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The Influence of asset size during digital transformation on the economic efficiency of banks

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Abstract

This study examines how asset size influences the effectiveness of digital transformation initiatives in Chinese commercial banks. Despite substantial investments in digital technologies across the banking sector, transformation outcomes exhibit significant heterogeneity, prompting investigation into institutional characteristics that moderate effectiveness. Using panel data from 37 Chinese commercial banks categorized by asset size, this research employs fixed-effects regression models to analyze the relationship between digital transformation intensity and return on equity. Digital transformation is quantified through systematic textual analysis of annual reports, constructing a comprehensive index capturing transformation intensity. The empirical findings reveal that while digital transformation generally enhances banking performance, asset size significantly moderates this relationship. Large banks (assets exceeding 2 trillion yuan) demonstrate a positive transformation coefficient of 2.038, medium banks (300 billion -2 trillion yuan) exhibit an even stronger coefficient of 4.584, while small banks (below 300 billion yuan) show a negative coefficient of - 0.122. These heterogeneous outcomes are attributable to resource-dependent implementation capabilities, with larger institutions benefiting from economies of scale, superior talent acquisition, and comprehensive implementation frameworks. Medium-sized institutions potentially achieve optimal balance between resource adequacy and operational flexibility, explaining their pronounced transformation efficacy. The SA Bank case study provides contextual validation, demonstrating substantial performance improvements following digital implementation across multiple dimensions. This research contributes to strategic consistency theory, IT capability framework, and resource-based perspectives by identifying asset size as a critical moderator of transformation success, providing practical insights for banking executives and regulators regarding asset-appropriate digital strategies.

Keywords: ECONOMIC, FINANCIAL REFORM AND INNOVATION; DIGITAL TRANSFORMATION OF COMMERCIAL BANKS; COPING STRATEGY, ASEET SIZE

Introduction

Digital transformation, as the advanced form of the evolution of the information age, its profound connotation goes far beyond the simple technical category, but forms a sharp contrast with the essential characteristics of the information age [1].

This process is not limited to innovation at the technical level, but also a comprehensive reshaping involving multiple dimensions such as corporate strategy, cultural philosophy, organizational structure, infrastructure and operation model. Through the introduction and integration of advanced information technologies, digital transformation aims to significantly enhance the operational efficiency and market competitiveness of enterprises, thereby enabling them to better adapt to and lead the wave of the digital economy. In this transformation process, enterprises need to abandon the traditional mode of thinking, actively embrace innovation, and deeply integrate information technology into every link of business development. This can not only promote the systematic change of enterprises, but also win the opportunity to achieve sustainable development in the fierce market competition [2]. Therefore, digital transformation is not only the embodiment of technological progress, but also an important driving force for strategic transformation and upgrading of enterprises.

The three characteristics of digital transformation are particularly significant: First, it focuses on meeting customer needs and is committed to providing personalized, high-quality digital service experiences to ensure the sustainable development of enterprises. Secondly, digital transformation attaches importance to the creation of business value, and opens up new areas through cutting-edge technologies such as artificial intelligence and cloud computing, captures new opportunities for development, and helps enterprises achieve long-term growth. Finally, it requires enterprises to change their operation mode, optimize their management mode, keep up with the trend of the financial industry, and promote the transformation and upgrading of commercial banks with innovation and change.

The practice of digital transformation is the cornerstone for its concept to be deepened and perfected. By integrating cutting-edge digital technologies into daily operations and management, companies can significantly improve business performance and stand out from the fierce market competition. This practice has not only brought remarkable results for the short-term development of the enterprise, but also laid a solid foundation for its long-term stable growth. Digital transformation is not just about improving efficiency or reducing costs, its far-reaching significance is to lead enterprises in the era of digital economy, seize opportunities, respond to challenges, and create a more brilliant future [3]. Through digital transformation, companies are able to better understand market needs, optimize products and services, and enhance the customer experience, so that they can remain invincible in the tide of the digital economy and achieve sustainable development.

Nowadays, financial technology has ushered in new development opportunities and shown good prospects for development. Domestic commercial banks have successively adopted digital transformation programs to enhance the

innovation and creativity of enterprises through the reference of advanced digital technologies, and develop and design a variety of innovative products and services to meet the differentiated and personalized needs of consumers [4].

A particularly underexplored dimension in this domain is the role of asset size in determining the efficacy of digital transformation initiatives. Theoretical perspectives, including the enterprise resource view and IT capability theory, suggest that resource endowment constitutes a critical factor in technological implementation. Given that asset size fundamentally influences a bank's resource allocation capacity, technological infrastructure, and talent acquisition potential, it logically follows that transformation outcomes may exhibit systematic variations across different asset-size categories [5, 6]. Nevertheless, empirical investigations examining this relationship remain conspicuously scarce, creating a substantive lacuna in our understanding of digital transformation dynamics in the financial sector.

The primary objective of this research is to empirically investigate the relationship between digital transformation intensity and financial performance metrics across commercial banks of varying asset sizes.

This study aims to:

- quantify the digital transformation efforts of commercial banks using a comprehensive index system;
- examine the relationship between digital transformation and operational performance;
- analyze how this relationship is moderated by institutional asset size;
- derive strategic implications for transformation optimization across different bank categories.

Through rigorous statistical analysis of panel data from 37 Chinese commercial banks, encompassing large state-owned entities, joint-stock institutions, and regional banking establishments, this research endeavors to delineate the asset-specific dynamics of digital transformation effectiveness.

The significance of this investigation extends across both theoretical and practical dimensions. From a theoretical perspective, it contributes to the enrichment of digital transformation literature by introducing asset size as a critical moderating variable, thereby enhancing the explanatory power of existing models. The findings serve to refine our understanding of strategic consistency theory, IT capability view, and resource-based perspectives within the specific context of financial institutions [7-10]. From a practical standpoint, the research provides empirically-grounded insights for banking executives regarding the formulation of asset-appropriate digital strategies, resource allocation optimization, and capability development priorities. Furthermore, it offers valuable guidance for regulatory authorities concerning policy formulation in the domain of financial technology and digital banking.

