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Digital transformation and bank capital adequacy in Sub-Saharan Africa

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ABSTRACT

This study examines the impact of digital transformation elements on the capital adequacy of deposit money banks in Sub-Saharan Africa, isolating the capital adequacy component of the CAMEL performance framework using six proxies of digitalization. An ex post facto study with panel data from listed banks in six countries (2013–2022) was analyzed with descriptive statistics, relevant diagnostic tests, and a random effects regression model, validated by the Hausman test. The findings indicate that financial inclusion, internet utilization, and bank size substantially enhance capital adequacy, whereas technology-related investments diminish it due to financial burdens and cyber-risk vulnerabilities. Using ATMs and mobile banking was insignificant, reflecting their maturity as baseline utilities that are already considered basic infrastructure and thus not able to generate a significant impact. The model accounted for 57.6% of the variation in capital adequacy, highlighting the significant yet partial role of digitalization in solvency. Findings highlight that digitalization is not uniformly beneficial; regulators and compliance institutions should integrate digital risks into supervisory frameworks, and banks should prioritize initiatives that strengthen prudential outcomes. The study extends digital transformation literature by addressing capital adequacy, offering evidence-based insights for balancing innovation with systemic stability in Sub-Saharan Africa.

Contribution/ Originality: This paper contributes theoretically by incorporating the Resource-Based View (RBV) and Diffusion of Innovations (DOI) into a unified framework. Practically, it informs regulators and managers by framing digital transformation as strategic for competitiveness and sustainability. Hence, this study reflects the integrated efforts of people, processes, and technologies in advancing resilience and inclusion.

1. INTRODUCTION

The banking sector in Sub-Saharan Africa is experiencing significant structural change driven by regulatory reforms and the integration of digital technologies into financial intermediation. In Nigeria, the Central Bank of Nigeria (CBN) (2024) launched the 2024 Banking Sector Recapitalization Programme, which substantially increased the minimum paid-in capital thresholds for all bank categories, including ₦500 billion for international commercial banks, ₦200 billion for national commercial banks, and ₦50 billion for regional commercial banks. These requirements, enforceable from April 2024 to March 2026, have already triggered a wave of capital raising through

rights issues, share placements, and secondary listings (Chima, 2025). Major institutions such as Access Holdings, Zenith Bank, and Guaranty Trust Holding Company (GTCO) have achieved compliance, while others, including UBA, Wema, Fidelity, and FCMB, are progressing through phased recapitalization strategies (Tokede, 2026). This regulatory tightening underscores the central role of financial resilience and consolidation in safeguarding systemic stability within Nigeria's banking industry and, by extension, the wider Sub-Saharan African financial architecture (Iwedi, Okey-Nwala, & Wachukwu, 2024).

Furthermore, digital transformation has become a pivotal factor in bank performance throughout the region, affecting efficiency, outreach, and competitiveness in increasingly technology-oriented financial markets. The implementation of mobile and internet banking platforms, digital payment systems, and technology-driven risk management has enhanced financial inclusion and transformed the provision of banking services, impacting both profitability and prudential stability (Ahmed et al., 2024; Klapper, 2024). Comparative evidence from other Sub-Saharan economies, including Kenya, Uganda, and the WAEMU and CEMAC monetary zones, underscores discrepancies in regulatory capital requirements while demonstrating a unified strategic dependence on digitalization to enhance banking sector performance (BCEAO, 2024; European Investment Bank (EIB), 2025). In this context, examining the effects of digital transformation components on banking performance in Sub-Saharan Africa is both opportune and essential, providing insights into the interplay between regulatory capital reforms and technological innovation in shaping competitiveness, resilience, and long-term sustainability (OECD, 2025).

The ever-increasing adoption and adaptation of digital technologies are redefining banking systems globally, including Sub-Saharan Africa, which is emerging as a formidable force in this transformation. As presented in Figure 1, internet penetration in the region has consistently increased from 28.8% of the population in 2018 to over 40% by 2023, and is projected to surpass 48% by 2027, reflecting a surge in connectivity that underscores the enabling infrastructure for digital banking adoption and highlights the importance of studying how such transformation affects core prudential indicators like capital adequacy. Financial institutions across the region are rapidly adopting mobile banking, internet platforms, data analytics, and automated risk management tools to enhance efficiency, optimize costs, and improve financial inclusion (Adeniran et al., 2022; Mogaji & Nguyen, 2022; Ononiwu, Onwuzulike, Shitu, & Ojo, 2024). In the region, digitalization has become a competitive benchmark, with some banks operating fully digital branches and enabling transactions beyond conventional business hours.

1.1. Statement of the Problem

However, as Thakur, Tunde, Noordin, Alam, and Prabowo (2024) noted, many transformation initiatives fail, often due to misaligned processes and inadequate integration of the People–Process–Technology (PPT) framework (Ejemeyovwi, Osabuohien, & Bowale, 2021; Olmstead, 2023). The academic discourse on the significance or effect of digital transformation on bank performance remains ongoing. While proponents highlight gains in operational efficiency and market reach, leading to an increase in deposit liabilities, the critics question whether such improvements translate into stronger prudential metrics and whether they're going to have a continuous effect beyond the short-term situation. In Sub-Saharan Africa, infrastructural constraints, regulatory diversity, and uneven digital literacy exacerbate this relationship (Barongo & Mbelwa, 2024; Ngo & Trinh, 2025; Xu, Kasperskaya, & Sagarra, 2025). This study focuses on the impact of digital transformation elements on the capital adequacy of deposit money banks in Sub-Saharan Africa (Nyapom & Padi, 2025; Olokundun, Ogbari, Falola, & Ibidunni, 2022) through the isolation of the capital adequacy element within the CAMEL framework and testing the role of specific digitalization proxies including ATM density, mobile banking, internet usage, financial inclusion, technology investment, and bank size and seeking clarify on whether digital transformation boosts or undermines banks' prudential strength.

