of Peking University, selecting banks that have publicly available annual reports for at least three years from 2010 to 2021. Based on theoretical analysis, in order to test the non-linear impact of commercial banks' digital transformation on operational performance, a multivariate regression benchmark model is designed using the unbalanced panel data of sample banks and the ordinary least squares (OLS) estimation method. The study finds that: the impact of the improvement of commercial banks' digitalization level (internal financial technology) on bank performance shows a "U-shaped" effect that first suppresses and then promotes. The "U-shaped" effect of first suppression and then promotion is more significant for non-listed banks, banks with lower registered digital financial development, and banks with lower financial technology development levels compared to listed banks, banks with higher registered digital financial development, and banks with higher financial technology development levels.

Keywords

Commercial Bank, Digital Transformation, Business Performance.

1. INTRODUCTION

Since the beginning of 2022, when the central bank released the second round of the "Financial Technology Development Plan (2022-2025)," it has been exactly two years. During this period, the "new infrastructure" in China's financial technology sector has gradually taken shape, successfully transitioning from the initial stage of "establishing pillars and beams" to a new phase of mature development characterized by "accumulating strength and momentum." As the main force in the financial industry, commercial banks are actively strengthening their strategic deployment from a long-term perspective, comprehensively promoting the process of digitalization and smart transformation. They are committed to efficiently utilizing talent and capital, using financial technology as a new engine to promote high-quality development, with the core goal of empowering financial services to improve quality and efficiency. In this process, commercial banks not only focus on the innovative application of financial technology but also pay more attention to its healthy and orderly development. They strive to deeply integrate digital elements into the entire process of financial services, from customer experience to product design, from risk management to business operations, all reflecting the innovation of digitalization and intelligence. Looking to the future, financial technology will continue to play a key role in the transformation and development of commercial banks. We have reason to believe that with the continuous advancement and application of financial technology, the

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quality and efficiency of China's financial services will be further improved, injecting strong momentum into the high-quality development of the economy and society.

Additionally, the rapid rise of financial technology is profoundly advancing the pace of interest rate liberalization, a process that undoubtedly poses a strong challenge to the traditional financial industry. For a long time, the interest spread on deposits and loans has been the main source of profit for commercial banks, and for non-shareholding commercial banks, it is even more the cornerstone of their profitability. However, as interest rate liberalization progresses, the traditional profit point of bank interest margins has been severely impacted first, leading to a reduction in the income of commercial banks and a significant decline in profitability. With the advancement of interest rate liberalization, the cost of bank funds increases, with a tendency to invest in high-risk investments, thereby increasing operational risks. Therefore, commercial banks should take the initiative to enhance their innovation capabilities, renew their concepts, introduce talent, embrace financial technology, and build a "virtual, digital, information-based, and intelligent" bank to achieve the integration of finance and technology. In summary, financial technology and interest rate liberalization bring both challenges and opportunities to traditional finance. Commercial banks need to seize this opportunity, actively meet the challenges, and achieve sustainable development through innovation and transformation.

In general, although there is a vast amount of academic literature on the operational performance of Chinese commercial banks, most studies focus on micro-details and delve into their operational effects. However, research from the emerging perspective of financial technology is relatively scarce. Whether focusing on the "technology spillover" or "market competition" effects, or starting from the perspective of bank risk management, these studies are essentially exploring how financial technology shapes the business ecosystem of commercial banks. But currently, most of the literature on the impact of financial technology on the operational performance of commercial banks still remains at the level of internet finance, and there is a need to strengthen the exploration of the newer and broader field of financial technology. This situation indicates that we still need to conduct more in-depth and comprehensive research in the intersection of financial technology and the operational performance of commercial banks. The digital economy and digital finance have been developing rapidly in China, and in recent years, commercial banks have also begun to digitalize in line with the trend. Whether these attempts at digital transformation have truly improved the operations of commercial banks, whether commercial banks should continue to deepen digital transformation in the future, and where they should start are questions that need to be addressed. This article, by studying the effects and mechanisms of digital transformation in commercial banks, has a certain guiding role for the operations of commercial banks in the context of financial digitization.

2. LITERATURE REVIEW

2.1. The Background of Commercial Banks' Digital Transformation

To achieve the goal of digital transformation, traditional commercial banks should not only actively introduce cutting-edge technologies but also adjust their internal organizational structures and reshape their business processes. Over the past few decades, although the development of computer technology has brought great potential for increased productivity, this potential has not been fully realized due to the complexity of the application of computer technology and the production process. Historically, the promotion of new technologies, whether in the electricity industry or computer technology, has always relied on innovation in specific segmented areas within the industry, aimed at meeting the unique needs of each industry (David)[1]. Financial technology helps commercial banks of different sizes and capital

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strengths to achieve differentiated digital transformation. Banks should choose the right digital transformation strategy based on their own characteristics and market demands (Xie Zhichun, 2018)[2]. The development of financial technology has essentially promoted the disguised evolution of interest rate liberalization, reshaped the bank's liability structure and asset allocation, and has had a profound impact on the bank's profit model, risk management, and regulatory policies. Since 2012, the pace of commercial banks' digital transformation has accelerated. The launch of "Yu'e Bao" in 2013 is considered one of the key factors that touched off the transformation of traditional banking. This trend of change has prompted banks to speed up their digital transformation (Qiu Han, 2018)[3].

2.2. The Advantages and Impacts of Digital Transformation on Commercial Banks

The digital transformation of commercial banks has brought unprecedented advantages and impacts. On the one hand, the development and application of financial technology in the banking industry have promoted technological innovation, thereby improving the financial intermediary efficiency of the mortgage loan market (Foster et al. 2019)[4]. At the same time, financial technology affects the business models of financial intermediaries, increases the opportunities for the unbanked to obtain credit, and the behavior of consumers, companies, and regulatory agencies in the digital domain (Berger 2020)[5]. Maoyong Cheng and Yang Qu (2020)[6] found that the development momentum of state-owned banks in financial technology is strong, and the pace is significantly ahead of other banks. Among the many sub-fields covered by financial technology, the rapid development of internet technology is particularly eye-catching, and its progress significantly surpasses other technological fields such as artificial intelligence, blockchain, cloud computing, and big data. Further analysis indicates that the negative impact of bank financial technology on credit risk is relatively weaker in large banks, state-owned banks, and listed banks.