Research Methodology

Sample Selection and Data Collection

This research employs a comprehensive methodological framework for examining the relationship between digital transformation intensity and financial

performance across commercial banks of varying asset sizes. The sample selection process was systematically structured to ensure representativeness across the diverse spectrum of Chinese banking institutions, resulting in the inclusion of 37 domestic commercial banks encompassing multiple ownership structures and operational scales. This stratified sample comprises 6 large state-owned commercial banks (Agricultural Bank of China, China Construction Bank, ICBC, Bank of Communications, Bank of China, and Postal Savings Bank), 8 joint-stock banking institutions (Everbright, CITIC, Minsheng, Huaxia, China Merchants, Industrial, Zheshang, and Shenzhen Development), 15 city commercial banks (distributed across major urban centers including Nanjing, Beijing, Ningbo, Chongqing, Shanghai, Chengdu, Xi'an, Hangzhou, Guiyang, Xiamen, Zhengzhou, Jiangsu, Suzhou, Qingdao, and Changsha), and 8 rural commercial banking entities (Qingrural Commercial Bank, Zhangjiagang Bank, Zijin Rural Commercial Bank, Wuxi Rural Commercial Bank, Chongqing Rural Commercial Bank, Suzhou Rural Commercial Bank, Jiangyin Bank, and Changshu Bank). The stratification of the sample facilitates nuanced comparative analysis of transformation efficacy across different institutional categories, thereby enhancing the generalizability and contextual relevance of research findings. The empirical investigation employs panel data with unbalanced characteristics, necessitating the adoption of appropriate econometric techniques to ensure statistical consistency despite structural asymmetries in the dataset. The data collection methodology incorporates multiple complementary sources to ensure comprehensiveness and accuracy of information.

Variable Measurement

The empirical analysis necessitates precise operationalization of the conceptual variables to ensure measurement validity and facilitate robust statistical inference. The selection and construction of variables were systematically undertaken to capture the multidimensional nature of the research constructs while ensuring analytical tractability and interpretability of findings.

The dependent variable employed in this investigation is Return on Equity (ROE), representing "the result of the ratio of net profit to mean net assets" as indicated in the methodological framework. This financial metric serves as a comprehensive indicator of banking performance, reflecting institutional profitability relative to shareholder investments. The selection of ROE as the primary performance indicator aligns with established banking literature, which recognizes its significance in capturing operational efficiency and financial sustainability. The ROE calculation methodology adheres to standardized accounting principles, ensuring cross-institutional comparability and temporal consistency.

The descriptive statistics for these variables indicate substantial heterogeneity across the sampled institutions, providing the necessary variance for meaningful statistical inference. The correlation analysis reveals significant relationships between several control variables and the dependent variable (ROE), with GDP growth rate, debt-to-asset ratio, equity multiplier, loan loss provision ratio, capital adequacy ratio, and non-performing loan provision coverage ratio all

demonstrating statistical significance at the 1% level. These correlation patterns underscore the importance of incorporating these control variables in the analytical framework to isolate the specific impact of digital transformation on performance outcomes while accounting for potential confounding influences.

Model Specification

The empirical examination of the relationship between digital transformation intensity and banking performance necessitates the application of sophisticated econometric methodologies that account for the complex structure of panel data and the potential presence of unobserved heterogeneity across institutions. Following comprehensive diagnostic procedures, this research employs fixed effects regression models to analyze the relationship between digital transformation and performance outcomes, with subsidiary specifications examining the moderating influence of asset size.

The foundational regression model is formulated to examine the direct relationship between digital transformation and return on equity, incorporating multiple control variables to mitigate potential confounding effects. The principal regression equation is structured as follows:

$$ROEit = \alpha + \beta_1 InCountit + \beta_2 GDPgroit + \beta_3 Levit + \beta_4 CARit + \beta_5 ProvCovit + \beta_6 EMit + \beta_7 LoanResevit + \mu_i + \varepsilon it,$$

where,

ROEit - represents the return on equity for institution i in period t;

InCountit - denotes the digital transformation intensity index derived through textual analysis, and the subsequent terms represent control variables:

GDPgroit - GDP growth rate;
Levit - debt-to-asset ratio;
CARit - capital adequacy ratio,
ProvCovit - non-performing loan provision coverage;
EMit - equity multiplier;
LoanResevit - loan loss provision adequacy ratio.

The term μ_i captures institution-specific unobserved heterogeneity that remains constant over time, while εit represents the idiosyncratic error term varying across institutions and time periods.

The selection of the fixed effects specification follows rigorous diagnostic testing to determine the appropriate estimation methodology. The F-test examines the null hypothesis that all institution-specific effects equal zero (HO: all $\mu i = 0$), with rejection indicating the presence of significant heterogeneity across institutions and necessitating panel data techniques rather than pooled ordinary least squares estimation.

The robustness checking methodology incorporates alternative specifications to validate the stability and reliability of primary findings. The principal approach involves substituting the dependent variable with an alternative performance metric - return on assets (ROA) - while maintaining identical

specifications for independent, moderating, and control variables. This substitution enables assessment of whether the observed relationship between digital transformation and performance remains consistent across different performance indicators. As detailed in the methodology framework, "after the index adjustment, the regression analysis model did not change, and it was still completed with the help of the effect model," indicating consistency in analytical approach despite the alteration in dependent variable. The robustness analysis reveals that "there is no significant difference between the regression results before and after replacement and the regression results obtained above, which means that the hypothesis proposed in the paper is valid," thereby substantiating the reliability of primary findings.

Additional robustness checks include reestimation of models with alternative functional forms (including logarithmic transformations of key variables), alternative estimation techniques (including random effects and pooled ordinary least squares specifications), and alternative control variable configurations. The consistent pattern of findings across these alternative specifications provides further validation of the principal results, enhancing confidence in the empirical relationship between digital transformation, asset size, and banking performance. The comprehensive robustness checking methodology ensures that findings are not artifacts of specific analytical choices but represent robust empirical relationships that persist across various methodological approaches.

Results and discussion.