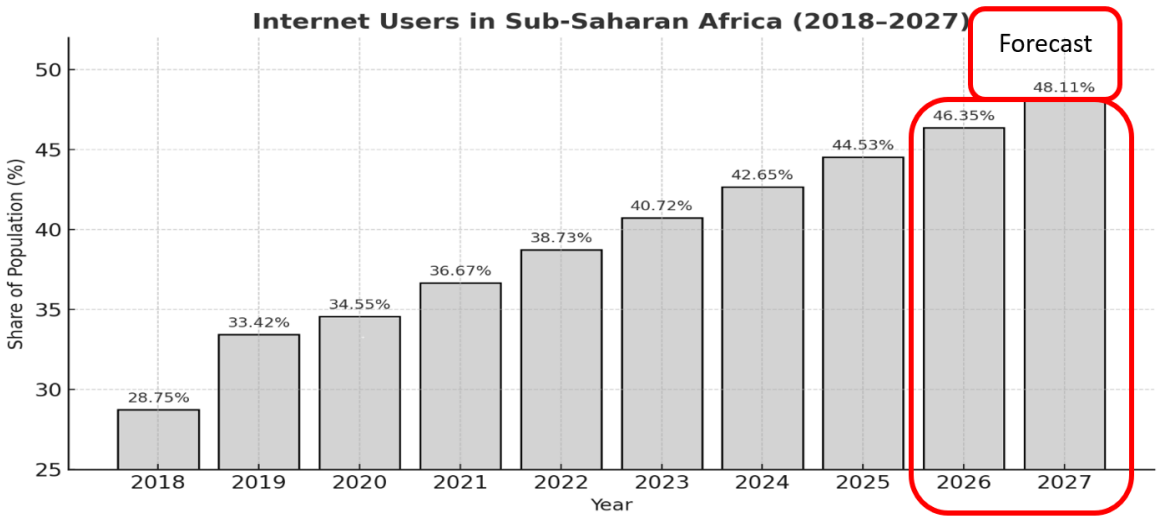

Figure 1. Internet users and forecast.

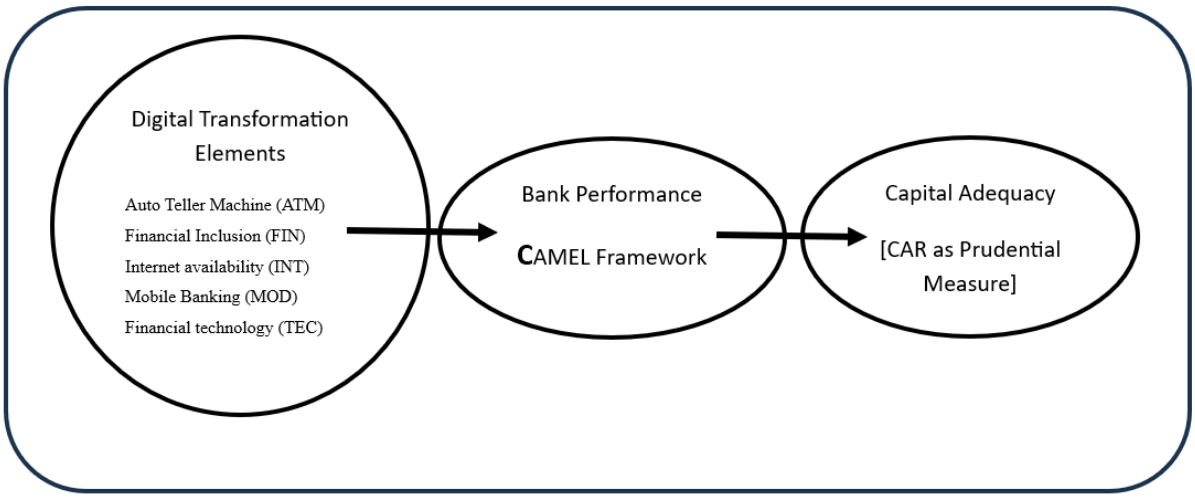

Figure 2. Conceptual framework: Digital transformation and bank capital adequacy.

Figure 2 illustrates the conceptual framework of the study of how the digital transformation elements influence capital adequacy, measuring banks' solvency and resilience.

2. LITERATURE REVIEW

2.1. Bank Performance and Capital Adequacy

Capital adequacy ratio serves as a critical measurement of bank performance and resilience, denoting the capacity of banks and other financial institutions to absorb unexpected losses while protecting depositors. The Capital Adequacy Ratio (CAR) expresses the proportion of a bank's capital to its risk-weighted assets as defined under the Basel Accord to guarantee solvency. While the Basel Accords set minimum global thresholds (8% for total capital, and 4% for Tier 1), many Sub-Saharan African regulators, such as the Central Bank of Nigeria, prescribe higher ratios like 15% for international banks, to strengthen buffers against systemic vulnerabilities (Central Bank of Nigeria (CBN), 2021; Jalloh, 2024). In the regional context, persistent challenges such as high non-performing loans, currency volatility, and nascent capital markets have heightened the importance of adequate capitalization for banking stability (Melo, Seal, & Salomao, 2024).

