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Digital Banking Innovations: An Imperative for Operational Efficiency in Listed Nigerian Deposit Money Banks

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Abstract: *The growing use of digital platforms in banking has greatly changed the way services are provided in Nigeria. There are still differences in how these innovations do, however, perform in terms of operations. The impact of digital banking innovations on operational efficiency of listed Deposit Money Banks (DMBs) in Nigeria (2010-2024) was studied. The study used an ex-post facto type of research design and secondary data was obtained from the annual reports of the 14 listed banks. Digital banking innovations were proxied by Automated Teller Machines (ATM) and Electronic Mobile Banking (EMB) transactions, while operational efficiency was measured by Non-Performing Loans (NPL) and Liquidity Ratio (LR) was used as a control variable. Data was analysed using correlation and panel regression. The results revealed that ATM had positive but insignificant relationship with NPL, whereas electronic mobile banking transactions had negative but insignificant relationship with NPL. Liquidity ratio had a positive and insignificant effect on the operational efficiency. The study finds that digital banking innovations and liquidity management can affect the operational performance, but do not have a significant impact to the extent that the study suggests on the loan performance of listed Nigerian deposit money banks. The study suggests that financial institutions should invest more in their ATM and mobile banking systems, encourage digital banking adoption, strengthen credit risk management, and ensure proper liquidity management to boost efficiency and reduce financial risks*

Keywords: digital banking innovations, operational efficiency, automated teller machines (ATM), electronic mobile banking (EMB), Nigerian banks

INTRODUCTION

Digital innovations in banking have revolutionized the financial landscape and the way banking services are rendered in the world. The advent of technology has brought with it digital platforms that enable financial transactions to be processed quickly, easily and efficiently. The

use of these innovations is fast becoming a trend among the deposit money banks in Nigeria due to changes in customer expectations, competition and the desire of the banks to improve their operations. Digital banking channels like Automated Teller Machines (ATMs) and Electronic Mobile Banking (EMB) applications have allowed the customers to bank anytime, away from the traditional banking halls and manual processes (Mboto et al., 2023; Ehiedu et al., 2023).

Digital innovations have been a major influence on the evolution of banking over the years, leading to better service delivery, faster time to transaction and increased access to financial services. To stay competitive and boost operational efficiency, Nigerian banks have been investing heavily in IT infrastructure, cybersecurity measures, and employee training programs (Chauhan et al., 2022). The advent of digital platforms has, however, presented a number of challenges, such as cybersecurity hazards, electronic fraud, unreliable network connectivity, power supply constraints, and access to digital services, which are significantly different between rural and urban areas. These issues can impact transactional reliability as well as user trust and confidence, and can even result in customers reverting to cash transactions despite the ease of use of digital banking channels (Awoniyi, 2022).

Although digital banking innovations are widely recognized for improving operational efficiency, empirical evidence in the Nigerian context remains mixed and inconclusive. Some studies suggest that innovations such as Automated Teller Machines (ATMs) and electronic mobile banking contribute to lower operational costs and greater efficiency, while others report weak or statistically insignificant relationships between digital adoption and performance outcomes (Uzor et al., 2022; Festus et al., 2020). These differing findings reveal a gap in the literature and emphasize the need for further research that applies more comprehensive and contextually relevant measures of operational efficiency

The purpose of this study is to empirically examine the effects of the digital banking innovations namely, Automated Teller Machines (ATMs) and Electronic Mobile Banking (EMB) application on operational efficiency of Nigerian banks. The results will help bank managers and regulators to enhance both the performance of their loans and the management of their liquidity. Moreover, the study will provide inputs as policy making and strategic decisions for digital transformation in the banking sector. Academically, it will contribute to the available literature by analyzing the impact of digital innovation on efficiency indicators, and will include the liquidity ratio as a control variable.

Few studies in Nigeria have looked at the operational efficiency of digital banking, with a primary emphasis on profitability, and non-performing loans (NPL) (Ehiedu et al., 2023) being an example of an important efficiency metric that has been overlooked. Furthermore, a large number of these studies only look at one digital channel at a time, e.g. ATMs or mobile banking, and do not measure how these digital channels impact bank performance (Iwedi, 2024; Otosi et al., 2024). This study is designed to fill these gaps by providing a combined analysis of the Automated Teller Machines (ATMs) and Electronic Mobile Banking (EMB) with the inclusion of the liquidity ratio, as a control factor, and the analysis of the 14 listed banks considering the increased regulatory relevance. Covering the period 2010 to 2024, it

provides a panel regression analysis that allows it to account for the impact of post-COVID digital reform and policy changes. The study provides solid evidence and answers these conceptual and methodological constraints of the role of digital innovations in operational efficiency of Nigerian banks.

LITERATURE REVIEW

This section includes conceptual review, theoretical review, and empirical analysis for the concepts of liquidity risk and profitability. Digital banking innovation (or electronic banking) describes the use of internet-based and automated technologies, which financial institutions use to deliver banking services to their customers from anywhere, anytime. Digital channels, including bank websites, mobile banking apps, and other digital platforms, enable customers to access financial products and services in real time, view their account balances, move money between accounts, pay their bills, and more, without having to go to a bank branch. Manual and paper-based operations have been replaced by digital processes, enhancing the efficiency, security, and customer convenience of banking services (Shanmugam & Nigam, 2020).