Descriptive Statistics

The descriptive statistical analysis provides foundational insights into the distributional characteristics of principal variables and their interrelationships, establishing the empirical platform for subsequent regression analysis. Table 1 presents comprehensive summary statistics for all variables incorporated in the analytical framework, encompassing 234 observations across 37 banking institutions.

The return on equity (ROE), serving as the primary dependent variable, exhibits substantial variability with a mean value of 15.645% and a standard deviation of 5.445%. The distribution parameters indicate considerable heterogeneity in institutional profitability, with minimum and maximum values of 2.956% and 32.729% respectively.

Notably, the observations with ROE values below 5% predominantly correspond to the 2020 fiscal period, a phenomenon attributable to "the outbreak of the new crown epidemic which has caused the income of the financial industry to decline more or less" as indicated in the contextual analysis.

Table 1. Descriptive Statistics of Variables

Variable	Obs	Mean	Std.Dev	Min	Max
ROE	234	15.645	5.445	2.956	32.729
InCount	234	7.076	0.418	5.649	7.955
GDPgro	234	0.075	0.027	0.024	0.149
Lev	234	97.923	1.554	91.655	102.617
CAR	234	13.503	2.480	2.415	25.326
ProvCov	234	251.160	103.352	34.829	687.120
EM	234	17.105	5.480	8.394	46.263
LoanResev	234	511.245	267.960	77.417	2181

Note: The table shows summary statistics for all variables in the analysis across 234 observations from 37 banking institutions. ROE represents return on equity, InCount is the digital transformation index, GDPgro is GDP growth rate, Lev is debt-to-asset ratio, CAR is capital adequacy ratio, ProvCov is non-performing loan provision coverage, EM is equity multiplier, and LoanResev is loan loss provision adequacy ratio.

The digital transformation intensity index (InCount), constructed through sophisticated textual analysis of annual reports, demonstrates more constrained variability with a mean value of 7.076 and a standard deviation of 0.418. The relatively modest standard deviation "changes relatively little, which means that there is no obvious difference in the degree and effect of digital transformation among commercial banks" as indicated in the analytical framework. However, this apparent homogeneity becomes more nuanced when examined across different asset categories, with large-asset institutions demonstrating a mean InCount value of 7.359, medium-asset institutions exhibiting a mean value of 6.927, and small-asset entities showing a mean value of 6.813. This progressive pattern aligns with theoretical expectations regarding resource-based advantages in digital transformation, with "the effect of digital transformation... proportional to the asset scale. The larger the scale, the more significant the transformation effect".

Among control variables, the GDP growth rate demonstrates a mean value of 0.075 with a standard deviation of 0.027, reflecting macroeconomic conditions during the observation period. The debt-to-asset ratio exhibits a mean value of 97.923% with a standard deviation of 1.554%, indicating relatively high leverage across the banking sector with modest inter-institutional variability. The capital adequacy ratio shows a mean value of 13.503% with a standard deviation of 2.480%, reflecting general compliance with regulatory requirements while exhibiting moderate heterogeneity across institutions.

The non-performing loan provision coverage ratio demonstrates substantial variability with a mean value of 251.160% and a standard deviation of 103.352%, indicating diverse approaches to risk provisioning across the banking sector. The equity multiplier exhibits a mean value of 17.105 with a standard deviation of 5.480, reflecting heterogeneous capital structures across sampled institutions. Finally, the loan loss provision adequacy ratio shows a mean value of 511.245%

with a substantial standard deviation of 267.960%, indicating diverse approaches to loss provisioning relative to reserves payable.

The correlation analysis presented in Table 2 reveals significant associations between several variables, providing preliminary insights into potential causal relationships.

Table 2. Correlation Analysis Results

	ROE	InCount	GDPgro	Lev	CAR	ProvCov	EM	Loan Resev
ROE	1							
InCount	0.088	1						
GDPgro	0.698***	-0.029	1					
Lev	0.462***	-0.0810	0.436***	1				
CAR	-0.246***	0.098	-0.321***	-0.764***	1			
ProvCov	0.311***	-0.0962	-0.151**	-0.0813	0.245***	1		
EM	0.269***	-0.112	0.446***	0.846***	-0.728***	-0.235***	1	
Loan Resev	0.049	-0.039	-0.312***	-0.121	0.188***	0.873***	-0.328***	1

*Note: *, *, *** *indicate significance at 10%, 5%, and 1% significance levels, respectively.*

The correlation between digital transformation (InCount) and return on equity (ROE) demonstrates a positive but statistically insignificant coefficient of 0.088, suggesting a potentially nuanced relationship requiring more sophisticated analytical techniques to uncover. However, multiple control variables exhibit statistically significant correlations with ROE at the 1% significance level. The GDP growth rate demonstrates a strong positive correlation of 0.698, suggesting that "the GDP growth rate is an important variable in the model" as noted in the analytical framework.

The debt-to-asset ratio exhibits a positive correlation of 0.462, indicating that higher leverage potentially associates with enhanced profitability in the banking sector. The capital adequacy ratio shows a negative correlation of -0.246, suggesting a potential trade-off between regulatory compliance and short-term profitability. The non-performing loan provision coverage ratio demonstrates a positive correlation of 0.311, indicating that stronger provisioning practices associate with higher profitability, potentially reflecting institutional quality in risk

management. The equity multiplier exhibits a positive correlation of 0.269, suggesting beneficial effects of financial leverage on institutional profitability.

Notably, the correlation analysis reveals significant interrelationships among several control variables, necessitating careful econometric specification to mitigate potential multicollinearity concerns. The GDP (Table 2) growth rate demonstrates significant correlations with multiple variables, including positive associations with debt-to-asset ratio (0.436) and equity multiplier (0.446), and negative associations with capital adequacy ratio (-0.321) and loan loss provision adequacy ratio (-0.312).

Similarly, the debt-to-asset ratio shows strong correlations with capital adequacy ratio
(-0.764) and equity multiplier (0.846), while the non-performing loan provision coverage ratio demonstrates significant correlations with capital adequacy ratio (0.245), equity multiplier
(-0.235), and loan loss provision adequacy ratio (0.873). These interrelationships underscore the complex financial dynamics within the banking sector and highlight the importance of comprehensive analytical approaches that account for multifaceted variable associations.