2.1.1. Digital Transformation and Capital Adequacy

Digital transformation has become a defining feature of banking in Sub-Saharan Africa, streamlining operations through mobile banking, internet platforms, and advanced data analytics. These innovations have the potential to improve capital adequacy indirectly by enhancing risk-weighted asset measurement, improving loan portfolio quality, and streamlining operations (Danquah & Adu, 2025). However, digitalization as an all-encompassing concept marks the evolution of cyber risks, higher technology costs, regulatory complications, and compliance constraints, which may lead to increased capital requirements. While financial inclusion and digital services expand deposits and strengthen solvency, the fallout of dependence highlights the need to critically evaluate the impact of advanced technology investments on capital adequacy. The contribution of specific digitalization elements, such as ATMs, mobile banking, and ICT infrastructure, regarding prudential outcomes remains mixed and context-dependent.

2.1.2. Conceptual Perspectives

This study is framed around the Technology–Organization–Environment (TOE) theory, which offers a panoramic view of the adoption and implementation of technological breakthroughs by organizations (Tornatzky & Fleischer, 1990). The TOE model, according to Ahmad, Omar, Ali, and Ali (2023), maintains that adoption is influenced by three interconnected contexts: technological, organizational, and environmental. The technical landscape in banking includes the availability, maturity, and appropriateness of technologies such as Automated Teller Machines (ATMs), mobile banking applications, and online platforms. The organizational context encompasses internal procedures, managerial policies, and human elements, including consumer literacy, behavioral patterns, and digital competencies. The environmental context involves external influences like regulatory reforms, including recapitalization mandates, competitive dynamics, and socio-economic demands for financial inclusion. This study employs the Technology-Organization-Environment (TOE) framework, identifying people, processes, and technology as fundamental factors influencing digital adoption. It illustrates how banks in Sub-Saharan Africa address internal requirements and external pressures concurrently.

The Technology-Organization-Environment (TOE) framework elucidates the diffusion of innovations, while the Resource-Based View (RBV) enhances the study by associating digital transformation with performance results. The RBV posits that organizations achieve enduring competitive advantage by cultivating resources and talents that are of immense value, unique, inimitable, and non-substitutable (Barney, 1991). In the banking sector, technology assets like ICT infrastructure, mobile platforms, and secure network architectures are regarded as critical resources. These resources are successful solely when integrated with organizational competencies, including customer engagement, transaction processes, and financial inclusion programs. This study integrates TOE, RBV, and DOI to provide a complete theoretical framework that encompasses the motivations and effects of digital transformation in Sub-Saharan African banks. The TOE framework elucidates the adoption process within technical, organizational, and environmental settings; the RBV correlates digital resources and organizational capabilities with performance results; and the Diffusion of Innovations (DOI) theory highlights the behavioral and social dynamics influencing customer acceptance of innovations. Collectively, these theories substantiate the study's emphasis on individuals, processes, technology, and performance metrics such as financial inclusion and total assets, while providing an analytical framework to examine how elements of digital transformation augment competitiveness and sustainability within the banking industry.

2.2. Digital Transformation Elements

Digital Transformation (DT) represents a significant opportunity, especially in the financial services sector of the economy and society. Enabling technologies are becoming cheaper and increasingly accessible, with rapidly spreading work processes and roles in abundant availability. The enormous resources being deployed into this phenomenon through substantial funding and incentives speak volumes, highlighting the need to assess the effects to

ensure there are commensurate returns for organizations. Three Digital Transformation elements will be reviewed for this paper, focusing on the specific elements analyzed in deposit money banks' annual reports are as presented in Table 1.

Table 1. Digitalization Matrix.

Item	People	Process	Technology
Automatic Teller Machine (ATM)	Customer behavioral pattern	Self-service transaction process	Hardware, software, network architecture
Financial Inclusion (FIN)	Easy entry for people and communities	Policies, outreach, and onboarding procedures	
Internet / Internet Banking (INT)	User skills, digital literacy	Online transaction workflows	Web platforms, cybersecurity systems
Mobile Banking (MOD)	Customer consumption trends, digital adoption	Mobile-based transaction processes	Smartphone apps, backend systems
Technology (TEC)			ICT tools, software, hardware
Total Assets (TA)		Asset management processes	

2.2.1. Digital Transformation in People

Artificial intelligence and computer-generated imagery are the two main technologies used to create digital people, which are humanoid characters with fully autonomous personalities. The most successful digital transformations occur at organizations that assign highly qualified individuals to the change management process. These colleagues are the initial adopters of new tools and technology; they acquire expertise in all new procedures and workflows and act as committed assets who remain committed for an extended period. If the "change managers" are recruited from within the organization, they will also yield interpersonal advantages due to their existing familiarity with the firm, its teams, and its culture (Life, 2022; Rokos, 2023).

Human comprehension is critical to the effective adoption of every innovation approach. This is because the adoption of new technology requires support from both higher-level management and lower-level employees. Lack of comprehension of its usage and significance will result in increased resistance to change. Digitization in every business offers two significant advantages: the automation of repetitive operations and time efficiency, enabling people to dedicate their efforts to more important work (Borsen, 2023; Sambo-Magaji, 2022).

2.2.2. Digital Transformation in Process

A business process, system, or function refers to a collection of interconnected and structured activities or tasks executed by people or technology in a predetermined order to generate a service or product for a particular client or customer, hence serving a specific business objective. Business structures are present at many hierarchical levels inside an organization and may or may not be readily apparent to customers (Dada, Akintoye, & Alawode, 2023). The development of business processes entails the construction of comprehensive business systems, which consist of six essential subsystems, including, but not limited to, the process substructure, documentation substructure, information substructure, and communication substructure. To combine these subsystems with a functioning organizational scheme, it is necessary to design and organize them. Additionally, a clearly defined system of informing inside the process structure frame should be established. All processes should be documented using the sequence principle, and an effective communication system should be implemented. The five fundamental business processes may be identified as follows: product development, sales and marketing, quality including service delivery, accounting and technology, and administrative procedures, which encompass human capital management. These are a set of procedures followed

in a precise sequence by an organization in order to accomplish its purpose or fulfill its mission (Kaniški & Vincek, 2018).

