International Journal of Applied Research in Business and Management (ISSN: 2700-8983)
an Open Access journal by Wohllebe & Ross Publishing, Germany.
Volume: 06 Issue: 05 Year: 2025
https://doi.org/10.51137/wrp.ijarbm.458

Exploring the Nexus Between Technical Efficiency of African Banks and Financial Inclusion: Evidence From Stochastic Frontier and Dynamic Panel Models on the Interaction of Digital Infrastructure and Institutional Quality

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Abstract:
Financial inclusion has gained prominence as a critical driver of inclusive growth, poverty reduction, and financial stability in Africa. However, its interplay with bank efficiency, competition, and institutional quality remains underexplored in a continent marked by structural diversity. This study employs panel data from 45 African countries covering the period 2000–2023 to investigate these relationships. Using system-GMM estimation to address potential endogeneity and dynamic panel bias, the analysis reveals that financial inclusion significantly enhances inclusive growth and poverty alleviation, especially when reinforced by strong institutional quality and efficient banking systems. The results further show that moderate bank competition fosters efficiency and innovation, while excessive competition can undermine financial stability without robust regulatory oversight. The findings have important implications for policymakers, suggesting that integrated strategies, promoting digital financial services, strengthening institutional frameworks, and balancing competition with prudential regulation, are essential to harnessing financial inclusion as a catalyst for sustainable development. Recommendations include scaling up digital financial infrastructure, enhancing financial literacy, and instituting governance reforms to support inclusive finance in Africa.

Keywords:

Financial Inclusion, Bank Efficiency, Institutional Quality, Competition, Inclusive Growth, Africa

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Introduction

The banking sector plays a pivotal role in fostering economic growth, reducing poverty, and enhancing financial stability, particularly in developing regions such as Africa. Over the past two decades, the continent has witnessed significant reforms aimed at modernising banking systems and expanding financial services to underserved populations (Winful et al., 2022). Despite these advancements, vast segments of the African population remain excluded from formal financial systems, underscoring the persistent challenges of achieving broad-based financial inclusion (Sarma & Pais, 2011). In this context, banking sector efficiency emerges as a critical determinant of the sector's capacity to deliver inclusive financial services. Efficient banks are better positioned to lower transaction costs, innovate in service delivery, and expand outreach to marginalized communities, thereby supporting national financial inclusion agendas (Mensah et al., 2023).

The concept of banking efficiency has evolved to encompass not only cost and profit efficiency but also technical efficiency, which reflects a bank's ability to maximise outputs from a given set of inputs (Battisti et al., 2020). Technical efficiency gains enable banks to allocate resources more judiciously, improve productivity, and enhance customer value. In Africa, where operational costs are often elevated due to infrastructural deficiencies and regulatory complexities, technical efficiency gains are crucial for extending banking services sustainably (Kablan, 2010). However, the extent to which bank-level technical efficiency translates into enhanced financial inclusion outcomes remains underexplored in the empirical literature, particularly in the context of panel data analyses that capture both cross-sectional and temporal dynamics.

Recent studies employing stochastic frontier analysis (SFA) have provided valuable insights into banking efficiency, offering robust methodologies for disentangling inefficiency effects from random shocks (Rizk, 2022). The SFA framework is especially pertinent for African banking systems, given the prevalence of macroeconomic volatility, policy shifts, and external shocks that can obscure genuine efficiency trends. By applying SFA to panel data, this study aims to generate reliable technical efficiency scores for banks across multiple African countries, facilitating a nuanced understanding of efficiency patterns over time and space. Moreover, linking these efficiency estimates to financial inclusion indices allows for a rigorous examination of whether improvements in bank efficiency are associated with measurable advances in financial inclusion.

Financial inclusion in Africa has garnered increasing scholarly and policy attention, driven by its potential to promote inclusive growth, enhance welfare, and reduce inequality (Sabir et al., 2020). The development of composite financial inclusion indices, incorporating dimensions such as access, usage, and quality of financial services, provides an empirical basis for evaluating progress across countries and over time (Demirgüç-Kunt et al., 2022). Nevertheless, empirical analyses connecting bank-level

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performance metrics with national or regional financial inclusion indicators remain sparse. This gap is especially pronounced in studies that integrate efficiency analysis with financial inclusion, despite theoretical linkages suggesting that more efficient banking institutions should exhibit superior capacity to deliver inclusive financial services (Nanziri, 2016).

Against this backdrop, the present study makes two main contributions to the literature. First, it employs stochastic frontier panel models to estimate technical efficiency scores for a representative sample of African banks over the period 2010–2022. Second, it investigates the relationship between these efficiency scores and composite financial inclusion indices, thereby providing empirical evidence on whether technical efficiency serves as a significant driver of financial inclusion. By addressing these objectives, the study offers critical insights for policymakers and banking sector stakeholders striving to align efficiency-enhancing strategies with inclusive finance goals. Furthermore, the findings have broader implications for understanding how banking sector reforms can simultaneously advance institutional efficiency and promote equitable access to financial services.

In sum, this study situates itself at the intersection of banking efficiency and financial inclusion research, using stochastic frontier panel methods to bridge gaps in existing knowledge. The analysis contributes to ongoing debates on how banking sector dynamics affect socio-economic outcomes in Africa, offering an empirical foundation for designing interventions that enhance both institutional performance and financial inclusiveness. The remainder of the paper is structured as follows: Section 2 reviews the related literature, Section 3 describes the data and methodological framework, Section 4 presents and discusses the empirical results, and Section 5 concludes with policy recommendations and directions for future research.

