



The Moderating Effect of Bank Size, Capital Strength and Organizational Structure in Nigeria Banking Digital Innovation Intensity–Efficiency Nexus

Ayadi Moniaye¹, Dr J. O. Omokehinde², Professor O. J. Akinyomi³

¹Department of Accounting and Finance Mountain Top University, Ibafo, Ogun State, Nigeria.

²Department of Accounting and Finance, Mountain Top University, Ibafo, Ogun State, Nigeria.

³Department of Accounting and Finance, Mountain Top University, Ibafo, Ogun State, Nigeria.

Abstract

The rapid diffusion of digital technologies has transformed the competitive landscape of the banking industry, particularly in emerging economies where financial institutions increasingly rely on digital innovation to improve operational efficiency and service delivery. However, the efficiency outcomes of digital transformation remain inconclusive because the benefits of digital innovation may depend on internal bank characteristics. This study examines the moderating effects of bank size, capital adequacy and holding company structure in the relationship between digital innovation intensity (DII) and bank efficiency in Nigeria. Using panel data from Nigerian deposit money banks and employing robust ordinary least squares, fixed effects and median-based GMM Probit estimation techniques, the study examines both continuous and categorical efficiency outcomes. The findings reveal that digital innovation has differential effects across cost and revenue efficiency dimensions. While digital innovation initially reduces cost efficiency due to technology-related adjustment costs, it enhances revenue efficiency. Furthermore, capital adequacy, bank size and holding company structure significantly moderate the digital innovation–efficiency relationship. The interaction effects show that stronger capital positions, larger asset bases and organisational structures strengthen the ability of banks to convert digital investments into efficiency improvements. The study contributes to the digital transformation literature by demonstrating that the efficiency effect of digital innovation is conditional on institutional and structural characteristics of banks.

Keywords: Bank efficiency; bank size; capital adequacy; digital innovation intensity; digital transformation; holding company structure; Nigeria.

INTRODUCTION

1.1 Background to the Study

The banking industry has experienced a fundamental transformation driven by technological advancement, digital platforms and changing customer expectations. Digital innovation has become a strategic necessity rather than an optional investment as financial institutions increasingly adopt electronic payment systems, mobile banking applications, artificial intelligence, cloud computing and automated decision-making technologies (Bazarbash, 2019; Frost et al., 2019). The adoption of these technologies has reshaped traditional banking models by altering the way financial services are produced, distributed and consumed.

Digital innovation intensity (DII) reflects the extent to which banks integrate technology-driven solutions into their operational processes and service delivery systems. Existing literature suggests that digitalisation can



improve efficiency through reduced transaction costs, improved information processing, enhanced customer access and improved resource allocation (Banna et al., 2021; Thakor, 2020). However, digital transformation also involves substantial implementation costs, including investment in infrastructure, cybersecurity, software development and employee capability enhancement. Therefore, the relationship between digital innovation and efficiency is not necessarily linear.

The Nigerian banking sector provides an important context for investigating this relationship. Following banking reforms, increased competition and regulatory-driven technological adoption, Nigerian banks have invested significantly in digital platforms. The expansion of mobile banking, electronic payment channels and fintech partnerships has positioned Nigeria as one of Africa's leading digital financial markets (CBN, 2023). Nevertheless, questions remain regarding whether digital investments have translated into measurable efficiency gains.

A key limitation in existing digital banking literature is that it often assumes digital innovation affects efficiency uniformly across institutions. However, banks differ substantially in their financial capacity, operational scale and organisational structure. These differences may determine whether digital investments produce meaningful efficiency improvements.

First, capital adequacy may moderate the digital innovation–efficiency relationship. Well-capitalised banks possess greater capacity to absorb technology-related costs and sustain long-term digital investments. According to the resource-based view, firms with stronger internal resources are better positioned to exploit strategic capabilities such as technology adoption (Barney, 1991; Wernerfelt, 1984).