2.2.3. Digital Transformation in Technology

Technology – Systems represent the digital backbone of an organization's transformation efforts, serving as the integrated framework that supports the seamless collection, processing, storage, and transmission of data (OECD, 2024). This concept includes a range of hardware components, like servers, computers, mobile devices, and IoT sensors, all of which work together to capture and process information. Equally important are the networking elements that facilitate high-speed, secure communication between devices, ensuring that data flows efficiently within an organization and between external partners (Liu, Zhang, Xie, & Mei, 2024). Technology systems are the foundation of digitalization by establishing a linked and interoperable environment. This environment not only supports day-to-day business operations but also drives innovation, enhances data-driven decision-making, and provides a competitive edge in the modern world involving a rapidly evolving digital landscape (Metz, Marin, Marskell, Clark, & Karpinski, 2022; Nadkarni & Prügl, 2021; Wu, 2023).

The field of Banking Process Management has attracted significant attention from the banking and financial sector in the last ten years. The demand for mobile and online banking services is steadily rising due to the growing technological proficiency of bankers. Every financial transaction is intended to provide convenience, speed, and accuracy. The Banking and Financial Industry has been redefined through Business Process Management, some of which include Blockchain, Artificial Intelligence, Open Banking, Analytics, Biometrics, Cloud Banking, Computing, Cybersecurity, and Digital Payments. Technology is revolutionizing the banking sector by enhancing client experiences, augmenting security, and reducing expenses.

2.3. Theoretical Review

2.3.1. Technology–Organization–Environment (TOE) Framework

The Technology–Organization–Environment (TOE) framework remains a widely propounded fundamental model by Tornatzky and Fleischer in 1990 in the study of technology adoption and innovation diffusion. The TOE framework asserts that the adoption and implementation of technological innovations within organizations are influenced by three interconnected contexts: the technological context, which evaluates the availability, attributes, and perceived advantages of the technology; the organizational context, which pertains to internal factors such as size, resources, and managerial support; and the environmental context, which includes external influences such as competition, regulatory and compliance structures, and macroeconomic conditions (Tolić, Sabljić, & Sabljić, 2022). The TOE paradigm asserts that adoption of innovation is influenced by multiple factors rather than a singular one, with organizations making adoption decisions based on the limits and opportunities of their respective contexts.

The TOE framework is characterized by its multi-dimensionality, adaptability across many sectors and technologies, and ability to integrate both internal and external factors influencing adoption. Critics have observed that the framework may be excessively broad, providing insufficient operational advice for assessing each contextual component (Ahmad et al., 2023). The TOE framework elucidates the rationale behind the use of sophisticated technologies, including mobile banking platforms, AI-driven credit scoring, blockchain transaction systems, and big data analytics, by banks in Sub-Saharan Africa within the realm of digital transformation (Li, 2020).

2.3.2. The Resource-Based View (RBV)

Barney (1991) pivoted the emergence of the resource-based view theory, though it was originally proposed by Wernerfelt (1984) and Chatterjee, Chaudhuri, Vrontis, and Thrassou (2025). The resource-based view (RBV) posits that organizations possess resources, some of which facilitate competitive advantage, and a portion of those that result in superior long-term performance. Resource-based theory argues that resources characterized by value, rarity,

inimitability, and non-substitutability optimally position a firm for long-term viability, and that these strategic resources have the capacity to provide the foundation needed to develop firm capabilities that will result in superior performance over time. This theory posits that the ownership and management of essential strategic assets are crucial for financial success, hence serving as a fundamental determinant of competitive advantage and overall viability. Thus, RBV is seen more from an internal perspective (Madhani, 2010). The Resource-Based View (RBV) complements the TOE perspective by providing an internally focused rationale for how chosen technologies enhance sustainable performance increases. The RBV asserts that an organization's competitive advantage arises from possessing and strategically using resources that are valuable, rare, inimitable, and non-substitutable, known as the VRIN criteria (Barney, 1991). It posits that not all organizations possess identical resources and that such resources are not readily transferable or replicable, establishing them as a basis for enduring competitive advantage. Within the framework of capital adequacy, RBV emphasizes that internal resources, including predictive risk models, real-time monitoring systems, and specialized compliance teams, empower banks to effectively manage risk-weighted assets, sustain optimal capital buffers, and comply with capital regulatory mandates. The integration of TOE and RBV offers a comprehensive framework for understanding the adoption and performance effects of digital transformation activities in banks across Sub-Saharan Africa. The TOE framework clarifies the factors, obstacles, and readiness conditions influencing the adoption of digital innovations by banks, while the RBV describes the processes by which these technologies, once integrated, generate competitive advantage and enhance capital adequacy. Therefore, integrating TOE and RBV not only supports digital transformation adoption but also links it to measurable performance outcomes essential for the stability and competitiveness of the banking sector.