These innovations are a broad spectrum of technology-based financial services that have revolutionized banking processes by minimising reliance on cash transactions and promoting electronic methods of payment and contactless payments (Babarinde et al., 2020; Pazarbasioglu et al., 2020). Online banking, Automated Teller Machines (ATMs), and mobile banking have made financial transactions quicker, more secure, and more accessible in Nigeria (Dong et al., 2020; Gbanador, 2022). By incorporating ITCs into their business, banks have been able to reduce cost of operation, improve service delivery and extend financial services, especially in rural areas (Osiolo & Sije, 2023).

From the different digital platforms, Automated Teller Machines (ATMs) and mobile banking are still the two major indicators of banking innovation for the technology sector (Sugihyanto & Arsjah, 2024; Chinoda & Kapingura, 2024). ATMs enable customers to make withdrawals, transfer funds and even see balances, without having to speak to a bank employee. They have reduced the congestion in banking halls, made access easier and have made banking more convenient for customers (Gambo, 2020; Nwakoby et al., 2020). Despite these advantages, the use of ATMs in Nigeria is still mainly restricted to withdrawals, thus undermining their full potential in advancing electronic banking (Osakwe et al., 2023). However, mobile banking, which involves transactions and financial service delivery using mobile devices and other mobile devices, encourages cashless transactions and expands banking services to underserved regions (Awoniyi, 2022; Osinubi et al., 2022). It improves the efficiency of operations by automating repetitive tasks and reducing the workload for bank employees (Mang et al., 2023). Despite these advantages, it still has several drawbacks, including transaction fees, network reliability, and security concerns (Adukanya et al., 2023).

Mobile banking is one of the biggest breakthroughs in the financial industry that allows users to perform banking activities through a mobile app, USSD code or SMS service. Users can use these channels to send money, pay bills, buy airtime, and easily and conveniently access their accounts securely (Zayyanu et al., 2022; Aigbovo et al., 2022). Mobile banking not only

provides convenience to customers, but also can help banks reduce operational expenses and reach customers in remote and underserved communities. Despite this, financial literacy and user awareness are still low and greater public financial education efforts and supportive policy measures are needed to unlock its potential (Adekoya & Yusuf, 2024; Osakwe et al., 2024). In addition to digital banking channels, the liquidity ratio is also included as a control variable because it is a key factor in guaranteeing financial stability and efficiency. The liquidity ratio is an indicator of a bank's ability to satisfy short-term demands for liquidity with a bank's liquid assets (Kanu, 2021; Odongo, 2022). The higher the liquidity ratio, the more resilient and sound the financial practices of an organization are, while the lower the ratio, the greater the risks of liquidity pressures and financial exposure in the organization (Habib et al., 2022; Afolabi & Ogunleye, 2022). The efficient management of liquidity also helps banks to allocate their resources efficiently, ensure stable cash flows, and ensure overall financial stability (Airout et al., 2023; Abba, 2023).

In this case, operational efficiency is the ability of a bank to produce the maximum output given the minimum input, meaning that the bank is using its resources, automation and processes optimally (Idolor & Agbadudu, 2020). This includes cost cutting, service delivery, risk management and customer satisfaction (Eferakeya & Erhijakpor, 2020). The Non-Performing Loans (NPL) ratio is one of the indicators that is often used to measure this efficiency (Bueno, 2024; Atasyadila, 2024). The NPL ratio is a ratio that shows the percentage of loans that are in default or that are at the risk of being defaulted, it is used to measure the credit risk and the quality of the bank's asset (Ugwu et al., 2020; Patel et al., 2020). High levels of NPLs can create liquidity limits, profitability problems and challenges to the financial stability of a bank (Uchendu, 2021; Louzis et al., 2022).

These technological solutions, especially predictive analytics, help banks to control NPLs at an early stage by identifying potential loan default and improve credit monitoring systems (Dong, 2022; Adegbite & Okonkwo, 2022). The ratio of non-performing loans to total loans and advances, which is used as a proxy of credit risk and internal operational efficiency, is termed as NPL ratio in this study. It will help to give the picture as to the impact of digital innovation in the banking industry on the operations of listed banks accepting deposits in Nigeria.

This conceptual framework represents the intertwining of the main concepts explored in this study and is illustrated in the figure below. It shows the effect of innovations in banking that are considered digital banking, especially Automated Teller Machines (ATMs) and electronic/mobile banking (EMB) on the operational efficiency of Nigerian Banks, as shown in Non-Performing Loans (NPL). According to the framework, digital technologies improves efficiency by automating processes and providing better service (Eze et al., 2021). Besides that, the liquidity ratio is also controlled to accentuate its effect on strengthening the relationship between digital innovation and operational efficiency (Udeh & Chinedu, 2021).