The descriptive statistical analysis establishes the empirical foundation for subsequent regression modeling, providing initial insights into variable distributions and interrelationships while highlighting potential analytical considerations regarding heterogeneity, correlation patterns, and econometric specification. The substantial variability observed across primary variables provides the necessary statistical variation for robust regression analysis, while the correlation patterns suggest complex relationships requiring sophisticated analytical techniques to disentangle causal mechanisms.

Baseline Regression Results

The baseline regression analysis employing fixed effects estimation methodology reveals substantive empirical evidence regarding the relationship between digital transformation intensity and banking performance metrics. Table 3 presents the comprehensive regression results, with the coefficient for digital transformation (InCount) demonstrating a statistically significant positive value of 3.110, significant at the 5% level (t-statistic: 2.49). This finding provides robust empirical support for hypothesis H1, confirming that "digital transformation can improve bank operating performance" as postulated in the theoretical framework. The magnitude of this coefficient suggests that a one-unit increase in the digital transformation index corresponds to a 3.110 percentage point enhancement in return on equity, indicating substantial economic significance beyond mere statistical association. The coefficient of determination (R^2) for the baseline model demonstrates a value of 0.796, indicating that the specified variables collectively explain approximately 79.6% of the variance in return on equity across observations, suggesting considerable explanatory power and model adequacy.

Table 3. Baseline Regression Results

Variable	Coefficient	T-Statistic	P-Value
InCount	3.110**	2.49	0.013
GDPgro	143.4***	5.28	0.000
Lev	0.707	0.70	0.484
CAR	-0.216	-0.42	0.675
ProvCov	0.0326**	2.66	0.008
EM	-0.0917	-0.22	0.826
LoanResev	0.00624	-1.56	0.120
_cons	-82.97	-0.98	0.328
N	234		
R^2	0.796		

*Note: *, *, *** *indicate significance at 10%, 5%, and 1% significance levels, respectively. The dependent variable is Return on Equity (ROE). The fixed effects model was selected based on the F-test value of 18.345 (p-value: 0.000) and Hausman test chi-square value of 12.788 (p-value: 0.047).*

Among control variables, the GDP growth rate exhibits the most substantial influence on banking performance, with a highly significant coefficient of 143.4 (t-statistic: 5.28, significant at the 1% level). This finding aligns with theoretical expectations regarding the influence of macroeconomic conditions on banking profitability and confirms that "the GDP growth rate is an important variable in the model" as indicated in the analytical framework. The non-performing loan provision coverage ratio (ProvCov) demonstrates a statistically significant positive coefficient of 0.0326 (t-statistic: 2.66, significant at the 5% level), suggesting that "a high ProvCov indicates that the bank's return on equity is ideal and the financial structure management is sound, which helps to improve operating performance". The remaining control variables, the correlation between digital transformation (InCount) and return on equity (ROE) demonstrates a positive but statistically insignificant coefficient of 0.088, suggesting a potentially nuanced relationship requiring more sophisticated analytical techniques to uncover. However, multiple control variables exhibit statistically significant correlations with ROE at the 1% significance level. The GDP growth rate demonstrates a strong positive correlation of 0.698, suggesting that "the GDP growth rate is an important variable in the model" as noted in the analytical framework. debt-to-asset ratio (coefficient: 0.707), capital adequacy ratio (coefficient: -0.216), equity multiplier (coefficient: -0.0917), and loan loss provision adequacy ratio (coefficient: 0.00624) - demonstrate statistically insignificant relationships with return on equity in the baseline specification, suggesting potentially complex or conditional associations requiring more sophisticated analytical approaches to uncover. The selection of the fixed effects specification follows rigorous diagnostic testing to determine the appropriate estimation methodology. The F- test examines the null hypothesis that all institution-specific effects equal zero (HO: all $\mu i = 0$), with rejection indicating the presence of significant heterogeneity across institutions and necessitating panel data techniques rather than pooled ordinary least squares estimation. Table 4 presents the F-test results, yielding a statistic of 18.345 with an associated p-value

of 0.000, providing statistically significant evidence at the 1% level against the null hypothesis and confirming the presence of institutional heterogeneity.

Table 4. F- test results

ROE	Coef.	St.Err.	t-value	p-value	95% Conf	Interval	Sig
InCount	-2.685	.879	-3.25	.003	-4.625	-1.041	***
Lev	2.29	.58	5.11	0	1.411	3.327	***
CAR	.288	.215	1.39	.162	-.126	.700	***
ProvCov	.031	.007	5.12	0	.019	.05	*
EM	-.2	.112	-1.88	.064	-.415	.005	***
LoanResev	-.010	.002	-3.79	0	-.013	-.005	***
Constant	-184.699	44.41	- 4.28	0	-272.23	- 97.454	***
Mean dependent var		15.289	SD dependent var				5.006
R-squared		0.386	Number of obs				234
F-test		18.345	Prob >F				0.000
Akaike crit. (AIC)		1137.311	Bayesian crit. (BIC)				1161.188

*Note: *, **, *** indicate significance at 10%, 5% and 1% significance levels, respectively.*

This finding substantiates the premise that "the assumption of 'HO: all μi=0' is incorrect," thereby validating the application of panel data methodologies. The empirical result of 0 "means that the assumption of 'HO: all μi =0' is incorrect" as indicated in the analytical framework, necessitating the incorporation of institution-specific effects in the regression specification.

The Hausman test determines the appropriate specification between fixed effects and random effects models by examining whether institution-specific effects correlate with other regressors. The null hypothesis assumes no correlation (consistent with random effects), with rejection indicating fixed effects as the more appropriate specification.

Table 5 presents the Hausman test results, yielding a chi-square statistic of 12.788 with an associated p-value of 0.047, providing statistically significant evidence at the 5% level against the null hypothesis. This finding confirms that "P is equal to 0.047, which is less than 0.05. The consistency test meets the requirements and is significant at the 1% level. It also proves that the original HO: all = εi,t hypothesis verification result is correct and will not be affected by the control variables".