2.4. Empirical Review

Jeff-Anyeneh, Abazu, and Ananwude (2022) study in examining the influence of electronic banking on the expansion of deposit money banks utilizing data from the Central Bank of Nigeria (CBN) annual reports and statistical bulletins, employing an Ordinary Least Squares (OLS) multiple regression model for analysis demonstrated that online banking and mobile banking significantly enhanced bank growth, whereas ATM operations and POS transactions exerted a lesser influence. Chukwu and Molokwu's (2022) study explored the influence of digital banking on the performance of Nigerian commercial banks, utilizing secondary data from 2010 to 2019. The analysis employed the Autoregressive Distributed Lag (ARDL) framework, utilizing data from the annual reports of the Nigeria Deposit Insurance Corporation (NDIC) and the statistics bulletins of the Central Bank of Nigeria (CBN), demonstrating that digital banking exerted a substantial and favorable impact on bank performance. The Kayani and Hakiman (2023) study focused on assessing the influence of CAMEL factors in Indonesia, particularly the external components of digitalization and bank size, on financial performance measured by return on assets. It found that digitalization improves asset quality, as measured by return on assets, with a conclusive suggestion that banks should continue innovating in digital banking while increasing their customer base and paying attention to infrastructure costs associated with digitalization. The study conducted by Madugba, Egbide, Jossy, Agburuga, and Chibunna (2021) examined the relationship between electronic banking and the profitability of Nigerian deposit money banks from 2010 to 2018, using data from the Statistical Bulletin of the Central Bank of Nigeria (CBN) and the CBN Financial Stability Reports. It found a positive correlation between mobile banking models and the earnings component of Return on Assets. Okolie and Eze (2023) used data from First Bank Plc, while Gbanador, Makwe, and Olushola (2022) also adopted an ex-post facto research design with data from the Central Bank of Nigeria's statistical bulletin to all arrive at the same conclusion that electronic banking, which is a variable of the digitalization concept impacts on the earnings of the banks in Nigeria. Shanti, Siregar, Zulbainarni, and Tony (2023) examined the impact of digital transformation on digital business models, focusing on its effect on bank profitability. Larger banks benefit more from computer software, while banks with stronger capitalization have more resources for significant software

investments. Conversely, smaller and less financially robust banks must incur substantial software costs to sustain operations. Regulators should emphasize this reality to these entities (Bertay & Huizinga, 2021).

Huang (2023) investigated the impact of digital transformation on the profitability of commercial banks analyzed data from 16 Chinese listed commercial banks and found that the implementation of digital transformation has a substantial positive impact on the financial performance of commercial banks, the Cao, Han, Huang, and Xie (2022) paper examines how digital transformation affects the ex post risk differentiation of large and small banks, as determined by nonperforming loan (NPL) ratios, while Huang (2023) asserts that the advancement of digital finance is intricately linked to the progress of digital technology, including the Internet, cloud computing, artificial intelligence, and other relevant digital technologies, with a beneficial impact on the operational effectiveness of publicly listed commercial banks.

3. METHODOLOGY

3.1. Research Design and Model

This study adopted an explanatory research approach to elucidate the correlation between a bank's performance and the components of CAMEL. Quantitative data were obtained from the banks' annual reports. The research model is delineated according to the study objectives and with reference to prior studies by Guo and Xu (2021) and Zhai, Razali, and Sulaiman (2022). Capital adequacy is used as a bank performance proxy and is globally recognized with the Basel Accord minimum ratio prescribed for tiers of banks.

3.2. Model Specification

One of the most feasible controls of deposit money banks in SSA is their capital level and the key determinant of capital adequacy, which is the minimum safety net set via the Basel Accord, with the capital adequacy ratio to be maintained at 12.9% (Al-Sharkas & Al-Sharkas, 2022). For the Tier 1 capital ratio, the minimum should be 10.5%, and the Tier 2 capital ratio should be 2% of risk-weighted assets. Additionally, banks are also expected to maintain a capital conservation buffer of 2.5%, while counter-cyclical buffers at 0-2.5% should also be maintained. According to Al-Sharkas and Al-Sharkas (2022), CAR is practically a worldwide standard for measuring banks' solvency and a de facto standard for almost all banks through its widespread adoption by national banks, while also serving as an early warning signal for banks' solvency risks (International Monetary Fund (IMF), 2019; Mchugh, 2015; Ndubueze, 2025). Therefore, the capital adequacy, as the dependent performance variable, was measured against the independent digital transformation elements of ATM, financial inclusion (FIN), internet availability (INT), mobile banking (MOD), technology (TEC), and the natural log of total assets (lnTA) for stability.

$X = (x_1, x_2, x_3, x_4, x_5, x_6)$.

Where;

x_1 = Auto Teller Machine (ATM).

x_2 = Financial Inclusion (FIN).

x_3 = Internet availability (INT).

x_4 = Mobile Banking (MOD).

x_5 = Financial technology (TEC).

x_6 = natural log of Total Assets (lnTA).

Bank Performance (BPS) - Y = Dependent Variable.

Where;

$Y = y_1$ = Capital Adequacy Ratio (CDEQ).

3.2.1. Functional Relationship

$y_1 = f(x_1, x_2, x_3, x_4, x_5, x_6)$

$$CDEQ = f(ATM, FIN, INT, MOD, TEC, lnTA) \quad \text{(Main Objective)}$$

$$Y = f(x_1)$$

$$y_1 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \varepsilon_i$$

$$CDEQ_{ti} = \beta_0 + \beta_1 ATM_{ti} + \beta_2 FIN_{ti} + \beta_3 INT_{ti} + \beta_4 MOD_{ti} + \beta_5 TEC_{ti} + \beta_6 lnTA_{ti} + \varepsilon_{ti} \quad \text{(Main Equation)}$$

3.3. Data Collection and Sources

Data on publicly listed banks' financial statements and annual reports will be collected from 2013 to 2022 using the model's objectives and variable descriptions from the authorized stock exchanges across Sub-Saharan Africa. Information on digital transformation is gathered through the examination of a bank's annual reports. The study will collate words and phrases associated with digital transformation. Data were gathered from six countries across Sub-Saharan Africa. The time frame for data collection was from 2014 to 2023 and was limited to data availability during those periods. To assess the interest of countries in investing in digital transformation, the five most frequent keywords in the measure of digitalization were identified as Digitalization, Financial Technology, Automated Teller Machine (ATM), and Information and Communication Technology (ICT). The data collected will be encrypted and entered into EViews for computation and analysis.