On the other hand, the development of financial technology will also have a certain impact on the traditional banking industry. Digital transformation has also promoted non-bank technology companies to enter the banking industry, thereby increasing market competition, but also increasing the investment costs for traditional banking practitioners and related financial service companies. Qiu Han's (2018)[3] research shows that the progress of financial technology will affect the asset structure of commercial banks. With the continuous advancement of financial technology, the proportion of resident deposits has shown a downward trend, while the proportion of interbank liabilities has gradually increased. This transformation in the bank's liability structure has further affected the bank's behavior in asset selection. Due to the increase in the cost of bank liabilities caused by financial technology, banks are more inclined to choose high-risk assets to compensate for the losses. At the same time, the lending interest rates of banks have decreased, and the net interest margin has also declined, indicating that the increase in the cost of funds has not been successfully passed on to downstream enterprises. Huan Tang[7] found in the consumer credit market that P2P lending platforms are either a substitute or a supplement to banks when it comes to consumer credit. P2P lending may only lead to credit expansion among borrowers who already have bank credit. Thakor (2020)[8] believes that the advantages of financial technology include: improving the efficiency and quality of financial services, reducing the cost of financial services, expanding the coverage of financial services, and promoting financial innovation and competition in the financial market. The disadvantages of financial technology include: regulatory risks, information security risks, moral risks, etc.

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2.3. The Impact of Digital Transformation on the Operational Performance of Commercial Banks

Whether the improvement of commercial banks' digital level promotes or inhibits their operational performance, and whether the "competitive effect" or the "technology spillover effect" of financial technology is more significant, existing research has not reached a unanimous conclusion. One view holds that the "competitive influence" of financial technology is more pronounced than its "technology spillover effect." Its rapid development has not only weakened the profit potential of commercial banks but also increased the risks in their business operations, thus posing a significant challenge to the improvement of commercial banks' operational performance (Wang Xiaohua, 2022)[9]. Xiong Jian (2021)[10] points out that, on the whole, the squeezing effect of financial technology on commercial banks exceeds the technology spillover effect, thereby significantly weakening the performance of commercial banks; and as the level of technological innovation in financial institutions increases, the extrusion effect gradually weakens, the technology spillover effect is further enhanced, and a nonlinear state of suppression followed by enhancement appears between financial institution technology and the operational performance of commercial banks.

Another view holds that the improvement of commercial banks' digital level will significantly enhance their operational performance. Technology spillover and cost optimization effects are the main driving forces, with total factor productivity and cost-income ratio playing a key role in this process (Zhang Qingjun, 2022)[11]. The research by Li Jianjun and Jiang Shichao (2021)[12] shows that bank financial technology promotes the growth of deposit and loan services through the law of increasing marginal benefits and decreasing costs. Especially in county areas, financial technology services such as online payment, funds, insurance, foreign exchange, etc., have a particularly significant effect on enhancing bank profitability and reducing costs. Huang Yinchuan (2019)[13], by comparing the performance changes before and after the digital transformation of credit unions' inclusive finance business, concluded that the digital transformation of inclusive finance business has a positive impact on the operational performance of credit unions. The early stage of commercial banks' digital transformation requires substantial investment costs, and the benefits of transformation have a lag, leading to a significant "U-shaped" relationship between digital transformation and the operational performance of commercial banks, showing a clear "decreasing costs and increasing benefits" pattern (He Xiaogang, 2023)[14]. In addition, financial technology can efficiently guide credit resources from inefficient "zombie" state-owned enterprises to efficient high-quality private enterprises by enhancing information screening capabilities and optimizing risk management strategies, thereby promoting structural debt optimization for enterprises (Zhang Jinqing, 2021)[15].

3. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

After reviewing the existing literature, we find that banks' investments in IT, internet, and financial technology do not always directly enhance bank performance. Although these investments bring technological innovation and upgrades to banks, their actual impact on performance is constrained by various factors. The specific mechanism by which internal financial technology affects the performance of commercial banks remains an unresolved issue, which deserves our in-depth study and discussion.

3.1. Profit Perspective

In the profit structure of commercial banks, the interest margin from deposits and loans has always been at the core. However, driven by the wave of digitalization, the continuous deepening of interest rate liberalization and the rapid rise of financial technology companies have brought

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significant impact on the banks' net interest margins. This change directly affects the income situation of banks, leading to a decline in their operational performance levels. But at the same time, commercial banks have also gained many opportunities through active digital transformation. Digital transformation has significantly enhanced banks' customer acquisition capabilities. With the help of big data technology, banks can more accurately analyze customer information, construct detailed customer portraits, and thus develop more precise marketing strategies. This not only alleviates the problem of information asymmetry between banks and customers but also enhances the banks' pricing power, giving them a more competitive edge in the market. In addition, digital transformation has also brought great convenience to bank business processing. The promotion of online platforms not only reduces the business pressure on bank branches, lowers operating costs, and reduces customers' transaction costs. By integrating financial functions and life scenarios, banks not only increase business volume and customer loyalty but also expand customer acquisition channels, thereby effectively improving profitability.

Therefore, although interest rate liberalization and the development of financial technology have brought certain challenges to commercial banks, digital transformation also provides new opportunities for development. Commercial banks should seize this opportunity, develop financial technology, and accelerate digital transformation to achieve more stable and sustainable development.

3.2. Cost Perspective

In the initial phase of the digital transformation of commercial banks, due to the need to invest heavily in human, physical, and financial resources, this often leads to a short-term decrease in the performance level of commercial banks. However, as the level of digitalization continues to improve, these investments begin to show their positive effects. Specifically, by introducing big data technologies such as cloud computing, the internal business management systems of commercial banks have been significantly optimized, and both operational efficiency and information management efficiency have been greatly enhanced. Cloud computing technology enables more effective allocation of resources, reducing marginal costs and significantly lowering the cost of information transmission. Driven by the continuous wave of digitalization, commercial banks actively promote the online process of their businesses and, in line with the national policy direction of digital development, achieve innovation and upgrading of business models. Since 2018, the number of physical branches of commercial banks in China has seen a negative growth, which not only greatly saves the operational costs of commercial banks in terms of human resources, rent, and equipment for physical branches but also provides banks with more resources to further improve their level of digitalization.

By utilizing these reduced costs, commercial banks can further accelerate the upgrade of financial services, optimize internal management processes, reduce management costs, and improve the efficiency of resource allocation. Ultimately, these efforts will translate into a substantial improvement in the operational performance of commercial banks, laying a solid foundation for the bank's long-term stable development.

3.3. Competitive Perspective

While commercial banks strive to enhance their digital capabilities, influenced by national policies and the overall economic environment, numerous non-bank financial institutions have emerged. These institutions, aimed at benefiting the public and businesses, provide financing support to small and medium-sized enterprises (SMEs), addressing the issues of "difficulty and expense in obtaining finance." This change has not only challenged the long-standing monopoly position of banks in the financial market but has also led to the loss of a large number of high-quality customers, thereby affecting their profitability. Moreover, with the rapid development

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of mobile payments and third-party payment services, the intermediary business income of commercial banks has also been severely impacted. At the same time, the diversified investment and financing services offered by other financial institutions have further squeezed the profit space of traditional commercial banks.