Second, bank size may influence the effectiveness of digital transformation. Large banks often possess stronger infrastructure, wider customer networks and greater investment capacity, allowing them to benefit more from digital innovation. However, large size may also create bureaucratic complexity that reduces flexibility (Berger & Humphrey, 1997).

Third, holding company structure may shape the effectiveness of digital innovation. Organisational structures that integrate multiple banking and non-banking subsidiaries may provide opportunities for technology sharing and operational synergy, although they may also introduce coordination challenges.

Consequently, this study argues that digital innovation does not independently determine bank efficiency; rather, the effect depends on the moderating influence of institutional characteristics.

1.2 Statement of the Problem

Although digital transformation has become central to banking strategy, empirical evidence regarding its effect on efficiency remains mixed. Some studies report that technology adoption reduces operational costs and improves productivity, while others find that digital investment creates short-term cost pressures and does not immediately generate efficiency benefits (Beccalli, 2007; Berger, 2003).

The inconsistency may arise because previous studies have focused primarily on the direct relationship between digitalisation and performance while paying limited attention to the conditions under which digital investments become productive.



In Nigeria, banks have invested heavily in digital infrastructure, yet differences remain in efficiency outcomes across institutions. Some banks have successfully converted digital investments into improved service delivery and profitability, while others continue to experience rising technology expenditure without corresponding efficiency improvements.

The problem therefore is not simply whether digital innovation affects efficiency, but whether the internal characteristics of banks determine the magnitude and direction of this effect.

Specifically, the study addresses the following unresolved issues:

1. Does digital innovation intensity improve cost and revenue efficiency?
2. Does capital adequacy strengthen or weaken the efficiency benefits of digital innovation?
3. Does bank size enhance the ability of banks to convert digital investment into efficiency gains?
4. Does holding company structure influence the digital innovation–efficiency relationship?

1.3 Objective of the Study

The main objective is to examine the moderating effects of bank characteristics in the relationship between digital innovation intensity and bank efficiency in Nigeria.

The specific objectives are to:

1. Examine the effect of digital innovation intensity on cost efficiency.
2. Examine the effect of digital innovation intensity on revenue efficiency.
3. Determine whether capital adequacy moderates the relationship between digital innovation intensity and cost efficiency.
4. Determine whether capital adequacy moderates the relationship between digital innovation intensity and revenue efficiency.
5. Examine the moderating effect of bank size on the digital innovation–efficiency relationship.
6. Determine the moderating role of holding company structure in the relationship between digital innovation and efficiency.

1.4 Research Questions

1. What is the effect of digital innovation intensity on bank efficiency?
2. Does capital adequacy influence the relationship between digital innovation and efficiency?
3. Does bank size moderate the effect of digital innovation on efficiency?
4. Does holding company structure alter the efficiency outcome of digital innovation?

1.5 Research Hypotheses

H01: Digital innovation intensity has no significant effect on bank efficiency.

H02: Capital adequacy does not significantly moderate the relationship between digital innovation intensity and bank efficiency.



H03: Bank size does not significantly moderate the relationship between digital innovation intensity and bank efficiency.

H04: Holding company structure does not significantly moderate the relationship between digital innovation intensity and bank efficiency.

1.6 Contribution to Literature

This study contributes in three major ways.

First, it extends the digital transformation literature by introducing bank-specific moderators into the digital innovation–efficiency relationship.

Second, unlike studies that rely only on profitability measures, this study examines efficiency outcomes using cost and revenue efficiency measures.

Third, the study applies multiple estimation approaches including fixed effects, robust OLS and binary efficiency modelling to provide more robust evidence.

I. LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Digital Innovation Intensity and Banking Transformation

Digital innovation refers to the application of digital technologies to create new products, improve existing processes and redesign organisational activities. Unlike traditional technological adoption, digital innovation involves continuous integration of technologies such as artificial intelligence, big data analytics, cloud computing, mobile platforms and automated systems into business models (Nambisan et al., 2017).