Table 2. Descriptive statistics.

Variables	CDEQ	ATM	FIN	INT	MOD	LNTA	TEC
Mean	19.2303	12.3600	8.5700	17.6300	8.0700	15.9300	18.9522
Median	18.9000	12.0000	9.0000	16.5000	8.0000	15.5000	20.1368
Maximum	32.9000	21.0000	15.0000	27.0000	15.0000	22.0000	23.1081
Minimum	12.1300	8.0000	4.0000	12.0000	4.0000	10.0000	13.8936
Std. Dev.	4.7991	3.0302	2.4995	4.7347	2.5396	2.6295	3.2354
Skewness	0.4722	0.8222	0.0707	0.4788	0.3489	0.2104	-0.2625
Kurtosis	2.8830	2.8308	2.4223	1.8444	2.5889	2.4745	1.3580
Jarque-Bera	3.7735	11.3872	1.4740	9.3842	2.7328	1.8883	12.3826
Probability	0.1516	0.0034	0.4785	0.0092	0.2550	0.3890	0.0020
Sum	1923.03	1236.00	857.00	1763.00	807.00	1593.00	1895.22
Sum Sq. Dev.	2280.06	909.04	618.51	2219.31	638.51	684.51	1036.29
Observations	100	100	100	100	100	100	100

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

The descriptive statistics in Table 2 suggest that the variables CDEQ, FIN, MOD, and LNTA satisfy the normality assumption, as their Jarque-Bera p-values exceed 0.05, indicating symmetrical distributions with slight skewness. Conversely, ATM, INT, and TEC do not exhibit normal distributions, with p-values below 0.05 and moderate skewness (ATM and INT are right-skewed, TEC is left-skewed), implying the presence of outliers or uneven data distribution. The mean values show elevated averages for CDEQ (19.23), INT (17.63), and TEC (18.95), while FIN (8.57) and MOD (8.07) have moderate averages, and ATM averages 12.36.

Table 3. Correlation test.

Variable	CDEQ*	ATM	FIN	INT	MOD	TEC	LNTA
CDEQ*	1.0000						
ATM	0.2044	1.0000					
FIN	-0.0522	0.5000	1.0000				
INT	0.2618	0.6475	0.1265	1.0000			
MOD	-0.1037	0.3293	0.4807	0.2919	1.0000		
TEC	0.1138	0.8773	0.5973	0.4658	0.3401	1.0000	
LNTA	0.1435	0.0090	-0.2130	0.1515	-0.0263	-0.0421	1.0000

Note: *Capital adequacy (CDEQ) is isolated as a measure of bank performance from the CAMEL criteria.

4.2. Diagnostic Tests

The data in Table 3 shows a cluster of strong interconnections among ATM, TEC, FIN, and INT, while CDEQ and LNTA exhibit generally weaker links to the other variables.

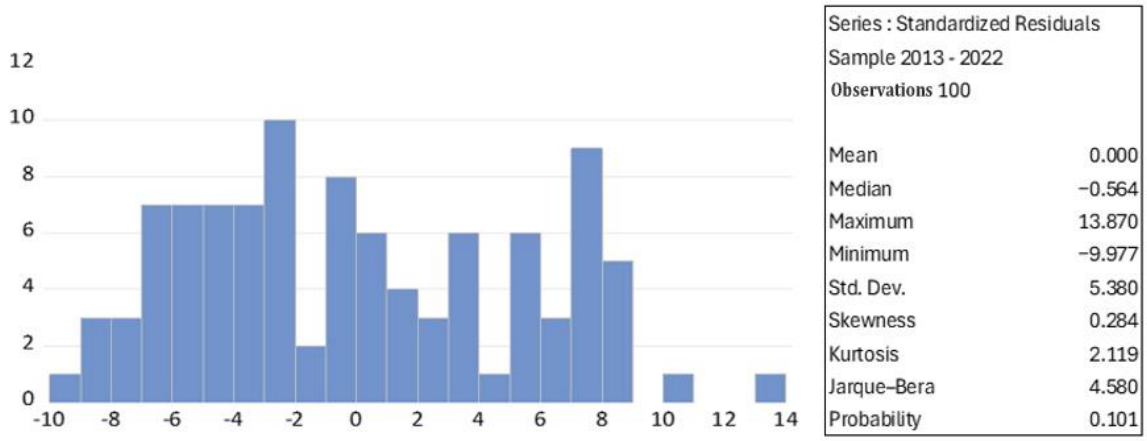

Figure 3. Normality test.

In Figure 3, the Jarque-Bera of 4.5805 and p= 0.1012 (higher than 0.05) dictated that we accept the null hypothesis that the residuals are normally distributed.

Table 4. Hausman test - variable-level comparison (Fixed vs. random effects).