However, in the face of these challenges, traditional commercial banks have not remained passive. They have actively used digital transformation to enhance their business capabilities and, under the guidance of government and local policies, have continuously increased their investment in digital transformation. By leveraging financial technology tools such as big data, commercial banks can more accurately identify and analyze customer profiles, thereby enhancing their customer acquisition capabilities and marketing strategies. Due to the public's inherent trust in commercial banks, as well as their scale advantages and policy support, they have quickly improved their competitiveness within the industry. By meeting the personalized needs of customers and providing more convenient and efficient services, commercial banks have successfully captured the long-tail customers, uncovered more potential clients, and thereby increased market share and operational performance.

3.4. Efficiency Perspective

Amidst the wave of digital transformation, commercial banks actively recruit top talents, meticulously deploy digital strategies, construct efficient digital platforms, and continuously upgrade digital technologies. These initiatives enable banks to grasp vast amounts of user data and achieve precise identification through big data analysis. Based on this, banks utilize credit rating systems to devise personalized and differentiated marketing strategies to better meet customer needs. At the same time, the application of digital technology significantly enhances the transparency and effectiveness of data information, making the acquisition of information more convenient. This not only improves the efficiency of internal operations and management within banks but also makes the expansion and popularization of online business possible. With the continuous increase in the rate of business transactions conducted off-site, service efficiency has been greatly improved, and economies of scale have become apparent. Commercial banks allocate resources through online terminals, strengthening communication and collaboration across departments, thereby saving significant human and material costs. Additionally, banks provide personalized asset allocation plans for various individual and corporate clients and offer online consulting services, further improving the efficiency of resource allocation. These measures not only increase the efficiency with which clients conduct their affairs but also enhance their willingness to transact and loyalty.

In summary, digital transformation has significantly enhanced the operational efficiency of commercial banks, thereby promoting an increase in their operational performance. In the tide of the digital age, commercial banks will continue to deepen their transformation to better adapt to market changes and achieve sustainable development.

3.5. Risk Perspective

In the early stages of digital transformation in commercial banks, due to the immaturity of risk assessment mechanisms and credit rating systems, and the regulatory and behavioral norms in the financial technology sector still being in the formative stage, this has led to an exacerbation of information asymmetry, thereby increasing the non-performing loan ratio for banks. Furthermore, the insufficient maturity of digital technology applications has also increased the technological risks faced by banks themselves, potentially even triggering systemic risks. However, with the financial system's increasing regulation and standardization of financial technology, and the continuous development and improvement of digital technology, the introduction and implementation of relevant policies have provided strong support for commercial banks. Supported by big data technology, commercial banks and the financial

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system jointly use credit systems, utilizing artificial intelligence technology for precise identification and real-time monitoring of credit risk. At the same time, through intelligent risk control systems, banks can effectively supervise and manage at various stages of all businesses and issue timely risk warnings. These measures have greatly alleviated the problem of information asymmetry, significantly reduced the credit risk of banks, and effectively controlled operational risks. Additionally, they have enhanced the stability of the internal systems of banks, laying a solid foundation for improving the level of operational performance. As digital transformation continues to advance, commercial banks will be better able to cope with risk challenges and achieve more stable and sustainable development.

In summary, this paper proposes the following Hypothesis 1: The impact of the improvement of commercial banks' digital level on bank performance shows a "U-shaped" effect that first suppresses and then promotes.

3.6. Heterogeneity of Different Commercial Banks

Furthermore, different types of commercial banks show significant differences on the path of digital transformation, which also leads to different levels of investment in digital transformation and varying output effects. Similarly, the impact of the improvement of the digital level on the performance level of commercial banks will also produce heterogeneity.

3.6.1.Whether the Bank is Listed

There are multiple differences between listed and non-listed banks in the process of digital transformation, mainly stemming from differences in financial strength and investment scale, business scale and coverage, regulatory requirements and information disclosure, strategic positioning and choice of partners, risk tolerance and decision-making mechanisms. Therefore, when formulating digital transformation strategies, banks of all types need to fully consider their actual situation and characteristics to ensure the success and sustainable development of the transformation. Due to the different choices and strategies of various banks, the impact path on operational performance will also differ.

3.6.2.The Level of Digital Finance Development in the Registration Location

In areas with a higher level of digital finance development, commercial banks usually have a greater advantage in acquiring and applying new technologies and models, and customer demand for digital financial services is also more vigorous. This prompts commercial banks to continuously innovate service models and improve customer experience to meet the diverse needs of customers. At the same time, areas with a higher level of digital finance development often have more comprehensive regulatory policies and regulatory systems, providing strong institutional support for the digital transformation of commercial banks. These policies and regulations not only regulate market order and reduce transformation risks but also provide clear transformation directions and paths for commercial banks. However, there are differences in the level of digital finance development in different regions, which may lead to different challenges and opportunities for commercial banks in the process of digital transformation. It cannot be determined that the impact of the improvement of digital level on the operational performance of commercial banks with higher digital finance development in their registration location is more significant. Therefore, when formulating digital transformation strategies, commercial banks need to fully consider the characteristics of digital finance development in their own regions and promote transformation work according to local conditions.

3.6.3. The Level of Financial Technology Development

Commercial banks with different levels of financial technology development will show significant differences in the process of digital transformation, mainly manifested in technological application and innovation capabilities, the breadth and depth of digital transformation, risk management capabilities, customer service experience, strategic positioning, etc. The more mature the financial technology development, to a large extent, indicates a higher level of internal digitalization within the bank. Differences in the internal

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financial technology development level of commercial banks may also lead to heterogeneity in the impact of the improvement of digital level on operational performance.

In summary, this paper proposes the following Hypothesis 2: There is heterogeneity in the impact of the improvement of digital level on the operational performance of commercial banks when considering whether the bank is listed, the level of digital finance development in the registration location, and the level of financial technology development.

4. RESEARCH DESIGN

4.1. Sample and Data Sources

This paper takes the digital level of commercial banks as the research object to explore the impact of the improvement of commercial banks' digital level on their operational performance. The article is based on the "Peking University Commercial Bank Digital Transformation Index" compiled by the Digital Finance Research Center of Peking University (Wang Shihui, Xie Xuanli 2021)[16], and the weight of its digital transformation index system is detailed in Table 1. To ensure the reliability of the index data, this study only selects banks that can obtain at least three years of annual reports from public channels between 2010 and 2021. A total of 246 banks were finally included in the index calculation, covering 6 state-owned large commercial banks, 12 joint-stock commercial banks, 128 city commercial banks, 54 rural commercial banks, 29 foreign banks, and 17 private banks. Looking at the distribution of total assets, the bank samples used in this study (excluding banks missing annual reports in each year) account for more than 96% of the total assets of commercial banks in each year, fully indicating that the banks focused on in this study are quite representative. Given that the data mainly comes from the annual report text content and patent information of each commercial bank from 2010 to 2021, as well as other external data, the research interval of this paper is also determined to be from 2010 to 2021. In addition, other financial data of commercial banks in this paper all come from the Guotai Junan (Csmar) database and Wind (Wind) database, supplemented by the author's manual collation. At the same time, to reduce the impact of extreme outliers on the research results, we have performed tail trimming on all continuous variables at the bank level at the 1% level.