In banking, digital innovation intensity represents the degree to which financial institutions incorporate digital technologies into their operations and customer engagement processes. Banks increasingly rely on digital channels to reduce transaction costs, improve information processing, enhance financial inclusion and strengthen competitive positioning (Thakor, 2020).

Theoretically, digital innovation improves efficiency through several mechanisms. First, automation reduces dependence on physical branches and manual processes. Second, digital platforms improve information availability and reduce asymmetric information problems. Third, technology enables banks to serve more customers without proportional increases in operational resources (Bazarbash, 2019).

However, digital innovation may also create efficiency challenges. Investments in digital infrastructure require substantial financial resources, cybersecurity systems, regulatory compliance and employee retraining. Consequently, the efficiency benefits of digitalisation may emerge only after a transition period (Beccalli, 2007).

2.1.2 Bank Efficiency

Bank efficiency refers to the ability of financial institutions to transform inputs into outputs while minimising costs or maximising revenues. Efficiency analysis has become important because banking performance cannot be fully captured by profitability indicators alone.

The literature generally distinguishes between:



1. Cost efficiency — the ability of banks to produce a given output level at minimum cost.
2. Revenue efficiency — the ability of banks to generate maximum revenue from available resources.

Cost efficiency is influenced by operational management, technology adoption and resource utilisation, while revenue efficiency reflects market positioning, customer engagement and income-generation capability (Berger & Humphrey, 1997).

Digital innovation may affect these efficiency dimensions differently. Technology investment may increase costs initially but improve revenue generation through improved customer experience, payment services and product innovation.

2.1.3 Capital Adequacy as a Moderator

Capital adequacy represents the financial strength and resilience of banks. Under the Basel regulatory framework, banks are required to maintain adequate capital to absorb risks and protect financial stability (Basel Committee on Banking Supervision, 2019).

From the resource-based perspective, capital provides strategic capacity. Well-capitalised banks are more capable of investing in advanced technologies and sustaining innovation projects (Barney, 1991).

However, excessive capital may reduce efficiency because resources remain tied to regulatory requirements rather than productive investment. Therefore, the effect of capital adequacy on digital innovation outcomes remains an empirical question.

In the Nigerian context, capital strength may determine whether banks can successfully transform digital investments into efficiency improvements.

2.1.4 Bank Size as a Moderator

Bank size represents the scale of operations measured through total assets. Large banks generally possess greater financial capacity, wider customer networks and stronger technological infrastructure.

According to economies of scale theory, larger banks can spread technology costs over a larger operational base, thereby improving efficiency (Berger & Mester, 1997).

However, large institutions may also experience diseconomies of scale due to organisational complexity, slower decision-making and bureaucratic structures.

Therefore, size may strengthen or weaken the impact of digital innovation depending on institutional capability.

2.1.5 Holding Company Structure as a Moderator

Holding company structures have become increasingly relevant in the Nigerian banking sector following regulatory reforms that encouraged banks to restructure into diversified financial groups.

A holding company structure allows banks to integrate banking, investment, technology and financial service subsidiaries. Such structures may enhance efficiency through resource sharing, technological integration and diversification benefits.



However, complex organisational structures may create coordination costs and reduce operational flexibility. The role of holding company structure in digital transformation remains underexplored, particularly in emerging markets.

II. 2.2 Theoretical Framework

2.2.1 Resource-Based View (RBV)

This study is anchored on the Resource-Based View developed by Wernerfelt (1984) and Barney (1991). The RBV argues that firms achieve competitive advantage through valuable, rare, inimitable and non-substitutable resources. Digital capabilities represent strategic resources because they enable banks to improve operational processes, innovate products and enhance customer relationships.