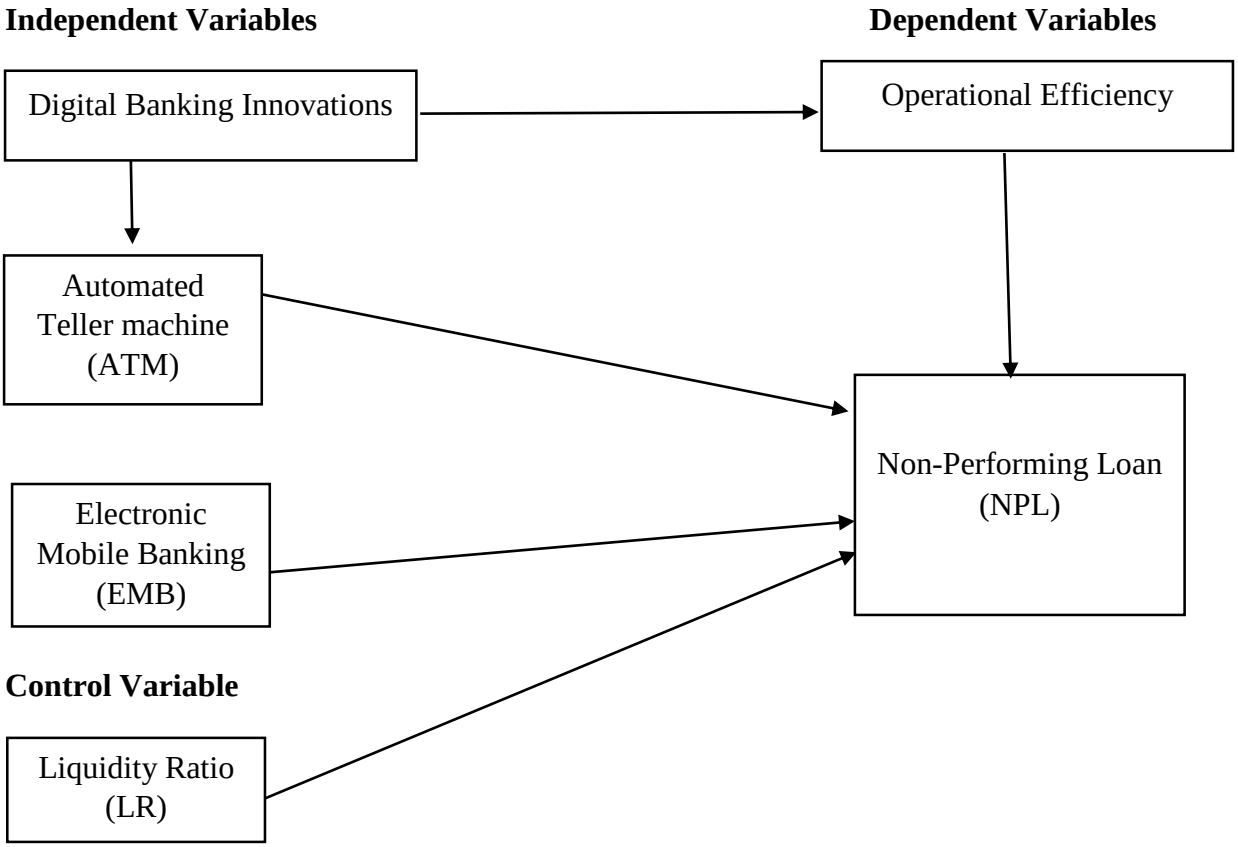

Figure 1: Shows the link between digital banking innovations and Operational Efficiency. Source: Author's Framework (2026)

Theoretical Review

This research is based on eleven theories and models which can give good theoretical foundation for this research. These are the Innovation Diffusion Theory (IDT), Contingency Theory, Disruptive Innovation Theory, Kane's Theory of Regulatory Dialectics, Financial Intermediation Theory, Innovator's Solution Theory, Theory of Reasoned Action (TRA), Unified Theory of Acceptance and Use of Technology (UTAUT), and Technology Acceptance Model (TAM), and Transaction Cost Economics (TCE). Innovation Diffusion Theory, which was developed by Everett Rogers in 1962, suggests that innovations are diffused when the user sees them as being useful, compatible with the status quo, and easy to use.

In 1964, Fred Fiedler proposed the Contingency Theory which states that the success of technology acceptance relies on its match with the environment and structural factors within an organization. Proposed by Clayton Christensen in 1995, Disruptive Innovation Theory illustrates how simple and low end technologies can steadily develop, gradually invading and outcompeting the market leaders. Edward Kane theorized in 1984 that regulations can create new innovations which help the regulation to become more flexible. The Technology Acceptance Model (TAM), by Fred Davis in 1986, and the Unified Theory of Acceptance and

Use of Technology (UTAUT) by Venkatesh Moris in 2003 show that factors that affect the adoption of technology include perceived usefulness, ease of use, social influence and facilitating conditions.

The basis for the development of digital technologies is the philosophy of Transaction Cost Economics as proposed by Oliver Williamson in 1975, which sees them as a way to reduce coordination and operational costs. Likewise, the Theory of Reasoned Action developed by Fishbein and Ajzen in 1975 correlates technology usage with people's attitudes, intentions to use technology and social norms within their environment. William Silber, in 1975, presented his Constraint Theory of Innovation, which stated that organizations innovate mainly to address regulatory or operational issues. In the 1970s, Leland and Pyle (1977) developed the Financial Intermediation Theory to explain how financial institutions help to lower information asymmetry and transaction costs, and the digital technologies reinforce this function. Last but not least, the Innovator's Solution Theory (2003) from Christensen and Raynor offers a framework in which to think about innovations: innovation is most effective when it solves a particular job to be done by a particular customer.