Table 1. Weights of the Commercial Bank Digital Transformation Index System (Principal Component Analysis Method)

First-Level Indicator	First-Level Weight	Second-Level Indicator	Specific Indicator Weight
Strategic Digitalization	14.89%	Mention of Digital Technology	100%
Business Digitalization	31.22%	Digital Channels	42.22%
		Digital Products	47.18%
		Digital R&D	10.60%
Management Digitalization	53.88%	Digital Infrastructure	20.84%
		IT Directors	28.60%
		IT Executives	28.21%
		Digital Collaboration	22.35%

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4.2. Variable Definition

4.2.1. Dependent Variable: Commercial Bank Operational Performance Indicator

From existing research, the operational performance of commercial banks can be measured from both short-term and long-term perspectives. Long-term performance is generally considered using the Tobin's Q value, while short-term performance can be measured in various ways, including financial indicators such as cost-to-income ratio, equity, net profit, return on assets (ROA), return on equity (ROE), non-performing loan ratio, provision coverage ratio, asset quality, solvency, etc. In addition, non-financial indicators such as customer satisfaction, employee satisfaction, and employee growth and development can also be used to fully reflect the performance. It is worth mentioning that the recent performance evaluation method for commercial banks released by the Ministry of Finance has adjusted the original evaluation dimensions. The previous four core indicators of profitability, operational growth, asset quality, and solvency have been transformed into four new evaluation dimensions: service to national development goals and the real economy, development quality, risk prevention and control, and operational efficiency, with each dimension being given a weight of 25% in the evaluation to ensure comprehensiveness and balance. Considering that Tobin's Q value can only be calculated with capital value data from listed companies, but the data sample in this study includes many non-listed commercial banks, sample missing would cause bias. Drawing on the research methods of numerous scholars (Wang Xiaohua 2022, Xiong Jian 2021,Zhang Qingjun 2022,He Xiaogang 2023, Cai Weixing 2016, Liu Jiasong 2019)[9,10,11,14,17,18], this paper selects the return on total assets and return on equity of each commercial bank as the dependent variable to measure operational performance.

4.2.2.Core Explanatory Variable

The core explanatory variable in this paper is the Commercial Bank Digital Transformation Index (Index), which comes from the "Peking University Commercial Bank Digital Transformation Index" (Xie Xuanli and Wang Shihui 2020)[16]. To comprehensively and objectively measure the digital transformation status and development trend of commercial banks in China, this index constructs an indicator system from three dimensions: Strategic Digitalization (14.89%), Business Digitalization (31.22%), and Management Digitalization (53.88%). To avoid the coefficient of the core explanatory variable in the regression model being too small, this index is scaled down by a factor of 100 in the text.

4.2.3. Control Variables

Drawing on previous research literature on the operational performance of commercial banks (Wang Xiaohua 2022, Xiong Jian 2021,Zhang Qingjun 2022,He Xiaogang 2023, Cai Weixing 2016, Liu Jiasong 2019)[9,10,11,14,17,18], this paper ultimately selects bank size (Size), bank age (Age), debt-to-asset ratio (Lev), growth capability (Growth), loan ratio (Loanratio), net interest spread (Jlc), operating cost (Cost), market share (Mks), cost-to-income ratio (Cir), non-performing loan ratio (Npl), per capita Gross Domestic Product (GDP), and Consumer Price Index (CPI) as control variables to control the impact of commercial bank characteristics on their operational performance. Table 2 shows the definitions and descriptions of the main variables used in this paper.

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Table 2. Definition and Explanation of Main Variables

Variable Type	Variable Name	Variable Code
Dependent Variable	Return on Total Assets	ROA
	Return on Equity	ROE
Independent Variable	Commercial Bank Digital Transformation Index	Index
	Square of the Commercial Bank Digital Transformation Index	Index2
Control Variable	Bank Size	Size
	Bank Age	Age
	Debt-to-Asset Ratio	Lev
	Growth Capability	Growth
	Loan Ratio	Loanratio
	Net Interest Margin	Jlc
	Operating Costs	Cost
	Market Share	Mks
	Cost-to-Income Ratio	Cir
	Non-Performing Loan Ratio	Npl
	Gross Domestic Product per Capita	GDP
	Consumer Price Index for Residents	CPI

4.3. Design of the Econometric Model

Based on theoretical analysis, to examine the nonlinear ("U-shaped") impact of commercial banks' digital transformation on operational performance, a multivariate regression benchmark model is designed using the unbalanced panel data of sample banks and the Ordinary Least Squares (OLS) estimation method:

$$ROA_{i,t} (ROE_{i,t}) = \alpha + \beta_1 Index_{i,t} + \beta_2 Index^2_{i,t} + \gamma Controls_{i,t} + \theta_t + \theta_i + \varepsilon_{i,t.} \quad (1)$$

In model (1), the dependent variable $ROA_{i,t}$ and ($ROE_{i,t}$) represents the operational performance level of bank i in period t. The core explanatory variable Index is the Commercial Bank Digital Transformation Index, and $Index^2$ is the quadratic term of the Commercial Bank Digital Transformation Index. Controls represents the control variables of this study; θ_i is the fixed effect of the bank entity; θ_t is the fixed effect of time; $\varepsilon_{i,t}$ is the residual term.

4.4. Descriptive Statistics

Table 3 presents the descriptive statistical results for the main variables. The results show that the mean and median values of the return on assets (ROA) and return on equity (ROE) for commercial banks are relatively close, which can effectively mitigate the impact of variable distribution on the results of empirical research; comparing the minimum and maximum values reveals a significant difference in the operational performance of sample banks, necessitating further investigation. When examining the Commercial Bank Digital Transformation Index, the standard deviation and extreme values indicate a considerable variation in the degree of digital transformation among different commercial banks. These observations provide insights for subsequent heterogeneity analysis, and it is necessary to consider heterogeneity issues when studying the impact of the improvement of commercial banks' digital levels on their operational performance.