However, the effectiveness of these resources depends on complementary organisational capabilities. Therefore, capital strength, size and organisational structure may determine whether digital resources translate into efficiency gains. This theory supports the argument that digital innovation alone may not improve efficiency unless supported by adequate financial and organisational resources.

2.2.2 Technology–Organisation–Environment (TOE) Framework

The TOE framework developed by Tornatzky and Fleischer (1990) explains technology adoption through three dimensions:

1. Technological factors
2. Organisational factors
3. Environmental factors

The framework suggests that the success of technology adoption depends not only on technology availability but also organisational readiness.

In this study:

DII represents technological capability.

Capital adequacy, size and holding company structure represent organisational readiness.

The Nigerian banking environment represents institutional conditions.

The TOE framework therefore provides support for examining moderating effects.

III. 2.3 Empirical Review

Several studies have examined the relationship between technology and banking efficiency.

Beccalli (2007) investigated the impact of ICT investment on European banks and found that technology contributes to productivity improvements, although the effects depend on implementation effectiveness. Berger (2003) argued that electronic banking technologies reduce transaction costs and improve operational efficiency but require complementary organisational changes.

Bazarbash (2019) found that digital technologies improve financial service delivery by reducing information constraints and improving risk assessment. Thakor (2020) noted that fintech and digital banking innovations



enhance competition and customer access but may increase short-term investment costs. Recent evidence from emerging markets indicates that digitalisation improves banking performance, but institutional differences determine the magnitude of the effect (Banna et al., 2021).

Studies focusing on bank size suggest mixed findings. Large banks may benefit from economies of scale, but complexity can reduce efficiency (Berger & Mester, 1997). Similarly, capital adequacy has been found to influence banks' ability to adopt innovation. Strongly capitalised banks are better positioned to undertake technology investments and withstand adjustment costs (Dietrich & Wanzenried, 2014).

Despite these contributions, three gaps remain.

First, previous studies mainly examine direct effects of digitalisation without considering moderators.

Second, many studies focus on profitability rather than efficiency.

Third, evidence from African banking systems, particularly Nigeria, remains limited.

This study addresses these gaps by examining whether size, capital strength and organisational structure condition the digital innovation–efficiency relationship.

IV. METHODOLOGY

3.1 Research Design

The study adopts an ex-post facto research design using bank-level panel data. This approach is appropriate because the study examines historical relationships between digital innovation, bank characteristics and efficiency outcomes without manipulating variables.

3.2 Population and Sample

The population comprises Nigerian deposit money banks. Annual observations covering the period 2000–2024 were analysed using bank-level panel data.

The bank identifier is represented as CRSS while year values range from 0 (2000) to 24 (2024).

3.3 Measurement of Variables

Variable	Measurement
Cost Efficiency	DEA-based cost efficiency score
Revenue Efficiency	DEA-based revenue efficiency score
DII	Digital Innovation Intensity
CAR	Capital adequacy ratio
TA	Total assets
HOLDCO	Holding company structure dummy

3.4 Model Specification

The moderation model is specified as:



$$EFF_{it} = \alpha_i + \beta_1 DII_{it} + \beta_2 M_{it} + \beta_3 (DII * M)_{it} + \epsilon_{it} \text{-----} \{1\}$$

Where:

EFF = efficiency score

M = moderating variable (CAR, TA or HOLDCO)

3.5 Estimation Techniques

Three estimation techniques are applied:

Robust OLS

Used to examine the relationship while correcting for heteroskedasticity.

Fixed Effects Model

The FE model controls for unobservable bank characteristics that remain constant over time.

GMM Probit

Efficiency scores are converted into binary outcomes using the median value:

1 = high efficiency

0 = low efficiency

The GMM Probit approach accounts for the dynamic nature of efficiency outcomes.

V.

VI. RESULTS AND DISCUSSION

4.0 Preamble

This section presents the empirical results on the moderating role of capital adequacy (CAR), bank size (TA), and holding company structure (HOLDCO) in the relationship between Digital Innovation Intensity (DII) and bank efficiency in Nigeria.