Test Type	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**	
Cross-section random	9.4056	6	0.152	
Variable	**Fixed Effect Coef.**	**Random Effect Coef.**	**Var(Diff.)**	**Prob.**
ATM	0.1247	0.1233	0.0001	0.9030
FIN	0.3381	0.2065	0.0021	0.0042
INT	0.2554	0.2693	0.0009	0.6468
MOD	-0.2320	-0.2565	0.0002	0.1111
TEC	-0.1662	-0.1466	0.0001	0.0507
LNTA	2.7600	0.9730	0.3893	0.0042

Table 4 presents the Hausman test result (χ^2 = 9.406, p = 0.152) supporting the random effects model, as the null hypothesis of no systematic difference between fixed and random effects cannot be rejected. The Correlated Random Effects–Hausman Test was conducted to determine the appropriate panel data estimation technique for the study, which confirmed the suitability of the random effects model in examining the relationship between digital transformation elements and capital adequacy (CDEQ) of deposit money banks from 2013 to 2022. Regression results revealed that financial inclusion (FIN), internet usage (INT), and bank size (LNTA) exerted significant positive effects on capital adequacy, while technology (TEC) had a significant negative effect. ATM density and mobile banking (MOD) were statistically insignificant, indicating no measurable impact within the study period. The test produced a Chi-Square statistic of 9.4056 with degrees of freedom of 5 and a p-value of 0.152, which is insignificant at the 5% level. Therefore, we fail to reject the null hypothesis that the random effects estimator is consistent, meaning the random effects model is preferred for analyzing CDEQ over the fixed effects model.

4.3. Test of Hypothesis

Research Objective: Examine the effect of digital transformation elements on the capital adequacy of the deposit money banks in Sub-Saharan Africa.

Research Question: How do digital transformation elements affect the capital adequacy of deposit money banks in Sub-Saharan Africa?

Research Hypothesis (Ho): Digital transformation elements do not affect the capital adequacy of deposit money banks in Sub-Saharan Africa.

Table 5. Random effects regression results.

Dependent variable: CDEQ Sample: 2013–2022 (Balanced panel: 100 obs.)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-33.748	14.610	-2.310	0.023
ATM	0.125	0.0764	1.634	0.106
FIN	0.338	0.145	2.326	0.022
INT	0.255	0.102	2.510	0.014
MOD	-0.232	0.123	-1.891	0.062
TEC	-0.166	0.053	-3.130	0.002
LNTA	2.760	0.767	3.600	0.001
R^2	0.640	S.E. of regression		3.082
Adjusted R^2	0.576	F-statistic (*Prob*)		9.953 (*0.000*)
		Durbin–Watson stat		1.851

Note: Dependent variable: Capital adequacy.
*significant at 5%

Model

$$CDEQ = \beta_0 + \beta_1 ATM_{it} + \beta_2 FIN_{it} + \beta_3 INT_{it} + \beta_4 MOD_{it} + \beta_5 TEC_{it} + \beta_6 lnTA_{it} + \varepsilon_i$$

$$CDEQ_2 = -33.748 + 0.125ATM + 0.338FIN + 0.255INT - 0.232MOD - 0.166TEC + 2.76lnTA$$

The regression estimates, as contained in Table 5, indicate that digital transformation, assessed by Automated Teller Machines, financial inclusion, and internet availability, positively influences capital adequacy as a performance metric. However, the combination of technology and mobile banking adversely impacts performance (β_0 = -33.748; $\beta_{1</sub}$ = 0.125; β_2 = 0.338; β_3 = 0.255; β_4 = -0.232; β_5 = -0.166; β_6 = 2.76). The *Adjusted* R^2 of the model indicates that 57.56% of the variation in capital adequacy among the sampled deposit money banks can be attributed to the digitalization elements employed in this study, while the remaining 42.44% is due to other factors not included in this model, suggesting additional variables strongly influence performance as measured by capital adequacy. Under the random effects model, FIN (financial inclusion), INT (internet usage), TEC (technology), and LNTA (log of total assets) are statistically significant at the 5% level. FIN and INT have positive coefficients, indicating that greater financial inclusion and internet usage are associated with higher CDEQ values. TEC has a negative coefficient, implying increased technology scores are linked to lower CDEQ. LNTA is positive and highly significant, suggesting larger banks tend to have higher capital adequacy. ATM and MOD are not statistically significant at the 5% level.

Decision: The *F-statistic* is 9.9528 at a significance level of 5% with *df*=5, and the *P*=0.000, both below the 0.05 threshold. Consequently, the study rejected the null hypothesis that digital transformation does not influence bank performance as measured by capital adequacy in deposit money institutions. This outcome aligns with the theoretical and empirical evidence collected throughout the investigation.

4.4. Discussion of Findings

The descriptive statistics indicated that capital adequacy (CDEQ), financial inclusion (FIN), mobile banking (MOD), and bank size (LNTA) conformed to the normality assumption, while ATM usage, internet adoption (INT), and technology (TEC) showed deviations, suggesting irregular distributions and potential outliers. Capital adequacy (19.23), internet usage (17.63), and technology (18.95) had higher mean values than other factors, highlighting their significance within the sample.

Diagnostic assessments additionally validated the dependability of the analysis with the correlation matrix indicating robust interrelationships among ATM, TEC, FIN, and INT, although capital adequacy and bank size exhibited fewer correlations with other predictors, implying relatively independent impacts. A normality test of residuals indicated that the regression errors followed a normal distribution, while the Hausman specification test affirmed the random effects estimator as preferable to fixed effects, affirming its appropriateness for the model. The regression analysis revealed that elements of digital transformation had a varied impact on the capital adequacy of banks in Sub-Saharan Africa. Financial inclusion and internet usage showed a positive and significant correlation with enhanced capital buffers, suggesting that expanded outreach and digital transaction flows improve solvency. The size of the bank exhibited a highly significant positive impact, suggesting that larger institutions uphold greater resilience in accordance with Basel criteria. Conversely, technology-related investments demonstrated a substantial adverse effect, highlighting the financial costs and cyber-risk exposures linked to swift digitalization in the absence of efficiency improvements. The usage of ATMs and mobile banking was statistically insignificant, indicating that these established channels have evolved into baseline utilities rather than catalysts for prudential strength.