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Table 3. Descriptive Statistics of Main Variables

Variable Name	Observations Mean	Standard	Deviation	Minimum	Maximum
ROA	1,825	0.009	0.004	0.001	0.022
ROE	1,825	0.130	0.061	0.004	0.303
Index	1,825	0.587	0.397	0.000	1.970
Index²	1,825	0.502	0.588	0.000	3.881
Size	1,825	25.943	1.650	23.092	30.776
Age	1,825	2.697	0.577	0.693	4.159
Lev	1,825	0.924	0.023	0.794	0.958
Growth	1,825	0.182	0.149	-0.100	0.773
Loanratio	1,825	0.476	0.104	0.225	0.731
Jlc	1,825	0.011	0.012	0.000	0.041
Cost	1,825	0.009	0.003	0.003	0.019
Mks	1,825	0.029	0.048	0.001	0.225
Cir	1,825	0.343	0.093	0.186	0.773
Npl	1,825	0.015	0.012	0.000	0.284
GDP	1,825	11.080	0.467	9.964	12.068
CPI	1,825	102.316	1.002	100.5	105.636

5. EMPIRICAL RESULTS AND ANALYSIS

5.1. Regression Results of the Benchmark Model

This paper primarily investigates the impact of the improvement in the digital level of commercial banks on their operational performance, using the Commercial Bank Digital Transformation Index (Index) and the square of the Commercial Bank Digital Transformation Index (Index^2) to regress on the Return on Assets (ROA) and Return on Equity (ROE). Table 4 and 5 displays the results of the regression estimation. From columns (1), (3), and (5), (7), it can be observed that the coefficients are not significant, indicating that the relationship between the digital transformation of commercial banks and their operational performance is not linear. Referring to existing research, a regression analysis was conducted again using the square of the Commercial Bank Digital Transformation Index (Index^2). The results, as shown in columns (2), (4), and (6), (8), suggest that the enhancement of the digital level of commercial banks has a suppressive effect followed by a promotional effect on the bank's operational performance.

In the era of the thriving digital economy, many traditional commercial banks have begun to enhance their digital capabilities. However, this transformation process requires substantial financial support. In the initial stages, the benefits of digitalization are often insufficient to offset the significant investments in capital and human resources, thus, it generally has an inhibiting effect on the bank's operational performance in the short term. But as financial technology continues to evolve and technical support across various industries keeps strengthening, the scale effects of digital transformation gradually emerge. This transformation not only improves the bank's profitability but also significantly enhances its operational efficiency. By optimizing business processes and reducing redundant steps, banks have successfully reduced operational costs. At the same time, by leveraging advanced technologies such as big data and artificial intelligence, banks' risk management capabilities have been greatly improved, enabling them to better cope with market fluctuations and credit risks. These positive changes collectively drive the improvement of commercial banks' operational performance, ultimately manifesting as a promotional effect. Therefore, although digital transformation may face some challenges and pressure in terms of investment in the early stages, in the long run, this strategic transformation

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will bring broader development opportunities and a more robust operational foundation for commercial banks.

Thus, the impact of the enhancement of commercial banks' digital level on bank performance manifests as a "U-shaped" effect that initially suppresses and then promotes, confirming Hypothesis 1.

Table 4. Regression Results of Commercial Bank Digital Transformation and Operational Performance (ROA) Main Regression Results

Variable	(1)	(2)	(3)	(4)
	ROA	ROA	ROA	ROA
Index	0.0005	-0.0052***	0.0000	-0.0031***
	(0.8287)	(-4.1244)	(0.0690)	(-3.1204)
$Index^2$		0.0035***		0.0020***
		(5.4428)		(3.8273)
Size			-0.0012**	-0.0009*
			(-2.3902)	(-1.8107)
Age			0.0009	0.0015**
			(1.5072)	(2.2534)
Lev			-0.0090	-0.0102
			(-1.1450)	(-1.3755)
Growth			0.0030***	0.0028***
			(4.7619)	(4.6090)
Loanratio			-0.0010	-0.0012
			(-0.5218)	(-0.6313)
Jlc			-0.0627***	-0.0540**
			(-2.7301)	(-2.4568)
Cost			0.6198***	0.6201***
			(7.1666)	(7.5573)
Mks			0.0122	0.0104
			(0.8965)	(0.7579)
Cir			-0.0236***	-0.0219***
			(-8.5700)	(-8.4027)
Npl			-0.0341	-0.0340
			(-1.5873)	(-1.5868)
GDP			-0.0013	-0.0019*
			(-1.1541)	(-1.6749)
CPI			0.0002	0.0002
			(0.7415)	(1.0821)
_Cons	0.0062***	0.0081***	0.0492	0.0403
	(9.5723)	(11.5587)	(1.5068)	(1.2675)
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	1825	1825	1825	1825
adj.R^2	0.502	0.530	0.660	0.667

Note: *, **, *** represent that the coefficient estimates are significant at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the robust standard errors.

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Table 5. Regression Results of Commercial Bank Digital Transformation and Operational Performance (ROE) Main Regression Results

Variable	(5)	(6)	(7)	(8)
	ROE	ROE	ROE	ROE
Index	-0.0248**	-0.0719***	-0.0130*	-0.0448***
	(-2.5778)	(-4.1148)	(-1.6600)	(-3.3436)
$Index^2$		0.0285***		0.0204***
		(2.9547)		(2.7843)
Size			-0.0154**	-0.0119
			(-2.0984)	(-1.6502)
Age			0.0190**	0.0247***
			(2.4208)	(3.0246)
Lev			0.8641***	0.8516***
			(11.5712)	(11.9558)
Growth			0.0193**	0.0176*
			(1.9996)	(1.8379)
Loanratio			-0.0379	-0.0397
			(-1.4186)	(-1.5337)
Jlc			-0.5106	-0.4215
			(-1.5431)	(-1.3031)
Cost			6.1490***	6.1524***
			(6.0246)	(6.2342)
Mks			0.0268	0.0085
			(0.1776)	(0.0538)
Cir			-0.2570***	-0.2403***
			(-7.4282)	(-7.2416)
Npl			-0.4547*	-0.4542*
			(-1.7246)	(-1.7234)
GDP			-0.0131	-0.0196
			(-0.7394)	(-1.0957)
CPI			0.0046*	0.0053**
			(1.7201)	(2.0074)
_Cons	0.1106***	0.1259***	-0.5923	-0.6835*
	(11.5145)	(12.8234)	(-1.4316)	(-1.6765)
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	1825	1825	1825	1825
adj.R^2	0.566	0.574	0.695	0.698

Note: *, **, *** represent that the coefficient estimates are significant at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the robust standard errors.

5.2. Robustness Test

5.2.1. Replacement of the Dependent Variable

Due to the lack of uniformity in the measurement of Return on Assets (ROA), the dependent variable ROA (ROA1) is replaced with the ratio of net profit to year-end assets. Table 6 reports the regression results. The estimation results are consistent with the hypothesized results, indicating that the regression results are robust.