The analysis considers two dimensions of efficiency:

1. Cost Efficiency VRS
2. Revenue Efficiency VRS

The results are presented using:

Robust OLS

Fixed Effects (FE)

Median-based GMM Probit model

The interaction term is interpreted as the moderating effect:

DII×Moderator

A positive and significant interaction implies that the moderator strengthens the effect of digital innovation on efficiency, while a negative significant interaction implies that the moderator weakens the effect.



VII. 4.1 Moderating Effect of Capital Adequacy ($DII \times CAR$)

4.1.1 Cost Efficiency VRS

Robust OLS Results

Variable	Coefficient	p-value	Interpretation
DII	-0.002947	0.0000	Negative and significant
CAR	-0.012321	0.0000	Negative and significant
DII×CAR	0.000352	0.0000	Positive and significant

Fixed Effects Results

Variable	Coefficient	p-value	Interpretation
DII	-0.002433	0.0000	Negative and significant
CAR	-0.015293	0.0002	Negative and significant
DII×CAR	0.000301	0.0000	Positive and significant

Discussion

The negative coefficient of DII indicates that digital innovation reduces cost efficiency when considered independently.

For the FE model:

$$\beta = -0.002433, p < 0.01$$

This suggests that digital transformation creates immediate cost pressures through technology acquisition, infrastructure investment, cybersecurity expenditure and staff training.

CAR also has a negative significant effect:

$$\beta = -0.015293, p < 0.01$$

This indicates that higher capital requirements may reduce cost efficiency because funds are tied up as regulatory capital rather than being used for productive operations.

However, the interaction term is positive and significant:

$$DII \times CAR = 0.000301, p < 0.01$$

This confirms that capital adequacy moderates the digital innovation effect. Well-capitalised banks are better able to absorb the initial costs associated with digital transformation and eventually obtain efficiency benefits.

4.1.2 Revenue Efficiency VRS

Fixed Effects Results

Variable	Coefficient	p-value	Interpretation
DII	0.003637	0.0000	Positive significant
CAR	0.020802	0.0000	Positive significant
DII×CAR	-0.000456	0.0000	Negative significant



Discussion

Unlike cost efficiency, DII improves revenue efficiency:

$$\beta=0.003637, p<0.01$$

This implies that digital innovation enhances revenue generation through improved customer access, electronic channels and increased transaction opportunities.

CAR also improves revenue efficiency:

$$\beta=0.020802, p<0.01$$

Strong capital positions allow banks to expand lending and undertake profitable investments.

However, the interaction effect is negative:

$$DII \times CAR = -0.000456, p<0.01$$

This suggests that excessive capital reduces the marginal revenue benefits of digital innovation. Highly capitalised banks may have fewer incentives to aggressively exploit digital opportunities.

VIII. 4.2 Moderating Effect of Bank Size ($DII \times TA$)

4.2.1 Cost Efficiency VRS

Fixed Effects Results

Variable Coefficient p-value

DII -0.003128 0.0000

TA -0.012657 0.0053

$DII \times TA$ 0.000336 0.0000

Discussion

The negative DII coefficient indicates that digital innovation initially reduces cost efficiency.

TA also reduces efficiency:

$$\beta=-0.012657, p<0.01$$

This suggests that larger banks may experience complexity costs, administrative layers and coordination challenges.

However:

$$DII \times TA = 0.000336, p<0.01$$

The positive interaction confirms that size strengthens the ability of banks to convert digital investment into efficiency gains.

Large banks have: greater technology budgets, stronger infrastructure, and wider customer networks, which allows them to benefit more from digital transformation.



4.2.2 Revenue Efficiency VRS

Fixed Effects Results

Variable Coefficient p-value

DII 0.004424 0.0000

TA 0.020507 0.0005

DII×TA -0.000492 0.0000

Discussion

DII positively affects revenue efficiency:

$\beta=0.004424$, $p<0.01$

indicating that digital innovation enhances revenue creation.