The model accounted for approximately 57.6% of the variation in capital adequacy, while the remainder (42.4%) may be attributable to other factors such as earnings capacity, liquidity management, and macroeconomic conditions. These findings align with previous research of Cao et al. (2022); Chukwu and Molokwu (2022); Gbanador et al. (2022); Madugba et al. (2021); Okolie and Eze (2023), and Shanti et al. (2023) that highlight the opportunities and risks associated with digital transformation in banking. Digitalization enhances resilience through financial inclusion and online platforms, but indiscriminate or mismanaged technological expenditures may jeopardize capital adequacy. This underscores the need to align digital strategies with prudent risk management to ensure long-term stability.

The regression results reveal that technology (TEC) has a significant negative effect on Capital Adequacy Ratio (CAR) ($\beta = -0.166$, $p < 0.01$), indicating higher technology adoption reduces banks' capital buffers due to ICT costs, system upgrades, and cyber-risks and this aligns with the studies of Aderinto and Faforiji (2025) and Aldasoro, Gambacorta, Giudici, and Leach (2020). Similarly, mobile banking (MOD) shows a negative though marginal effect, indicating potential vulnerabilities linked to fraud and cybersecurity gaps as contained in Jimmy (2024) and Oyewole, Okoye, Ofodile, and Ugochukwu (2024). These findings imply that while digitalization promotes efficiency, its associated risks and costs can erode profitability and capital reserves, thus weakening CAR unless supported by strong regulatory oversight and risk management frameworks (Eyo-Udo, Apeh, Bristol-Alagbariya, Udeh, & Ewim, 2025).

5. CONCLUSION AND RECOMMENDATIONS

The results of this study highlight several issues that banks and regulators in Sub-Saharan Africa must consider. This study has shown that financial inclusion makes capital adequacy stronger. Therefore, banks must develop affordable digital products and reach out to people who do not have access to them. Regulators can encourage these efforts by offering tax breaks or capital relief programs. Internet banking was also found to have a beneficial effect on capital adequacy, which shows that banks need to make more secure online platforms. To get the most out of this, regulators should set minimum cybersecurity standards and conduct stress tests regularly to ensure that systems can handle cyber threats.

The results also show that the size of a bank is positively related to its capital adequacy, which means that consolidation and scale can make things more stable. As a result, banks may consider merging or forming strategic partnerships to improve efficiency. At the same time, regulators clarify how to recapitalize and follow Basel III rules. The study, on the other hand, found that technology has a damaging effect on capital adequacy because it raises investment costs and cyber risks. To address this, banks should make phased investments in ICT backed by cost-benefit analyses. Regulators should also require banks to have separate capital buffers for operational and cyber risks. Lastly, during the study period, Automated Teller Machines and mobile banking had no significant effect on capital adequacy. This indicates that banks need to reconsider how much money they allocate to these channels. Regulators

can also assist by making it easier for different systems to work together and share infrastructure to reduce costs and improve efficiency. Overall, these suggestions highlight the importance for Sub-Saharan African banks to ensure their digital transformation aligns with Basel Accord standards, as shown in Figure 4, enabling both innovation and strength.

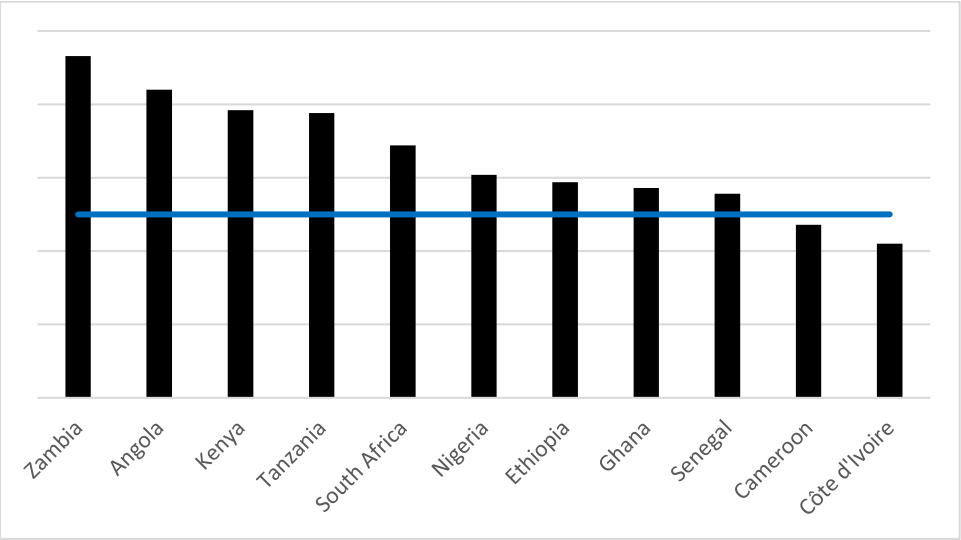

Figure 4. Basel Accord Comparison.

5.1. Suggestion for Further Studies

Further studies to expand the scope of this paper could be multidimensional in terms of cross-continental analysis, expanding the capital adequacy ratio spectrum, or analyzing the impact on CAMEL as a performance criterion based on industry maturity and the compliance environment.

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