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Table 6. Robustness Test 1: Replacement of the Dependent Variable

Variable	(1)	(2)	(3)	(4)
	ROA1	ROA1	ROA1	ROA1
Index	0.0016**	-0.0037***	0.0007	-0.0022***
	(2.5471)	(-3.2381)	(1.4787)	(-2.7384)
$Index^2$		0.0031***		0.0018***
		(5.4790)		(4.2571)
Size			-0.0005	-0.0001
			(-1.1729)	(-0.3310)
Age			0.0008	0.0014**
			(1.5003)	(2.3064)
Lev			-0.0066	-0.0080
			(-1.1293)	(-1.4382)
Growth			-0.0007	-0.0008*
			(-1.3371)	(-1.6837)
Loanratio			0.0007	0.0007
			(0.4176)	(0.4409)
Jlc			-0.0344*	-0.0263
			(-1.9708)	(-1.6211)
Cost			0.6305***	0.6248***
			(8.1055)	(8.4597)
Mks			0.0093	0.0066
			(0.6744)	(0.4846)
Cir			-0.0239***	-0.0223***
			(-11.0957)	(-10.5757)
Npl			-0.0880***	-0.0885***
			(-4.4129)	(-4.6264)
GDP			-0.0012	-0.0018**
			(-1.4258)	(-2.1122)
CPI			0.0000	0.0001
			(0.0276)	(0.3354)
_Cons	0.0048***	0.0064***	0.0409	0.0319
	(7.3138)	(9.5230)	(1.5937)	(1.2706)
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	1684	1684	1684	1684
adj. R^2	0.493	0.520	0.706	0.713

Note: *, **, *** represent that the coefficient estimates are significant at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the robust standard errors.

5.2.2. Reverse Causation

The enhancement of a bank's digitalization level may promote the bank to improve its operational efficiency, and at the same time, the improvement in operational efficiency may lead to an increase in the bank's digital transformation investment, thereby raising its digitalization level. This can create a problem of reverse causation. In this paper, the explanatory variable is lagged by one period to avoid the endogeneity caused by reverse causation, and Table 7 reports the regression results. The estimation results are consistent with the hypothesized results, indicating that the regression results are robust.

5.2.3. Endogeneity Issue — Two-Stage Least Squares Estimation (2SLS)

In addition to the variables and effects controlled in the benchmark model, there may still be endogeneity issues caused by other factors. Following the approach of He Xiaogang (2023), this

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paper constructs two variables as instrumental variables: "the average digital transformation index (averageindex) of other banks of the same type in the same year, excluding the sample bank" and "the square of the average digital transformation index (averageindex2) of other banks of the same type in the same year, excluding the sample bank." The results of the re-estimation of the variables are shown in Table 8. After addressing the endogeneity issue, the research conclusions remain robust.

Table 7. Robustness Test 2: Lagged Explanatory Variable by One Period

Variable	(1)	(2)	(3)	(4)
	ROA	ROA	ROA	ROA
L.Index	0.0005 (0.6929)	-0.0045*** (-3.7131)	-0.0002 (-0.4990)	-0.0025*** (-2.6255)
L.Index^2		0.0031*** (4.9334)		0.0015*** (2.8162)
Size			-0.0013** (-2.2667)	-0.0011* (-1.8255)
Age			0.0007 (0.8701)	0.0011 (1.3384)
Lev			-0.0133 (-1.3701)	-0.0138 (-1.4647)
Growth			0.0034*** (5.0825)	0.0033*** (4.9750)
Loanratio			-0.0006 (-0.2994)	-0.0005 (-0.2263)
Jlc			-0.0759*** (-3.0626)	-0.0700*** (-2.8863)
Cost			0.6364*** (7.3283)	0.6347*** (7.6269)
Mks			0.0118 (1.0041)	0.0092 (0.7725)
Cir			-0.0228*** (-7.8099)	-0.0218*** (-7.7523)
Npl			-0.0663*** (-3.3427)	-0.0657*** (-3.3548)
GDP			-0.0016 (-1.3411)	-0.0020* (-1.6969)
CPI			0.0001 (0.4475)	0.0002 (0.7445)
_Cons	0.0062*** (9.4526)	0.0077*** (11.2407)	0.0648* (1.8109)	0.0547 (1.5040)
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	1657	1657	1657	1657
adj. R^2	0.517	0.537	0.684	0.688

Note: *, **, *** represent that the coefficient estimates are significant at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the robust standard errors.

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5.2.4. Endogeneity Issue — System Generalized Method of Moments Estimation (SYS-GMM)

Due to the particular nature of bank operations, their operational income often exhibits a high degree of persistence. Therefore, the lag of one period for the explanatory variable is introduced, and a dynamic panel is used for the SYS-GMM estimation to mitigate endogeneity issues in the model. The regression estimation results are shown in Table 9, and the SYS-GMM estimation results are presented in columns (3) and (4) of Table 8. The P-values for AR(1) are both 0, indicating that there is a significant first-order serial correlation in the difference of the random disturbance term; the P-values for AR(2) are 0.995 and 0.937, respectively, indicating that there is no second-order serial correlation in the random disturbance term. The results show that the coefficients of the dependent variable and its square term are both significant at the 1% level, which is consistent with the conclusion that the impact of the degree of digitalization on the performance of commercial banks shows a "U-shaped" effect of initial suppression followed by promotion. The regression results are robust.

Table 8. Robustness Test 3: Instrumental Variables Method

	(1)	(2)	(3)
	First-Stage Regression Index	First-Stage Regression Index^2	Second-Stage Regression ROA
IV	0.2839** (2.1192)	-0.4643** (-2.0042)	
IV2	0.1434*** (2.8599)	0.9273*** (10.6923)	
Size	0.0868*** (3.8834)	0.0579 (1.4988)	-0.0005 (-1.0686)
Age	-0.1501*** (-5.2981)	-0.3580*** (-7.3055)	0.0011** (1.9748)
Lev	-0.9079*** (-3.1777)	-0.6069 (-1.2283)	-0.0136*** (-2.7014)
Growth	-0.0393 (-1.1599)	-0.0197 (-0.3364)	0.0027*** (5.5737)
Loanratio	0.2632*** (3.4063)	0.4520*** (3.3830)	-0.0004 (-0.2953)
Jlc	0.9626 (1.0502)	-0.6739 (-0.4252)	-0.0510*** (-3.9223)
Cost	2.6857 (0.8887)	4.0650 (0.7778)	0.6283*** (15.1591)
Mks	-2.3334*** (-3.7264)	-4.8277*** (-4.4584)	0.0053 (0.5536)
Cir	-0.1842** (-2.3120)	-0.9083*** (-6.5922)	-0.0218*** (-17.5021)
Npl	-0.0735 (-0.1952)	-0.3375 (-0.5186)	-0.0331*** (-6.5135)
GDP	0.0567 (1.3594)	0.3359*** (4.6567)	-0.0022*** (-3.3480)
CPI	-0.0276*** (-2.6283)	-0.0614*** (-3.3785)	0.0002 (1.0954)
_Cons			-0.0073* (-1.7005)
Index			0.0030** (2.2827)
Index^2	1.6523 (1.2555)	3.3112 (1.4549)	0.0450** (2.4651)
Bank FE	YES	YES	YES
Year FE	YES	YES	YES
N	1825	1825	1825
adj. R^2	0.775	0.691	0.656

Note: *, **, *** represent that the coefficient estimates are significant at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the robust standard errors.

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6. HETEROGENEITY ANALYSIS

According to existing literature, commercial banks with different characteristics may exhibit varied performance during the digital transformation process, leading to differences in the impact of the improvement of digital levels on the operational performance of commercial banks. This paper conducts a heterogeneity analysis from three aspects: whether the commercial bank is listed, the level of development of digital finance, and the level of development of financial technology.