The verification of this consistency test provides empirical justification for the application of the fixed effects estimation methodology, enhancing confidence in the validity of the baseline regression results.

Table 5. Hausman test results

Variable	Coef.
Chi-square test value	12.788
P-value	0.047

The robustness checking methodology incorporated alternative specifications to validate the stability and reliability of primary findings.

Table 6 presents results from substituting the dependent variable with return on assets (ROA) while maintaining identical specifications for independent and control variables.

Asset Size-Based Subsamples Analysis

The heterogeneous relationship between digital transformation and banking performance across different asset categories constitutes a central dimension of this investigation. Stratified regression analysis conducted on asset-based subsamples provides nuanced empirical evidence regarding the moderating influence of institutional scale on transformation efficacy, substantiating the theoretical propositions regarding resource-contingent digital returns [11-13].

Table 6. Robustness test results

Variable	ROA
1	2
lnCount	0.193**
	(2.57)
GDPgro	10.16***
	(6.18)
Lev	-0.0412
	(-0.68)
CAR	0.00999
	(0.32)
ProvCov	0.00196**
	(2.65)
EM	-0.0128
	(-0.50)
LoanResev	-0.000370
	(-1.53)
_cons	2.532
	(0.50)
N	234
R^2	0.777

*Note: (1) The t statistic is in brackets; (2) *, **, *** indicate significance at the significance level of 10%, 5%, and 1%, respectively.*

The large-asset subsample analysis, encompassing 85 observations from institutions with total assets exceeding 2 trillion yuan, demonstrates a statistically significant positive relationship between digital transformation intensity and return on equity. As presented in Table 2, the regression coefficient for InCount exhibits a value t-statistic: 2.49, p-value: 0.013. This finding indicates that "the digital transformation (InCount) strategy carried out by commercial banks can positively affect operating performance and keep consistent with the trend of asset return rate". The coefficient of determination (R^2) for this subsample demonstrates an exceptionally high value of 0.962, suggesting that the specified variables explain approximately 96.2% of the variance in return on equity for large-asset institutions, indicating substantial model adequacy for this institutional category. Among control variables, GDP growth rate exhibits the most substantial positive influence with a coefficient of 110.2 (t-statistic: 6.73, significant at the 1% level), while debt-to-asset ratio demonstrates a marginally significant negative association with a coefficient of -0.863 (t-statistic: -2.01, p-value: 0.068). Non-performing loan provision coverage ratio exhibits a highly significant positive relationship with a coefficient of 0.0204 (t-statistic: 3.55, p-value: 0.004), while equity multiplier demonstrates a significant positive association with a coefficient of 0.816 (t-statistic: 3.41, p-value: 0.005). These findings collectively suggest that large-asset institutions derive substantial performance benefits from digital transformation initiatives, potentially attributable to their enhanced resource capabilities, technological sophistication, and implementation capacities.

The medium-asset subsample analysis, encompassing 97 observations from institutions with total assets between 300 billion and 2 trillion yuan, reveals an even stronger positive relationship between digital transformation and performance metrics. As presented in Table 1, the regression coefficient for InCount exhibits a value of 4.584, significant at the 10% level (t-statistic: 1.92, p-value: 0.077). This finding confirms that "the digital transformation (InCount) strategy carried out by commercial banks can positively affect operating performance and has a significant positive relationship with return on equity (ROE). The coefficient of determination (R^2) for this subsample demonstrates a value of 0.906, indicating that the specified variables explain approximately 90.6% of the variance in return on equity for medium-asset institutions, suggesting considerable model adequacy for this category.

Among control variables, GDP growth rate exhibits a substantial positive influence with a coefficient of 138.0 (t-statistic: 4.48, significant at the 1% level), while non-performing loan provision coverage ratio demonstrates a significant positive association with a coefficient of 0.0484 (t-statistic: 3.18, p-value: 0.007). Equity multiplier exhibits a significant positive relationship with a coefficient of 1.528 (t-statistic: 2.36, p-value: 0.034), while loan loss provision adequacy ratio demonstrates a marginally significant negative association with a coefficient of -0.0101 (t-statistic: -2.10, p-value: 0.056). These findings suggest that medium-asset institutions potentially derive the most substantial benefits from digital transformation initiatives among the institutional categories examined, possibly attributable to an optimal combination of resource adequacy and operational flexibility that enhances transformation efficacy.

The small-asset subsample analysis, encompassing 40 observations from institutions with total assets below 300 billion yuan, reveals a starkly different relationship between digital transformation and performance metrics.

As presented in Table 7, the regression coefficient for InCount exhibits a negative value of
-0.122, though statistically insignificant (t-statistic: -0.09, p-value: 0.925).

This finding indicates that "the digital transformation of commercial banks is negatively correlated with operating performance" for small-asset institutions, suggesting potential adverse effects of transformation initiatives on financial outcomes for this category.

Table 7. Regression results of fixed effect model for small asset commercial banks

	Small asset scale commercial banks (ROE)		
	Coefficient	T-statistic	P-value
1	2	3	4
nCount	-0.122	-0.09	0.925
GDPgro Lev	126.718 1.412	6.98 2.83	0 0.005
CAR	0.179	0.86	0.392
ProvCov EM	.006 -0.319	0.52 -2.74	0.006 0.005
LoanResev	.001	0.41	0.68
_cons	-127.021	-2.65	0.008
N R^2	40 0.820		

*Note: *, **, *** indicate significance at the significance level of 10%, 5%, and 1%, respectively.*

The coefficient of determination (R^2) for this subsample demonstrates a value of 0.820, indicating that the specified variables explain approximately 82.0% of the variance in return on equity for small-asset institutions, suggesting considerable model adequacy despite the insignificant digital transformation coefficient. Among control variables, GDP growth rate exhibits a substantial positive influence with a coefficient of 126.718 (t-statistic: 6.98, significant at the 1% level), while debt-to-asset ratio demonstrates a significant positive association with a coefficient of 1.412 (t-statistic: 2.83, p-value: 0.005). Equity multiplier exhibits a significant negative relationship with a coefficient of -0.319 (t-statistic: -2.74, p-value: 0.005), contrasting with the positive associations observed in larger institutions.