Theoretical framework

The study is based mainly on the Innovation Diffusion Theory and Technology Acceptance Model (TAM), which are given a lot of attention in the field of research regarding adoption and use of innovations in digital banking and their impact on operational efficiency. The concept of the Innovation Diffusion Theory is important to consider when looking at how innovations are accepted within an organization and in different industries and business areas and can be useful when thinking of how technological advancements are being adopted in the banking sector. It emphasizes how digital innovations, like mobile banking and electronic money transfers, can boost convenience and boost working efficiency. The theory also holds that long-term technological adoption is conducive to strategic growth, competitiveness and modernization of commercial banks. In contrast, the Technology Acceptance Model (TAM) is a model that proposes that perceptions of usefulness and ease of use mediate the relationship between a user's behavioral intention to use a digital technology and his or her actual use of the technology. In banking, TAM can be used to describe the interactions between customers and staff with digital platforms like mobile and internet banking. The framework is thus useful for understanding the adoption of technology and its impact on operational efficiency among the Nigerian Deposit Money Banks.

Empirical Review

Digital banking innovations have gained increased interest among researchers because of the perceived potential improving operational efficiency and enhancing financial performance of banking institutions. However, empirical studies conducted across various nations have yielded mixed results on how digital innovations such as Automated Teller Machine (ATM), mobile banking, and internet banking affect bank performance. According to Wanalo et al. (2020), innovations associated with ATMs improved the financial performance of commercial banks in Kenya, despite the negative effect of liquidity ratios on the association between ATM innovation and financial performance. In another empirical study, Hailu (2020) indicated that transactions through ATMs had a positive effect on the profitability of commercial banks in

Ethiopia, but mobile banking innovations did not demonstrate significance in influencing profitability.

In Ngwa (2020) study, the use of ATM had a negative effect on the performance of banks, but the use of electronic mobile banking positively impacted performance. There are also cases where the adoption of digital technologies does not improve bank performance. Michael et al. (2020) noted that there is a negative relationship between the use of ATMs, internet banking, mobile banking, and bank performance. The effectiveness of the implementation of digital innovations in enhancing bank performance.

On the contrary, Mwawasaa & Ali (2020) noted that innovations in mobile and online banking led to increased performance in Kenya's banks, stressing the need for organizations' capabilities and adoption by users in the effective utilization of the technology benefits. However, Tiriongo & Wamalwa (2020) warned about the potential credit risk posed by the increased volume of mobile banking transactions as they could contribute to non-performing loans, implying that there might be some issues in credit assessment through digital means. Other researches also provide examples of how digital banking has both negative and positive consequences. For example, Asama et al. (2020) established that there is a correlation between mobile transactions in Ghana and a growing number of non-performing loans, implying the exposure to credit risk associated with mobile borrowing. At the same time, Orina (2020) showed that mobile banking positively affected the efficiency of bank operations in Kenya by highlighting the operational efficiency gained from efficient integration of digital banking platforms in the processes of banks. Additionally, Lasmini et al. (2020) argued that internet banking had a greater impact on financial performance in Indonesia than mobile banking, while Abdo (2020) reported that innovations in ATM, mobile, and internet banking positively.

Nonetheless, Alemayehu (2020) failed to find any significant relationship between the use of mobile and ATMs and efficiency within Ethiopian banks, implying that digitalization does not necessarily translate into efficiency improvements. On the other hand, Animaw (2020) found evidence of a positive link between the use of electronic banking and profitability within Ethiopia, suggesting that digital technology may indeed contribute to improved financial performance if it is dependable and extensively used. Deekor (2021), on the contrary, found out that mobile banking significantly influenced bank performance positively while ATM banking negatively impacted it, probably because of poor infrastructural facilities. Furthermore, Deng et al. (2021) found out that the use of fintech minimized risk-taking among Chinese banks.

Recent literature shows that the influence of digital banking on the performance of banks is still mixed. For example, Muriuki (2021) found a significant and positive correlation between the use of mobile banking and efficiency in Kenya, while Muthaura et al. (2021) revealed that both the use of ATMs and agency banking positively impacted efficiency in listed Kenyan banks. Moreover, Bochaberi and Job (2021) concluded that mobile banking may positively impact financial performance; however, it requires a proper strategy to achieve good outcomes. Similarly, Oguche (2021) confirmed the impact of ATMs, internet, and mobile banking on the profitability of commercial banks in Nigeria. The research proves the importance of the use of

digital services for financial performance. For instance, Opiyo (2021) and Virginia et al. (2021) found that digital banking had a significant impact on bank performance in Kenya. Furthermore, Ongayo et al. (2021) and Mohamud et al. (2021) showed that payment innovations and electronic transactions positively affected financial performance and increased competition. Similar results were obtained by Kabir et al. (2021) in Nigeria.

More studies have also highlighted the influence of context in shaping the effect of digital banking. Adugna et al. (2021) identified a positive correlation between ATM services and mobile banking on profitability at Ethiopian banks while Thio et al. (2021) concluded that mobile banking did not contribute significantly to the operational efficiency of Indonesian banks. Internet banking, on the other hand, played a role in enhancing bank performance according to Origin et al. (2022) in the case of Nigeria. Bhattacharya (2022) went further to reveal how technological innovations led to a reduction in non-performing loans in the banking sector in India with specific emphasis on banks with poor records of innovation adopting new technology. Other studies like those by Sumarta et al. (2022), M'mata & Weda (2022), Chen et al. (2022), Osakwe et al. (2023), and Sajid et al. (2023) suggest that the effectiveness of digital banking is shaped by contextual factors.