6.1. Commercial Banks' Listing Status

The listing status of a commercial bank is an indicator of its financial strength, operational system maturity, and comprehensive human resource allocation, which provides

Table 9. Robustness Test 4: System Generalized Method of Moments Estimation (SYS-GMM)

Variable	(1)	(2)	(3)	(4)
	ROA	ROA	ROA	ROA
L.ROA			0.8005***	0.7965***
			(14.6830)	(23.1929)
Index	0.0000	-0.0031***	-0.0001	-0.0012*
	(0.0690)	(-3.1204)	(-0.2063)	(-1.9251)
Index^2		0.0020***		0.0008**
		(3.8273)		(2.4585)
Size	-0.0012**	-0.0009*	-0.0009**	-0.0009***
	(-2.3902)	(-1.8107)	(-2.2216)	(-3.1516)
Age	0.0009	0.0015**	0.0004	0.0006
	(1.5072)	(2.2534)	(0.6750)	(1.2126)
Lev	-0.0090	-0.0102	-0.0196***	-0.0184***
	(-1.1450)	(-1.3755)	(-2.8566)	(-3.8602)
Growth	0.0030***	0.0028***	0.0015*	0.0015***
	(4.7619)	(4.6090)	(1.9066)	(2.8266)
Loanratio	-0.0010	-0.0012	-0.0044*	-0.0042***
	(-0.5218)	(-0.6313)	(-1.9082)	(-2.8396)
Jlc	-0.0627***	-0.0540**	0.0039	0.0041
	(-2.7301)	(-2.4568)	(0.2504)	(0.3365)
Cost	0.6198***	0.6201***	0.2499***	0.2509***
	(7.1666)	(7.5573)	(3.3789)	(4.8692)
Mks	0.0122	0.0104	0.0084	0.0088
	(0.8965)	(0.7579)	(1.2729)	(1.5490)
Cir	-0.0236***	-0.0219***	-0.0078***	-0.0078***
	(-8.5700)	(-8.4027)	(-2.7916)	(-3.8677)
Npl	-0.0341	-0.0340	-0.0116	-0.0111
	(-1.5873)	(-1.5868)	(-0.6816)	(-0.9231)
GDP	-0.0013	-0.0019*	0.0017*	0.0016***
	(-1.1541)	(-1.6749)	(1.7785)	(2.7167)
CPI	0.0002	0.0002	0.0002	0.0002*
	(0.7415)	(1.0821)	(1.4667)	(1.8888)
_Cons	0.0492	0.0403	0.0040	0.0048
	(1.5068)	(1.2675)	(0.1854)	(0.2954)
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	1825	1825	1657	1657
adj. R^2	0.660	0.667	—	—
AR(1)	—	—	0.000	0.000
AR(2)	—	—	0.995	0.937
Sargan	—	—	0.2459	0.2221

Note: *, **, *** represent that the coefficient estimates are significant at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the robust standard errors.

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ample capital to cope with the digital transformation of the bank. In Table 10, columns (1) and (2) present the results of the heterogeneity test for whether the bank is listed or not. The results show that non-listed commercial banks experience a greater degree of improvement in operational performance with the enhancement of digitalization levels, and the "U-shaped" effect is more pronounced. This may be because listed commercial banks have relatively stable operational performance and internal operational mechanisms with strong risk resistance capabilities. As digitalization levels increase, although there will be certain impacts on operational activities, these impacts are not as significant as those on non-listed banks. Listed commercial banks, due to their substantial financial resources and extensive operational experience, can more smoothly handle various challenges during the digital transformation process, resulting in relatively smaller fluctuations in operational performance. In contrast, non-listed banks may face more uncertainties and risks during the digital transformation process, leading to more significant fluctuations in operational performance. Therefore, the impact of digital transformation on the operational performance of listed commercial banks is relatively moderate.

6.2. Level of Digital Finance Development

The level of digital finance development in the location where a commercial bank is registered reflects, to some extent, the impact of the external digitalization level on the operational performance of commercial banks. Based on the inclusive finance index of the commercial bank's registration location, the level of digital finance development is divided into high and low groups. In Table 10, columns (3) and (4) present the results of the heterogeneity test for the level of digital inclusive finance development. The results show that commercial banks in areas with a lower level of digital finance development experience a more significant impact on their operational performance due to the bank's digital transformation, and the "U-shaped" effect is also more pronounced.

The possible reason is that in areas with a higher level of digital finance development, the level of digital transformation in commercial banks is also correspondingly higher. These areas typically have intense financial competition, not only among financial institutions but also with the active participation of non-financial institutions, making the business environment more diverse and complex. In such a competitive environment, financial innovation becomes an important way for commercial banks to enhance their competitiveness, but it also means that higher costs are required. These costs may include investment in technology research and development, talent training expenses, and market promotion expenditures.However, there is a certain offsetting effect between the economic benefits brought about by the improvement of the bank's digital level and the costs of these financial innovations. On the one hand, digital transformation can improve bank business efficiency and optimize customer experience, thereby increasing revenue. On the other hand, the high cost of innovation may also put some pressure on the bank's profitability. Therefore, in empirical testing, this balance between economic benefits and costs may lead to a reduction in the significance of the results.

In summary, in areas with a higher level of digital finance development, the level of digital transformation in commercial banks is high, but the competition in business is fierce, and the cost of financial innovation is high. These factors may jointly contribute to a reduction in the significance of the empirical test results.

6.3. Level of Financial Technology Development

The level of financial technology development in commercial banks is closely linked to the internal digitalization level of the banks. The more mature the financial technology development, the higher the internal digitalization level is likely to be. By dividing the level of financial technology development into high and low groups, Table 10, columns (5) and (6)

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present the results of the heterogeneity test for the level of financial technology development. The results show that commercial banks with a lower level of financial technology development experience a more significant impact on their operational performance due to the bank's digital transformation, and the "U-shaped" effect is also more pronounced.The possible reason is that for commercial banks with a lower level of financial technology development, they often need to invest more resources and costs in the initial stages of digital transformation. This is because these banks need to build or update infrastructure, introduce advanced technologies, train employees, and optimize business processes to meet the demands of the digital age. These high investments can have a significant impact on the bank's operational performance, potentially increasing operational costs and reducing profitability in the short term. However, as digital transformation progresses and the level of digitalization increases, these commercial banks will gradually reap the benefits of digital transformation. Their competitiveness will be significantly enhanced, allowing them to better meet customer needs and improve service efficiency and quality. At the same time, due to the effects of decreasing marginal costs and increasing marginal benefits, as banks expand their business scale, the per-unit cost will gradually decrease, while the per-unit benefit will gradually increase. This means that as digital transformation advances, the operational performance of commercial banks will gradually improve, achieving sustainable development.