These findings suggest that small-asset institutions potentially experience challenges in deriving performance benefits from digital transformation initiatives, possibly attributable to resource constraints, implementation difficulties, or disproportionate costs relative to institutional scale.

Comparative analysis across the asset-size subsamples reveals substantial heterogeneity in the relationship between digital transformation and banking performance, providing robust empirical support for hypothesis H2 regarding the moderating influence of asset size on transformation efficacy. The regression coefficients for digital transformation progressively change from 2.038 for large-asset institutions to 4.584 for medium-asset entities and -0.122 for small-asset banks, revealing a non-linear relationship between asset size and transformation benefits. This pattern aligns with theoretical expectations regarding resource-contingent digital returns, with the regression analysis demonstrating that "the impact of digital transformation on performance varies with asset size". The positive and significant coefficients for large and medium-asset institutions confirm that "large-scale banks can significantly improve their performance through digital transformation", while the negative coefficient for small-asset entities suggests that "the digital transformation of small-scale banks is negatively correlated with operating performance, with a goodness of fit of 0.820 and a regression coefficient of -0.122".

The heterogeneous nature of these findings suggests that "if small-scale banks invest too much in digital transformation, it may affect other businesses and lead to a decline in performance. These empirical results substantiate the theoretical proposition that asset size fundamentally moderates the relationship between digital transformation and performance outcomes, with institutional resource endowments potentially determining the efficacy of transformation initiatives.

The comparative analysis further reveals differences in the relationships between control variables and performance metrics across asset categories, suggesting distinct operational dynamics across institutional scales. The debt-to-asset ratio demonstrates a negative association with performance for large-asset institutions (-0.863) but a positive relationship for small-asset entities (1.412), potentially indicating different optimal leverage structures across institutional scales. Similarly, the equity multiplier exhibits positive associations with performance for large and medium-asset institutions (0.816 and 1.528 respectively) but a negative relationship for small-asset entities (-0.319), suggesting potentially different capital structure dynamics across institutional categories.

These divergent patterns underscore the importance of asset-contingent analytical approaches when examining banking operations, with institutional scale potentially moderating multiple financial relationships beyond digital transformation efficacy.

Robustness Tests

To substantiate the reliability and validity of primary findings, comprehensive robustness analyses were conducted addressing potential methodological concerns regarding measurement variance, endogeneity, and sample selection. These supplementary examinations collectively reinforce the empirical conclusions regarding the relationship between digital transformation intensity and banking performance metrics, while simultaneously mitigating concerns regarding analytical contingencies.

The principal robustness verification employed alternative performance metrics to ensure that findings were not contingent upon specific measurement approaches. Return on Assets (ROA), calculated as the ratio of net profit to total assets, was substituted for Return on Equity (ROE) as the dependent variable while maintaining identical specifications for independent, moderating, and control variables. As presented in Table 8, the regression coefficient for digital transformation (InCount) remained positive and statistically significant at 0.193 (t-statistic: 2.57, p-value significant at the 5% level), aligning with the primary finding regarding the positive relationship between digital transformation and banking performance. The coefficient of determination (R^2) for this alternative specification demonstrated a robust value of 0.777, indicating that the model retained substantial explanatory power despite the alteration in dependent variable. Among control variables, GDP growth maintained its significant positive association with a coefficient of 10.16 (t-statistic: 6.18, significant at the 1% level), while non-performing loan provision coverage ratio exhibited a statistically significant positive relationship with a coefficient of 0.00196 (t-statistic: 2.65, p-value significant at the 5% level). These results substantiate the stability of primary findings across different performance metrics, confirming that "there is no significant difference between the regression results before and after replacement and the regression results obtained above, which means that the hypothesis proposed in the paper is valid."

The robustness analysis further addressed endogeneity concerns regarding potential simultaneity or reverse causality between digital transformation and performance outcomes. The theoretical possibility exists that superior financial performance might enable greater digital investments rather than digital transformation enhancing performance, potentially biasing coefficient estimates. To mitigate this concern, the analytical framework incorporated multiple approaches. First, the fixed effects estimation methodology inherently controls for time-invariant unobserved heterogeneity that might simultaneously influence digital transformation decisions and performance outcomes, reducing potential omitted variable bias. Second, the comprehensive control variable framework incorporated multiple institutional characteristics potentially associated with both digital propensity and financial performance, reducing concerns regarding confounding influences. Third, the case study analysis of SA Bank provided temporal evidence regarding the sequencing of digital transformation and performance enhancement, with transformation initiatives preceding performance improvements. SA Bank "initiated the transformation of its retail business" in 2016 when "net profit growth rate hit a record low of only 3.36%," after which "the bank's net profit has shown a good trend of steady growth." This sequential pattern provides contextual support for the hypothesized causal direction from digital transformation to performance enhancement rather than vice versa.

Sample selection considerations were addressed through multiple methodological approaches to ensure generalizability of findings beyond the specific institutional sample. The stratified sampling methodology encompassing 37 diverse banking institutions across multiple ownership structures and operational scales enhances representativeness of the analytical sample, mitigating

concerns regarding selection bias. The inclusion of 6 large state-owned banks, 8 joint-stock institutions, 15 city commercial banks, and 8 rural commercial entities ensures comprehensive coverage across the banking sector spectrum, capturing diverse operational contexts and transformation approaches. Furthermore, the comparative analysis across asset-size subsamples explicitly acknowledges and examines potential heterogeneity in transformation efficacy, rather than assuming uniform effects across all institutional types. This stratified analytical approach enhances the external validity of findings by identifying conditional relationships rather than presuming universal patterns. Additionally, the robustness verification using alternative performance metrics and estimation specifications provides further assurance that findings are not artifacts of specific analytical choices but represent substantial empirical relationships that persist across various methodological approaches.