TA also improves revenue efficiency:

$\beta=0.020507$, $p<0.01$

This confirms the existence of scale advantages.

However, the interaction term is negative:

$DII \times TA = -0.000492$, $p<0.01$

This indicates diminishing returns. Although large banks benefit from digitalisation, very large institutions may experience reduced incremental benefits because existing structures may limit flexibility.

IX.4.3 Moderating Effect of Holding Company Structure (DII × HOLDCO)

4.3.1 Cost Efficiency VRS

Fixed Effects Results

Variable Coefficient p-value

DII -0.000147 0.0521

HOLDCO -0.056955 0.0026

DII×HOLDCO 0.000772 0.0026

Discussion

HOLDCO has a negative significant effect:

$\beta=-0.056955$, $p<0.01$

This indicates that holding company structures may initially create coordination and administrative costs.

However:

$DII \times HOLDCO = 0.000772$, $p<0.01$

shows that digital innovation works better within holding company structures.

The structure allows: technology sharing, integration across subsidiaries, and wider digital distribution channels.

Therefore, HOLDCO strengthens the efficiency impact of digital innovation.



4.3.2 Revenue Efficiency VRS

Fixed Effects Results

Variable	Coefficient	p-value
DII	0.000110	0.2530
HOLDCO	0.089562	0.0000
DII×HOLDCO	-0.001204	0.0000

Discussion

HOLDCO significantly improves revenue efficiency:

$$\beta=0.089562, p<0.01$$

This suggests diversified structures enhance revenue opportunities through multiple service channels.

However:

$$\text{DII} \times \text{HOLDCO} = -0.001204, p<0.01$$

The negative interaction suggests that holding company complexity reduces the additional revenue benefit of digital innovation.

This may occur because: decision-making becomes slower, technology integration becomes complex, and subsidiaries may not fully coordinate digital strategies.

X. 4.4 GMM Probit Results (Binary Efficiency Classification)

The efficiency scores were transformed using the median value:

1=High Efficiency, 0=Low Efficiency

Cost Efficiency Probability

Interaction	Direction	Significance
DII	Negative	Significant
CAR	Negative	Significant
DII×CAR	Positive	Significant
TA	Negative	Significant
DII×TA	Positive	Significant
HOLDCO	Negative	Significant
DII×HOLDCO	Positive	Significant

The GMM Probit results confirm the FE findings that digital innovation reduces the probability of achieving high cost efficiency initially, but financial strength, size and organisational structure improve the ability of banks to benefit from digital investment.



Revenue Efficiency Probability

Interaction	Direction	Significance
DII	Positive	Significant
CAR	Positive	Significant
DII×CAR	Negative	Significant
TA	Positive	Significant
DII×TA	Negative	Significant
HOLDCO	Positive	Significant
DII×HOLDCO	Negative	Significant

The probability model confirms that digital innovation improves the likelihood of achieving superior revenue efficiency, but the marginal benefit declines when banks become excessively large, highly capitalised or organisationally complex.

XI.4.5 Summary of Findings

The results provide strong evidence that the effect of digital innovation on efficiency is conditional.

The study finds that:

1. Digital innovation reduces cost efficiency initially but improves revenue efficiency.
2. Capital adequacy strengthens the digital innovation–cost efficiency relationship but weakens the additional revenue gains from digitalisation.
3. Bank size improves the capacity of banks to exploit digital investments, especially for cost efficiency, but creates diminishing revenue returns.
4. Holding company structure increases the ability of banks to achieve efficiency from digital innovation on the cost side but may reduce incremental revenue benefits due to complexity.

Overall, the findings support the Resource-Based View by showing that digital technology alone is insufficient. The efficiency benefits of digital transformation depend on complementary resources such as capital strength, operational scale and organisational structure.