Literature gap

Even though several scholars have studied innovations in digital banking in Nigeria, there are still some deficiencies that need to be considered. The majority of the literature focuses on the profitability of and market performance of financial institutions but not much attention is paid to operational efficiency, which is a key element in assessing internal resource optimization and quality of assets. Additionally, few researchers use non-performing loans as a measure of operational efficiency, thus, there is a lack of information about the impact of different digital services on the efficiency of operations. Another problem with previous research is that it evaluates the effect of single digital banking services, for example, ATMs or mobile banking, instead of looking at the combined impact of several digital platforms simultaneously. This paper attempts to fill this gap and evaluates the combined effect of ATMs and mobile banking while taking the liquidity ratio as a control variable – a component that is usually disregarded in previous literature.

First, many of the existing literature sources tend to select participants for empirical tests from a pool of different financial organizations, among which are not only the traditional commercial banks but also microfinance and regional banks that possess different regulatory policies and operational models. The current paper seeks to overcome the identified limitation by limiting the sample space to the 14 listed deposit money banks that operate on the Nigerian Exchange in December 2024. Second, previous researchers tend to apply the descriptive statistics approach or conduct simple regression tests without accounting for panel data or using control variables. Thus, this study employs a more complex approach based on the regression model, which enables estimating the effect of digital innovations on the operational efficiency of banks more accurately. Finally, the empirical analysis conducted in this paper is more timely than that carried out in the majority of existing literature sources. Many papers are completed before 2020; thus, the identified effects are not affected by the recent increase in the number of

transactions conducted via digital platforms, cashless policy of the Central Bank of Nigeria, and implementation of new fiscal tools such as TSA, IPPIS, and Zero-Based Budgeting.

Lastly, the empirical evidence obtained from past studies has been contradictory. While some studies have found a positive influence of digital banking services on efficiency (Al-Naimi et al., 2024; Otosi et al., 2024; Iwedi, 2024), other studies have found a negative effect of digital banking (Kalif, 2020; Michael et al., 2020; Virginia et al., 2021; Hoque et al., 2024), and yet some researchers have failed to establish any relationship between the two (Afifah et al., 2022; Fatmawati et al., 2022; Ehiedu et al., 2023). This demonstrates the need for a new and integrative analysis that takes into account the gaps identified earlier.

METHODOLOGY

The research philosophy entails a body of assumptions that govern the observation, collection, analysis, and interpretation of phenomena. It is connected with epistemology, the understanding of the connection between the researcher and the knowledge he/she wants to know. The ontology is associated with the belief concerning the reality and its nature. The current study adheres to the positivist research philosophy, which means that the reality is stable, and it can be objectively studied. According to Bergmann (2023), the positivist research philosophy has long been applied within the social sciences and provided a great contribution to many research papers. An ex post facto research design will be used for the research since it implies that the data is obtained from previously published financial statements and cannot be controlled by the researcher. The sample of the study includes fourteen (14) deposit money banks that are registered at the Nigerian Exchange (NGX) as of December 31, 2024. Since the sample is small and easily accessible, a census sampling technique will be utilized, covering all 14 banks.

The data utilized in this research were obtained from secondary sources such as audited annual reports of the selected banks and reports from CBN and NDIC for the period 2010-2024. The operational efficiency was determined based on Non-Performing Loan (NPL) index, which is expressed as the ratio of Total NPL to Total Loans, all multiplied by 100. The digital banking innovation was determined in terms of ATM and mobile banking transaction values. Liquidity ratio was used as a control variable and was determined as the ratio of Liquid Assets to Total Assets. For this research, both descriptive and inferential analyses were adopted. Descriptive analysis consisted of computing the mean and standard deviations of the data. On the other hand, inferential analysis entailed the stationarity tests, panel regression analysis, and model diagnosis to establish the statistical soundness of the model. Panel regression approach was applied in this study in an effort to estimate how the ATM and mobile banking transaction values and liquidity ratios affect the non-performing loans of listed deposit money banks in Nigeria.

Model Specification

The study adapted the model of Adesoye et al. (2024) with modifications to suit the current research context. The original model is expressed as:

FPERF = f(ATM, INTB, MOB, POS) ---------- 1

For this study, the performance measures and some digital banking variables were adjusted, and liquidity ratio was included as a control variable. The modified functional relationships are specified as:

NPL = f(ATM, EMB, LR) ---------- 2

Where:
NPL = Non-Performing Loans
ATM = Automated Teller Machine
EMB = Electronic Mobile Banking
LR = Liquidity Ratio

Panel regression analysis was used to estimate the models. The log-linear regression forms are:

$\ln NPL_t = \alpha_0 + \alpha_1 \ln ATM_t + \alpha_2 \ln EMB_t + \alpha_3 \ln LR_t + U_t$ ---------- 3

Here, α_1–α_4 are the coefficients of the explanatory variables, α_0 is the intercept, U_t represents the error term, and t denotes the time dimension.

Scope of the Study

The research examined the effect of transaction volume for automated teller machines and electronic/mobile banking services (EMB) on the efficiency of operations of the 14 listed deposit money banks in Nigeria between 2010 and 2024. Efficiency of the operations was measured in terms of the NPL ratio, while the liquidity ratio was used as a control variable. The data was collected from the annual report of the banks. Regression analysis was applied to analyze the association between the digital banking innovation and bank performance

FINDINGS AND DISCUSSIONS

This part deals with data gathering, presentation, and interpretation. For the purpose of the research, a panel regression approach was utilized, analyzing data obtained from the annual financial statements of the selected banks for a span of 15 years (from 2010 to 2024) with regard to how innovative technologies in digital banking affect deposit money banks' efficiency in Nigeria. Various methods were used to analyze the data, such as multivariate Granger causality test, along with pooled, fixed effects, and random effects estimation techniques.