Table 10. Heterogeneity Test Results

	Listed or not		Digital Finance Development		Financial Technology	
	(1) YES ROA	(2) NO ROA	(3) high ROA	(4) low ROA	(5) high ROA	(6) low ROA
Index	0.0003 (0.2258)	-0.0043*** (-3.4142)	-0.0010 (-1.0739)	-0.0028** (-2.0197)	-0.0012 (-1.0544)	-0.0047*** (-3.1865)
Index^2	0.0000 (0.0497)	0.0027*** (3.4738)	0.0005 (1.2062)	0.0025* (1.9230)	0.0009 (1.4710)	0.0024** (2.3644)
Size	0.0001 (0.1702)	-0.0010 (-1.5838)	0.0004 (0.3308)	0.0001 (0.1138)	0.0005 (0.7560)	-0.0007 (-0.9192)
Age	0.0014* (1.8873)	0.0015* (1.7485)	-0.0004 (-0.3572)	0.0039*** (3.7483)	0.0011 (1.5416)	0.0017* (1.9213)
Lev	-0.0165** (-2.0908)	-0.0089 (-1.0898)	0.0145 (1.5719)	-0.0299*** (-3.1555)	0.0044 (0.4018)	-0.0255** (-2.5918)
Growth	0.0047*** (4.5561)	0.0024*** (3.4992)	0.0024*** (2.7448)	0.0020** (2.5171)	0.0041*** (4.2369)	0.0017* (1.9179)
Loanratio	0.0054** (2.1247)	-0.0017 (-0.8079)	-0.0040* (-1.9679)	-0.0009 (-0.2535)	0.0030 (1.2009)	-0.0016 (-0.5806)
Jlc	-0.0249 (-1.1261)	-0.0736** (-2.4365)	-0.0430 (-1.5069)	-0.0045 (-0.1544)	-0.0038 (-0.1644)	-0.0606* (-1.7325)
Cost	0.6747*** (5.2770)	0.6053*** (6.5796)	0.4869*** (5.3875)	0.3949*** (3.2427)	0.6832*** (7.0440)	0.4185*** (3.7280)
Mks	-0.0051 (-0.4594)	0.0126 (0.5701)	0.0224 (1.5064)	0.0311 (1.6127)	-0.0103 (-0.6784)	0.0459 (1.0573)
Cir	-0.0218*** (-4.9943)	-0.0216*** (-7.5067)	-0.0129*** (-3.3670)	-0.0207*** (-4.0568)	-0.0248*** (-8.0626)	-0.0156*** (-4.2031)
Npl	-0.0549*** (-3.0246)	-0.0282 (-1.2491)	-0.0167* (-1.7203)	-0.0370* (-1.8952)	-0.0099 (-0.4990)	-0.0586*** (-3.2671)
GDP	-0.0024 (-1.5184)	-0.0022* (-1.7088)	0.0022** (2.3118)	-0.0047* (-1.9349)	-0.0009 (-0.6438)	-0.0015 (-0.8904)
CPI	-0.0002 (-1.2276)	0.0003 (1.2318)	0.0001 (0.9137)	0.0003 (0.8726)	0.0003 (1.3567)	0.0005 (1.5184)
_Cons	0.0665* (1.9869)	0.0320 (0.8059)	-0.0521 (-1.2860)	0.0514 (1.2314)	-0.0286 (-0.8835)	0.0137 (0.2780)
Bank FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	484	1341	714	734	801	802
adj. R^2	0.754	0.666	0.395	0.531	0.606	0.694

Note: *, **, *** represent that the coefficient estimates are significant at the 10%, 5%, and 1% levels, respectively, and the numbers in parentheses are the robust standard errors.

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Therefore, although commercial banks with a lower level of financial technology development face greater cost pressures and operational challenges in the early stages of digital transformation, in the long term, digital transformation will bring them higher competitiveness and better operational performance.

That is, the impact of the improvement of digitalization levels on the operational performance of commercial banks varies with whether the bank is listed, the level of digital finance development in the registration location, and the level of financial technology development, confirming Hypothesis 2.

7. CONCLUSION AND IMPLICATION

Based on the theoretical and empirical analysis in this paper, the study finds that: the enhancement of commercial banks' digitalization level (internal financial technology) has a "U-shaped" effect on bank performance, which first suppresses and then promotes. Non-listed banks, banks with lower levels of digital finance development in their registration locations, and banks with lower levels of financial technology development exhibit a more pronounced "U-shaped" effect compared to listed banks, banks with higher levels of digital finance development in their registration locations, and banks with higher levels of financial technology development.

The research conclusions of this paper offer the following insights:

1. Commercial banks should focus on improving their digitalization level and actively embrace financial innovation to enhance their core competitive advantages and keep pace with the times and policy directions. In terms of talent reserves, strategic planning, and system platform construction, commercial banks need to comprehensively promote digital transformation. By deeply integrating financial innovation with technological innovation, formulating personalized marketing and service strategies, achieving full online business operations, and effectively reducing operational costs, banks can further solidify their competitive foundation and ultimately enhance overall operational performance. This transformation process not only helps banks adapt to the development trend of the digital age but also enables them to gain a competitive edge in the future financial market.

2.Commercial banks need to strengthen resource management and talent cultivation. In the process of promoting the enhancement of commercial banks' digitalization level, resource management is particularly important. Especially in the context of the booming digital economy, the digitalization of customer resources has become a key part of bank transformation. As bank business increasingly relies on digital resources, enhancing data analysis and mining capabilities becomes crucial. Effectively collecting and utilizing digital resources can not only help banks understand customer needs more accurately but also provide strong support for business decision-making. The recruitment and training of digital talent are an indispensable part of improving digitalization levels. Commercial banks should establish a comprehensive talent training system and increase investment and management efforts in digital talent. By setting up incentive mechanisms, they can stimulate the innovative vitality and learning motivation of internal employees, forming a professional team with digital thinking and skills.

3. Financial regulatory authorities and commercial banks themselves must strengthen strict monitoring and effective prevention of risks during the process of enhancing digitalization levels, always being vigilant about potential systemic risks. With the enhancement of commercial banks' digitalization levels, a large amount of data and information is stored digitally, and bank business increasingly relies on online channels. Under this background, banks should further strengthen the management of digital resources to ensure that information security is not compromised. At the same time, regular inspection and maintenance of digital equipment are also crucial to prevent operational risks and internal risks caused by system failures. Financial regulatory authorities need to improve the supervision and

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management system and strengthen the monitoring and prevention mechanisms for risks. By strengthening compliance supervision of banks and other financial institutions, they can ensure standardized business operations and protect the financial security and information security of customers. In addition, regulatory authorities should work closely with commercial banks to jointly prevent systemic risks and maintain the stability and healthy development of the financial market. Through the joint efforts of both parties, the security and robustness of commercial banks' digital transformation can be effectively enhanced, aiding the sustainable development of the financial industry.

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