The comprehensive robustness verification procedures collectively enhance confidence in the empirical relationship between digital transformation, asset size, and banking performance. The consistency of findings across alternative performance metrics, the incorporation of approaches to mitigate endogeneity concerns, and the stratified sampling methodology addressing selection considerations collectively substantiate the reliability and validity of primary conclusions.

The empirical evidence consistently indicates a positive relationship between digital transformation and performance metrics, moderated by institutional asset size, with large and medium-asset institutions deriving substantial benefits while small-asset entities potentially experiencing challenges in transformation efficacy. These robust findings provide a solid empirical foundation for subsequent theoretical interpretation and practical recommendations regarding optimal digital transformation strategies across diverse banking contexts.

Practical implementation of the strategy.

Let's consider using the strategy digital business development to lay the foundation for transformation (by example SA Bank).

1. Strategic choice for retail business transformation

The development of financial technology depends on retail business, especially through the optimization of online services and the application of advanced technologies to develop pocket bank APP to meet customers' online service needs. At the same time, through the development of the "finance + life" platform, the SAT service system is built to provide personalized service experience. In addition, we will promote community-based smart retail stores, realize online and offline interactions, develop intelligent OMO financial service models, and promote the strategic transformation of the bank's retail business. SA Bank integrated various apps and created a comprehensive mobile financial online service platform to achieve one-stop comprehensive management and support the digital transformation strategy.

2. Strategic choice for corporate business transformation

As SA Bank, we have been committed to the development and application of five major trump cards, namely, the operation of the customer management

platform, the development of an ecological comprehensive business expansion platform, the extension of supply chain financial business, the implementation of bill optimization solutions, and the integration of various investment and financing businesses. With the multi-format collaborative development strategy proposed by Ping An, we will realize the application and promotion of various advanced technologies and lay a solid foundation for the digital construction and development of the bank's corporate business. At the same time, SA Bank will upgrade the existing pocket financial APP business, establish long-term trade relations with partners through the maintenance and update of the KYB platform, and emphasize the function and value of SAS in the upstream structure of the supply chain. Through high-quality services to customers, we will promote the transformation of the real economy structure and lay a solid foundation for the advent of the digital economy era.

Digital transformation is crucial to the banking industry, and SA Bank is committed to becoming a smart bank and improving its digitalization level. Bank transformation is transitioning from offline to online to all-round transformation, focusing on technology and service development, as well as changes in processes and organizational structures. Technology is the key support for digital transformation, and the development of financial technology provides impetus for economic and social transformation. SA Bank meets customer needs through innovative products and services, enhances endogenous driving force, and lays the foundation for digital strategic transformation. SA Bank invested nearly 7.383 billion yuan in IT, a year-on-year increase of 2.4%.

3. Building a comprehensive service platform on the mobile side

The development of the Internet and digital economy has prompted customers to accept mobile and online services. SA Bank evaluates service willingness based on the number of active users (MAU) and supports business development through APP traffic diversion. The bank uses MAU to evaluate business needs and satisfaction, realizes the transformation from customer to user thinking, promotes financial model innovation, attracts young customers, and optimizes customer resources. Pocket Bank provides a variety of login methods, such as fingerprint, face recognition or automatic login, to save user time. This business thinking helps to attract high-quality customers and expand the customer base.

4. Promoting digital transformation on the process side

Ping An Pocket Bank attracts customers through digital platforms, builds customer models to understand needs and optimizes APP. SA Bank has increased young customers by issuing multiple credit cards and cooperating, and its customer growth after digital transformation is about 30%. The bank develops self-media platforms, such as WeChat official accounts, to provide online business processing, including debit cards, credit card business and wealth management services, to enhance customer experience. SA Bank also uses internal recommendations and brand promotion to increase customer acquisition paths, laying the foundation for digital transformation.

To promote digital marketing, SA Bank introduced technology to develop an intelligent marketing platform to meet personalized service needs and establish long-term cooperative relationships. The bank integrates customer data, prevents

risks, analyzes behavioral habits, and uses visualization technology to analyze data, plan customer groups, and develop new service experience models. The Pocket Bank APP has built-in intelligent robots, and offline intelligent robots are set up in outlets to provide intelligent investment advisory services, analyze user wealth, control risks, and provide personalized investment and financing solutions. Digital transformation emphasizes product and service promotion, improves customer satisfaction, and enhances competitive advantages.

SA Bank simplifies and upgrades credit processes and launches "remote credit", with the approval and loan process taking less than 10 minutes. The bank also launched a mobile face-to-face signing system, using face recognition and remote video technology to complete loan business. These innovations reduce loan costs, meet financing needs, and are of great value.

The bank builds an intelligent risk control system, uses sound, fingerprint, and face recognition to confirm customer identity, and uses Ping An Cloud AI technology to enhance risk control. The bank uses big data analysis to predict customer credit limits, establish risk monitoring models, complete loan review and approval, eliminate information theft risks, and check suspicious accounts.

In terms of digital retail, SA Bank attaches great importance to business development, builds an OMO service system, and proposes a digital business operation model. The bank's technology upgrades the operating platform, develops application tools, simplifies processes, improves the capabilities of service personnel, and meets the personalized needs of customers.

5. Organizational structure to ensure digital transformation

5.1 Increase talent introduction

The digital economy era highlights the importance of scientific and technological talents, who are crucial to digital transformation. In order to promote the digital strategy, SA Bank actively builds a technical team, attracts and retains talents by increasing salaries, and expands the team size. The bank's management recognizes the value of compound financial technology talents and ensures talent reserves through recruitment and training. At the same time, SA Bank cooperates with domestic colleges and universities to attract potential talents and provide generous treatment and incentive mechanisms to support the talent development strategy.

5.2 Adjusting the organizational framework

SA Bank optimizes its internal structure through the digital transformation strategy, strengthens employee capabilities, analyzes business needs, draws on the experience of Internet and financial technology companies, and forms a professional team to support strategic implementation. The bank emphasizes the use of technology to improve communication efficiency, subdivides development teams, implements vertical management, stimulates work enthusiasm, and adopts flat management to improve quality. Establish a CIO position to promote inter-departmental coordination and participate in strategic decision-making to avoid risks and promote technological innovation. The bank also adjusts its organizational structure according to development needs, such as establishing a retail technology development center to accelerate the digital transformation of retail business, and ensure product research and development innovation to create favorable conditions

for digital transformation.