Descriptive Statistics

Table 4.1 provides the descriptive statistics for the research variables, which provide a picture of the characteristics of the variables. Descriptive statistics include statistical parameters like the mean, which refers to the average of all the variables' values. It also includes the standard deviation, which measures how varied the variables' values are. Minimum and maximum values are the highest and lowest variables' values.

The data used in this research consist of 210 observations collected during 14 periods of time from 14 deposit money banks. The average Non-Performing Loan (NPL) ratio is 6.43%, with a standard deviation of 7.07. This statistic suggests that there is moderate variation in asset quality among the banks. There were banks that had 0.00% of Non-Performing Loans in specific periods, while some of the other banks recorded up to 61.94%.

For digital banking innovations, the Automated Teller Machine (ATM) transaction value has a mean of 1,068.54 with a standard deviation of 2,071.89, with a minimum and maximum range of 0.00 and 17,560.80, respectively. Similarly, EMB transactions have the highest mean of 5,390.81 with a standard deviation of 12,040.89 and a range of 0.00 and 98,632.71, respectively. This shows that there is great variation in the level of usage of these digital banking services with a high possibility of growth in the future. For the Liquidity Ratio (LR), the mean is 45.18% with a standard deviation of 18.10% and a range of 0.00% and 148.90%. The Jarque-Bera normality test result shows that all the variables have p-values greater than 0.05.

Table 4.1 Summary Statistics of the Variables used in Model

	NPL	ATM	EMB	LR
Mean	6.431962	1068.543	5390.813	45.18252
Median	4.700000	384.7169	544.5072	43.00000
Maximum	61.94000	17560.80	98632.71	148.9000
Minimum	0.000000	0.000000	0.000000	0.000000
Std. Dev.	7.067807	2071.894	12040.89	18.09781
Skewness	4.550214	4.885339	3.779224	1.314162
Kurtosis	30.30860	33.07025	22.16186	9.046559
Jarque-Bera	7250.050	8747.254	3712.686	380.3534
Sum	1350.712	224394.0	1132071	9488.330
Sum Sq. Dev.	10440.37	8.97E+08	3.03E+10	68453.89
Observations	210	210	210	210

Source: Computed by the Researcher, (2026)

Result of Unit Root Test

As can be observed from Table 4.2, the unit root test statistics (Levin, Lin & Chu t-statistic and PP-Fisher Chi-square statistic) show that the null hypothesis is rejected at 5% significance levels for all the variables when tested on first differences. This implies that NPL and LR are stationary at level [I(0)], while ATM and EMB are stationary at first difference [I(1)].

Table 4.2: Unit Root Test

VARIABLES	LEVEL		FIRST DIFFERENCE		ORDER OF INTEGRATION
	Levin, Lin & Chu t*	PP-Fisher Chi-square *	Levin, Lin & Chu t*	PP-Fisher Chi-square *	
NPL	0.3575	0.0000	0.1478	0.0000	I(0)
ATM	1.0000	0.9993	0.3085	0.0000	I(1)
EMB	1.0000	1.0000	1.0000	0.0000	I(1)
LR	0.0166	0.0095	0.0038	0.0000	I(0)

Source: Computed by the Researcher, (2026)

Correlation Coefficients

Table 4.3 shows the relationship between digital banking innovations and operational efficiency of the banks. NPL Ratio has low negative correlations with ATM transactions (-0.0203), EMB transactions (-0.1152), and Liquidity Ratio (-0.0287). This suggests that increased digital banking activities as well as high liquidity are usually linked to decreased instances of loan defaults.

Table 4.3: Correlation Matrix

	NPL	ATM	EMB	LR
NPL	1.000000	-0.020335	-0.115215	-0.028740
ATM	-0.020335	1.000000	0.300534	0.204830
EMB	-0.115215	0.300534	1.000000	0.037594
LR	-0.028740	0.204830	0.037594	1.000000

Source: Computed by the Researcher, (2026)

Data Analysis

Multivariate Granger Causality Tests

Granger causality test of multivariate type was carried out employing Vector Autoregression model to investigate the causal relationships among digital banking innovations such as ATM and EMB transactions and operational efficiency measured as NPL. According to Table 4.4, there are no statistically significant results indicating that digital banking innovations can jointly predict the quality of assets. This is indicated in the joint test (p=0.91), where the impact of these digital innovations on NPL is zero throughout the research period.

Table 4.4: Granger Causality Test Results (Dependent Variable: NPL)

Excluded	Chi-sq	df	Prob.
ATM	0.254151	2	0.8807
EMB	1.529528	2	0.4654
All Variables	2.108747	4	0.9094

Pooled Regression

Table 4.5 below captures the findings from the pooled regression of the dependent variable (Non-Performing Loans). This table represents the influence of the independent variables (ATM, EMB, and LR) on the operational efficiency. The R-squared (0.0145) explains that the independent variables account for 1.5% of the variation in NPL. The value of the Durbin-Watson statistic (1.285) reflects mild positive serial correlation. Considering ATM and its individual impact on NPL, ATM has a positive yet insignificant influence on NPL (0.0000757, p = 0.7654). Similarly, the coefficient for EMB is -0.0000645 (p = 0.2158) which implies insignificant negative influence on NPL. The same can be concluded for LR whose coefficient (-0.011052, p = 0.6901) is insignificant.