CONCLUSION, POLICY IMPLICATIONS, LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

5.1 Conclusion

This study examined the moderating role of capital adequacy, bank size and holding company structure in the relationship between digital innovation intensity (DII) and bank efficiency in Nigeria. Specifically, the study responded to the identified research gap by moving beyond the conventional assumption that digital innovation produces uniform efficiency outcomes across banks. Consistent with the objectives of the study, the research investigated whether internal bank characteristics condition the extent to which digital transformation translates into cost and revenue efficiency improvements.



The study was motivated by the increasing digitalisation of the Nigerian banking sector and the recognition that technological investment alone may not guarantee efficiency gains. While previous studies have established that digital technologies can improve operational performance by reducing transaction costs, improving information processing and enhancing service delivery (Beccalli, 2007; Bazarbash, 2019; Thakor, 2020), the literature remains inconclusive regarding the circumstances under which digital investments generate superior efficiency outcomes. Therefore, this study incorporated moderating variables derived from the resource-based perspective, arguing that complementary organisational resources determine the effectiveness of digital innovation.

The findings provide several important conclusions.

First, the results demonstrate that digital innovation intensity has different implications for cost and revenue efficiency. Digital innovation reduces cost efficiency, particularly in the short run, suggesting that technology adoption involves substantial adjustment costs. This finding supports earlier arguments that digital transformation requires significant investments in infrastructure, cybersecurity, human capital and organisational restructuring before productivity gains become visible (Beccalli, 2007; Berger, 2003). The result aligns with the resource-based view (Barney, 1991), which suggests that strategic resources generate competitive benefits only when firms possess the complementary capabilities required to exploit them.

However, digital innovation improves revenue efficiency. This indicates that Nigerian banks are more likely to realise the benefits of digital transformation through revenue-enhancing mechanisms such as expanded customer reach, electronic payment services, improved product innovation and enhanced customer experience. This finding supports the argument of Thakor (2020) that digital banking technologies reshape financial intermediation by creating new channels for value creation.

Second, the study confirms the moderating role of capital adequacy. The interaction between DII and CAR was positive and significant for cost efficiency, indicating that well-capitalised banks are better positioned to absorb the initial costs associated with digital transformation. This supports the resource-based view that firms with stronger internal resources possess greater strategic capacity to exploit innovation opportunities (Barney, 1991). However, for revenue efficiency, the negative interaction effect suggests that excessive capital strength may reduce the marginal benefits of digital innovation. This may occur because excessive capital holdings create conservative investment behaviour and reduce the urgency to aggressively exploit digital opportunities.

Third, the study establishes the importance of bank size as a conditioning factor. The positive interaction between DII and TA for cost efficiency indicates that larger banks benefit more from digital innovation because they possess greater financial capacity, technological infrastructure and customer networks. This finding supports the economies-of-scale argument in banking efficiency literature (Berger & Humphrey, 1997). Nevertheless, the negative interaction effect for revenue efficiency suggests diminishing returns. As banks become larger, organisational complexity may limit flexibility and reduce the incremental revenue benefits associated with further digital investment.

Fourth, the findings reveal that holding company structure plays a significant moderating role. The positive interaction between DII and HOLDCO for cost efficiency indicates that diversified banking structures may improve technology utilisation through resource sharing, common platforms and operational integration. This



supports the Technology–Organisation–Environment framework (Tornatzky & Fleischer, 1990), which argues that organisational readiness influences the success of technological adoption.

However, the negative moderating effect of HOLDCO on revenue efficiency suggests that organisational complexity may reduce the ability of banks to fully convert digital capabilities into revenue growth. While holding structures provide diversification advantages, they may also introduce coordination problems, slower decision-making processes and integration challenges.

Overall, the study concludes that digital innovation does not automatically improve banking efficiency; rather, efficiency outcomes depend on the availability of complementary organisational resources. The evidence supports the central argument of the study that capital strength, operational scale and organisational structure determine whether banks successfully transform digital investment into efficiency gains.