SA Bank has implemented a digital transformation strategy and has achieved remarkable results. This paper evaluates the performance of the strategy by analyzing financial indicators and explores the relationship between digital transformation and operating performance. At present, there are few quantitative studies on corporate digital transformation, so it is necessary to clarify the definition, purpose and characteristics of digital transformation. The rapid development of commercial banks depends on the support of digital transformation, and corporate annual report data can reflect its development status and trends. This article refers to existing research and uses SA Bank's annual report data as a basis to evaluate the impact of digital transformation on operating performance by counting the frequency of relevant words, and constructs an evaluation index system. The system includes key indicators such as profitability, risk control ability, development ability and financial management, and the degree of their impact on bank performance is determined through correlation analysis of these indicators.

The spearman correlation test of each indicator is completed by SPSS software. The specific test results can be referred to Table 10. It can be seen from the table below that the correlation between the indicators is significant at a confidence level of 1% and 5%. In terms of return on equity, there is a significant negative correlation with the bank's digital transformation; in terms of loan growth rate, there is a significant negative correlation with digital transformation.

At the current stage, my country's economic development has slowed down, but more attention is paid to the quality of economic development. Small and medium-sized enterprises are subject to certain constraints and restrictions in terms of financing strength, resulting in a continuous decline in the credit yield of commercial banks.

In order to alleviate the financing pressure of small and medium-sized enterprises, SA Bank has made appropriate adjustments to its internal operating structure and changed the direction of its resource investment to support the development of retail business. From a macro perspective, this is in line with the development needs of the national economic strategy.

Table 8. Correlation between digital transformation and performance indicators

Variable		Digital transformation Return on equity Loan growth rate Capital adequacy ratio Non-interest income ratio	Digital transformation Return on equity Loan growth rate Capital adequacy ratio Non-interest income ratio	Digital transformation Return on equity Loan growth rate Capital adequacy ratio Non-interest income ratio	Digital transformation Return on equity Loan growth rate Capital adequacy ratio Non-interest income ratio	Digital transformation Return on equity Loan growth rate Capital adequacy ratio Non-interest income ratio
Digital transformation	Correlation coefficient	1	-0.929**	-0.786*	.0762*	.0881**
Return on equity		-0.929**	1	0.714*	-0.929**	-.0857**
Loan growth rate		-0.786*	0.714*	1	-0.476	-0.571
Capital adequacy ratio		.0762*	-0.929**	-0.476	1	.0714*
Ratio of non-interest income		0.881**	-.857**	-0.571	.0714*	1

***When the confidence level (double test) is 0.01, the correlation is significant;*
**When the confidence level (double test) is 0.05, the correlation is significant.*

Conclusions

Based on economic theories such as strategic consistency theory, this paper deeply explores the impact of commercial banks' digital transformation on operating performance. Through data integration and analysis of listed commercial banks, we draw the following conclusions:

First, the formulation of commercial banks' digital strategies, the cultivation

of digital capabilities, and the implementation of digital operation plans are key factors affecting banks' operating performance. These three complement each other and jointly promote the success of banks' digital transformation. Digital strategy points out the direction for transformation, digital capabilities provide the driving force for transformation, and digital operation plans are the specific path to achieve transformation goals. Second, digital transformation can significantly improve banks' operating performance. By constructing a measurement indicator system, we verify the positive impact of digital transformation on banks' operating performance. Therefore, commercial banks should increase their efforts in digital transformation, emphasize the deployment and planning of the overall strategy, cultivate their own digital capabilities, and improve their operating performance through digital operation models. In addition, differences in asset size will lead to certain heterogeneity in the degree and relationship of the impact on operating performance of commercial banks after digital transformation. Commercial banks with larger asset sizes have more obvious improvements in operating performance after digital transformation. Based on the above conclusions, we put forward the following suggestions: Increase the penetration of financial technology and cultivate high-quality talents. Banks should establish long-term cooperative relationships with Internet companies to increase the penetration rate of financial technology, while paying attention to the development of internal scientific research activities, attracting and cultivating compound talents. Create differentiated innovative products and services. Banks should have a deep understanding of customer needs, develop targeted products and services, and pay attention to the development and expansion of domestic and foreign investment and financing channels to meet customers' consulting service needs. The business structure needs to develop in a coordinated manner. While paying attention to the digital transformation of retail, banks should maintain the coordinated development of corporate business and interbank business, and pay attention to the adjustment and upgrading of business structure. Implement refined customer management plans. Banks should classify customers according to their differences, use big data technology to understand customer needs, and develop differentiated products and services suitable for different customers.

Pay attention to data governance and strengthen privacy protection. Banks should pay more attention to data governance, effectively protect customer privacy and avoid leakage. At the same time, data management talents should master data usage skills and methods to provide support for efficient data governance.

Deal with network security issues. Commercial banks should strictly control information security risks, reflect information security in all stages and nodes of digital transformation, and use advanced technologies and means to strictly control the network security line of defense.

To sum up, in the current complex and changeable market environment, commercial banks should actively grasp the pulse of The Times and vigorously promote digital transformation as a key path to improve business performance and core competitiveness. In this process of transformation, banks should not only pay attention to the innovation and application of technology, but also comprehensively consider and properly solve a series of accompanying challenges and problems.

Specifically, banks need to attach great importance to talent training and build an elite team with digital thinking and professional skills; Continuously promote product innovation to meet the increasingly diverse financial needs of customers; Promote the coordinated development of business structure and realize the deep integration of traditional business and emerging business; Strengthen customer management, enhance customer experience and loyalty; Deepen data governance to ensure the secure and efficient use of data; At the same time, build a strong network security defense line to escort digital transformation. Only in this way can we ensure the smooth progress of digital transformation and lay a solid foundation for the long-term development of the bank.

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