Fixed Effects Model

The results obtained from fixed effects regression analysis with respect to non-performing loans, NPL, as the dependent variable have been presented in Table 4.5 below. The values of R-squared (0.2322) imply that 23.2% of variation in NPL can be explained by the selected independent variables. At the same time, Durbin-Watson statistic value (1.518) reveals the presence of slight positive serial correlation. F-statistic (1.737, p = 0.0141) suggests model significance. Considering the individual effect of each variable on NPL, ATM (0.000158, p = 0.6035) is positively, but insignificantly associated with NPL, whereas EMB (-0.0000285, p = 0.6440) is negatively, but insignificantly associated. Additionally, Liquidity ratio is positively, yet insignificantly related (0.065251, p = 0.0861).

Random Effects Model

Table 4.5 below represents the output from a regression of Non-Performing Loans (NPL) with respect to ATM, EMB and Liquidity Ratio (LR) in 14 deposit money banks. It can be observed that the R-squared value (0.0097) is less than 1%, indicating very weak explanatory power for NPL. The positive serial correlation indicated by the Durbin Watson statistic (1.411) implies that there are slight autocorrelations between the residuals. On an individual basis, the variables ATM, EMB and LR indicate insignificantly positive (ATM; 0.000081; p = 0.7609), negatively insignificant (EMB; -0.0000612; p = 0.2515) and insignificantly positive (LR; 0.008147; p = 0.7944) relationships with NPL respectively.

Table 4.5: Presentation of Panel Regression Results for Non Performing Loan (NPL)

	Pooled Effect Model	**Fixed Effects Model**	**Random Effects Model**
C	7.244647 (0.0000)	3.376890 (0.0708)	6.299721 (0.0002)
ATM	7.57E-05 (0.7654)	0.000158 (0.6035)	8.09E-05 (0.7609)
EMB	-6.45E-05 (0.2158)	-2.85E-05 (0.6440)	-6.12E-05 (0.2515)
LR	-0.011052 (0.6901)	0.065251 (0.0861)	0.008147 (0.7944)
	Effect specification		SD
Cross section random			2.437134
Idiosyncratic random			6.710550
No. of Obs.	210	210	210
Durbin-Watson statistic	1.284935	1.518306	1.410913
F-statistic (P-value)	0.754196 0.556261	1.736966 0.014122	0.501214 0.734873
R^2	0.014503	0.232249	0.009685

Robustness of the Model

Manually choosing between fixed and random effects can be subjective and unreliable. To ensure an evidence-based selection, econometricians use formal tests like the Hausman Specification Test, which assesses whether unobserved individual effects are correlated with the regressors, guiding the choice of the most appropriate model for panel data analysis.

Hausman Test Result

The Hausman Specification Test identifies the appropriate model between fixed and random effects by checking whether unobserved individual effects are correlated with the explanatory variables. A significant p-value (<0.05) favours the fixed effects model, while a p-value >0.05 supports the random effects model. The test results for NPL are shown in Tables 4.6, guiding the selection of the suitable estimation method for each model. The table shows the Hausman test results for the NPL model, which evaluates whether fixed or random effects are appropriate. The Chi-square statistic is 1.550728 with a p-value of 0.6706, well above 0.05, indicating no significant correlation between explanatory variables and individual effects. This supports the use of the random effects model, which is therefore adopted for estimating the long-run impact of the independent variables on NPL

Table 4.6: Hausman Specification Test output for Non Performing Loan (NPL)

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section and period random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	1.550728	3	0.6706
Period random	6.016051	3	0.1108
Cross-section and period random	6.910316	3	0.0748

Histogram Normality Test

Non Performing Loan (NPL)

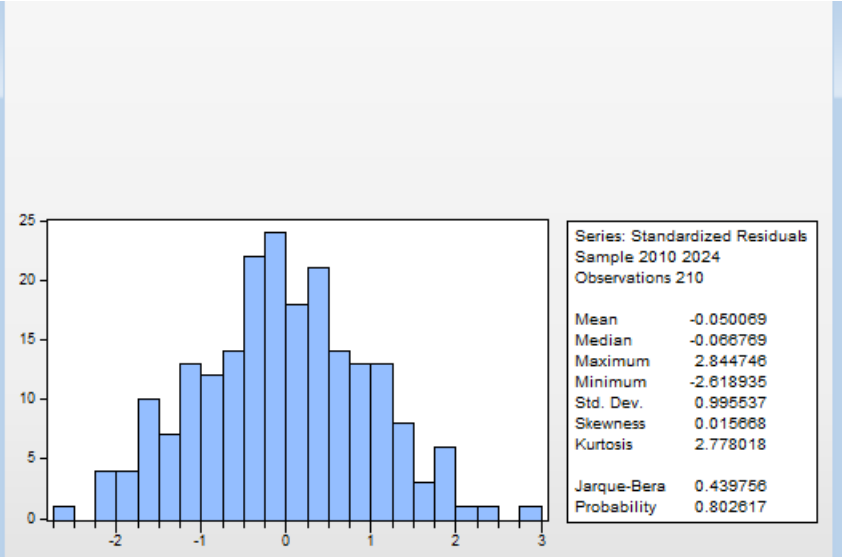

Figure 4.1: Normality Test of Model (NPL)

Figure 4.1 presents the post-estimation normality test for the model assessing the effect of ATM and EMB transactions, with Liquidity Ratio (LR) as a control, on Non-Performing Loans (NPL) in Nigerian deposit money banks. The Jarque-Bera statistics are all insignificant, indicating that the model and variables are normally distributed and validating the normality assumption for the dataset

DISCUSSIONS OF FINDING

This study investigated the effect of digital banking innovations on the operational efficiency of listed deposit money banks in Nigeria. The digital banking variables considered were transactions through Automated Teller Machines (ATM) and Electronic Mobile Banking (EMB), while operational efficiency was measured using Non-Performing Loans (NPL).