5.2 Policy Implications and Recommendations

The findings have important implications for banking regulators, policymakers and bank management.

1. Digital transformation policies should consider implementation capacity

The negative short-run effect of DII on cost efficiency suggests that digital transformation requires careful implementation. Regulatory authorities, particularly the Central Bank of Nigeria, should encourage banks to adopt digital technologies through sustainable strategies rather than rapid technology acquisition without operational integration.

Banks should focus on: technology governance, employee digital skills, cybersecurity readiness, and process redesign. Digital investment should be evaluated based on long-term efficiency outcomes rather than immediate cost reduction.

2. Strengthening bank capital should support digital competitiveness

The moderating role of CAR indicates that financially stronger banks are better positioned to benefit from digital innovation.

Therefore, policymakers should maintain a balance between: ensuring adequate capital buffers and avoiding excessive restrictions that limit productive investment. Capital regulations should encourage banks to allocate sufficient resources toward technology development and innovation.

3. Encourage strategic use of bank size advantages

The findings show that larger banks are better positioned to exploit digital investment.

However, the diminishing revenue effect suggests that size alone is insufficient. Large banks should reduce bureaucratic barriers and improve organisational flexibility.

Management should promote: agile technology adoption, faster innovation cycles, and decentralised digital decision-making.

4. Improve governance of holding company structures



Since HOLDCO strengthens the cost efficiency benefits of digital innovation but reduces additional revenue gains, regulators should encourage stronger coordination mechanisms within banking groups. Holding companies should ensure: effective technology sharing across subsidiaries, unified digital strategies, and efficient resource allocation.

5. Promote innovation-friendly banking ecosystems

Government and regulators should continue supporting: fintech partnerships, digital payment infrastructure, open banking frameworks, and cybersecurity development.

A supportive ecosystem will allow banks to achieve greater returns from digital transformation.

5.3 Limitations of the Study

Despite its contributions, this study has some limitations.

First, the study focuses on Nigerian deposit money banks; therefore, the findings may not automatically generalise to other emerging economies with different regulatory and technological environments.

Second, digital innovation intensity is measured using available bank-level indicators. Although this captures important dimensions of digital adoption, it may not fully reflect qualitative aspects such as artificial intelligence adoption, customer experience innovation and cybersecurity capability.

Third, efficiency is examined using cost and revenue efficiency measures. Other performance dimensions such as profitability, risk management efficiency and customer-based outcomes were outside the scope of this study.

Fourth, although the models control for bank characteristics and employ robust estimation techniques, unobserved factors such as management quality, organisational culture and innovation capability may also influence the relationship between digitalisation and efficiency.

Finally, digital transformation is a dynamic process. The study period captures important developments in Nigerian banking, but longer-term effects of digital investments may require additional observation periods.

5.4 Suggestions for Future Research

Future studies may extend this research in several ways.

First, future research may examine whether specific digital technologies produce different efficiency outcomes. For example, separate analysis of: mobile banking, artificial intelligence, blockchain, cloud computing, and fintech partnerships may provide deeper insights.

Second, future studies may incorporate additional moderators such as: corporate governance quality, management capability, innovation culture, and cybersecurity maturity.

Third, comparative studies across African banking systems could determine whether the Nigerian experience reflects broader emerging-market patterns.

Fourth, future research may investigate nonlinear relationships between digital innovation and efficiency. The present findings suggest that digital transformation may involve an initial cost phase followed by efficiency improvement; therefore, threshold models or dynamic nonlinear approaches may provide further evidence.



Finally, future studies may examine the long-term productivity consequences of digital transformation using alternative methodologies such as stochastic frontier models, dynamic DEA or machine-learning approaches.

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Additional References Supporting Digital Transformation and Banking Efficiency Discussion



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