Liquidity Ratio (LR) was included as a control variable. Unit root tests revealed that ATM and EMB transactions are stationary at first difference, I(1), whereas NPL and LR are stationary at level, I(0), confirming suitability for regression analysis. Multivariate Granger causality tests indicate that short-term variations in ATM and EMB do not significantly predict NPL, suggesting that fluctuations in digital transactions have minimal immediate impact on operational performance. These findings are consistent with Alemayehu (2020) and Uzor et al. (2022), but contrast with studies reporting positive effects of digital channels on bank efficiency and asset quality (Oguche, 2021; Wang et al., 2024).

Random effects regression shows that ATM transactions have an insignificant positive effect on NPL (coefficient = 8.09E-05, p = 0.7609), implying little effect on loan performance. The findings show that a one-unit rise in ATM transaction value is linked to a 0.01% increase in NPLs, though the effect is not significant. This supports earlier studies reporting a positive association between ATM usage and NPLs (Wanalo et al., 2020; Muthaura et al., 2021; Bhattacharya, 2022; Al-Naimi et al., 2024). However, it contrasts with Hoque et al. (2024) and Chinoda and Kapingura (2024), who found a negative and significant relationship. On the contrary, EMB had a negative but insignificant effects on NPL (coefficient = -6.12E-05, p = 0.2515). The findings indicate that a one-unit rise in EMB transaction value reduces NPLs by about 0.01%, suggesting slightly improved loan performance, though the effect is not significant. This supports studies showing a negative link between EMB usage and NPLs (Tiriongo & Wamalwa, 2020; Deng et al., 2021; Virginia et al., 2021). However, it contrasts with research reporting a positive relationship (Asama et al., 2020; Muriuki, 2021; Bochaberi & Job, 2021; Chen et al., 2022) and with studies that found no significant effect (Thio et al., 2021; Fatmawati et al., 2022). Similarly, Liquidity Ratio is positively related to NPL (coefficient = 0.008147, p = 0.7944). The relationship shows that changes in liquidity ratios do not have an impact on efficiency or loan quality. In other words, a change in liquidity ratio by one unit can increase the NPL ratio by 0.8% while being statistically insignificant. These findings concur with Kumshe et al. (2024), who also established a positive relationship between liquidity and non-performing loans among Nigerian deposit money banks. On the contrary, Wanalo et al. (2020) revealed a significant negative relationship between the two variables.

On the whole, it is clear from the results that the major digital banking channels – ATM and EMB – have little statistical significance on the operational efficiency of the bank as indicated by NPL. Moreover, the findings indicate that the major digital banking channels, along with the liquidity position of the bank, have little significance on the bank's overall performance. In view of the above discussion, the null hypothesis that innovations in digital banking channels and liquidity have little or no effect on operational efficiency is validated to a large extent..

CONCLUSION AND RECOMMENDATION

The current research was carried out to determine the influence of new innovations in digital banking on the operational efficiency of publicly listed deposit money banks in Nigeria between 2010 and 2024. Transactions made using the ATM and EMB were considered as the independent variables, whereas the Liquidity Ratio (LR) was included as a control variable. Operational efficiency was determined based on the Non-Performing Loans (NPL). This study

followed an ex-post facto research design and used panel regression analysis to establish the relationships between variables. The results obtained indicate that ATM transactions have a positive but insignificant influence on the NPL, showing that there is a weak link with credit risk. Likewise, the influence of EMB transactions on the NPL is negative but insignificant, indicating a slight impact on the performance of loans. Also, the liquidity ratio has a positive but insignificant relationship with the NPL, which implies that more liquidity can cause some increase in credit risk.

From the analysis, it would be advisable for the deposit money banks in Nigeria to improve the reliability, security, and efficiency of the ATM and EMB systems to enable them to contribute more to the performance of operations in the bank. The banks need to adopt sound practices for credit risk management and to integrate their electronic banking systems with appropriate monitoring tools so that the use of technology does not end up increasing the number of non-performing loans. In addition, the banks need to encourage the use of the electronic banking system by their customers without compromising on liquidity and cybersecurity.

The study makes a significant contribution to the existing body of knowledge because it either verifies or invalidates other related studies, thus making an important theoretical contribution to the subject matter. In particular, this study will make an important contribution to the discussion of the connection between innovations in digital banking and operational efficiency of quoted deposit money banks in Nigeria. Moreover, the research will make an important contribution to the understanding of how digital banking facilities like ATM, POS, and mobile banking ease banking operations and improve customers' access to banking services. Furthermore, the work adds to the growing body of evidence on the importance of digital innovations in transforming the banking sector by lowering transaction costs, improving service efficiency and boosting customer engagement. The study identified the variables and empirically analyzed their effect that provides useful insights into the variables that really matter in influencing the adoption and effectiveness of digital banking technologies in the Nigerian banking sector.

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