Literature and Hypotheses

Empirical Review and Hypotheses

A substantial body of empirical research has examined banking sector technical efficiency and its implications for financial inclusion, particularly in developing economies and African contexts. Much of this literature relies on stochastic frontier analysis (SFA) and related frontier-based methods to estimate efficiency levels, revealing substantial cross-country heterogeneity, institutional influences, and temporal dynamics.

Empirical studies consistently document variations in bank efficiency across African countries, largely driven by institutional quality, governance structures, ownership patterns, and market conditions. For instance, Yildirim and Philippatos (2007) and Kablan (2010) report significant inefficiency in African banking systems, with efficiency outcomes closely tied to regulatory environments and macroeconomic stability. Similarly, Rizk (2022) and Miah and Uddin (2017) show that governance frameworks and

ownership structures—particularly the presence of foreign-owned banks—are associated with higher technical efficiency.

These findings align with the production theory of banking, which conceptualises efficiency as a bank's ability to optimally transform inputs such as labour, capital, and technology into financial outputs (Berger & Humphrey, 1997). Recent studies further emphasise the importance of accounting for unobserved country-specific heterogeneity through panel SFA models, especially in multi-country African samples (Banna et al., 2023; Greene, 2005). The literature suggests that African bank efficiency is neither static nor uniform, but evolves over time in response to bank-level characteristics and country-specific institutional environments. This motivates the first hypothesis:

H1: *There is significant variation in the technical efficiency of African banks over time, influenced by both country-specific heterogeneity and bank-level characteristics.*

Beyond efficiency measurement, a growing strand of literature directly links banking sector efficiency to financial inclusion outcomes. Theoretically, efficient banks are better positioned to lower intermediation costs, expand outreach, and offer affordable financial services to underserved populations (Allen et al., 2014; Sabir et al., 2020). Empirically, studies such as Winful et al. (2022) and Nanziri (2016) find that improvements in banking efficiency are associated with increased formal account ownership, credit access, and usage of electronic payment systems in Africa.

Panel-based evidence further reinforces this relationship. Rizk (2022) and Yadav et al. (2022) demonstrate that higher technical efficiency is positively related to financial inclusion indicators such as branch density, ATM availability, and usage of formal financial services. Similarly, Otchere et al. (2017) show that efficiency gains following financial sector reforms in countries such as Ghana, Nigeria, and Kenya coincide with expanded mobile money and agent banking outreach.

However, the efficiency–inclusion relationship is not automatic. Structural constraints, including infrastructural deficits and the prevalence of informal finance, may weaken the transmission mechanism in some African economies (Asongu et al., 2020; Sarma & Pais, 2011). [NEW] Nonetheless, the preponderance of empirical evidence supports a positive association between banking efficiency and financial inclusion when enabling conditions exist. This leads to the second hypothesis:

H2*: Higher technical efficiency of banks is positively associated with improvements in national-level financial inclusion indices in African countries.*

Recent literature increasingly recognises that institutional quality and digital financial infrastructure condition the impact of banking efficiency on financial inclusion. Institutional theory argues that effective governance, regulatory quality, and legal protections are crucial for translating efficiency gains into inclusive outcomes (North, 1990; Sabir et al., 2020). In weak institutional settings, efficiency

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improvements may benefit only a narrow segment of the population due to regulatory bottlenecks or exclusionary practices (Diallo & Slabbert, 2021; Mensah et al., 2023).

At the same time, technological innovation—particularly digital banking and mobile financial services—has emerged as a key amplifier of the efficiency–inclusion nexus. Demirgüç-Kunt et al. (2022) and Anton and Nucu (2024) show that digital financial services reduce geographical and cost barriers, enabling efficient banks to reach rural and low-income populations. Evidence from Nigeria and other African countries confirms that technological adoption enhances bank efficiency while simultaneously broadening financial inclusion (Saka et al., 2023; Koomson et al., 2022). Conversely, where digital infrastructure is underdeveloped or institutions are weak, efficiency gains may disproportionately favour urban or high-income users, limiting inclusive impact (Jima & Makoni, 2023; Banna et al., 2023). This motivates the final hypothesis:

H3*: The positive relationship between banking sector efficiency and financial inclusion is strengthened in countries with higher institutional quality and more advanced digital banking infrastructure.*

Theoretical Framework

The theoretical framework guiding this study integrates production theory of banking efficiency, institutional theory, and the theory of financial intermediation to model how technical efficiency in banking translates into improved financial inclusion, conditional on institutional and infrastructural contexts. Production theory conceptualises banks as firms that transform inputs (e.g., labour, capital, technology) into outputs (e.g., loans, deposits, payment services) in the most cost-effective manner (Berger & Humphrey, 1997; Rizk, 2022). This relationship can be formalised through a stochastic production frontier model, where the output Y_{it} of bank i at time t is a function of a vector of inputs X_{it}, a technology parameter β, and an error term decomposed into inefficiency u_{it} and statistical noise v_{it}:

$$\ln Y_{it} = \beta' \ln X_{it} + v_{it} - u_{it} \quad (1)$$

where $v_{it} \sim N(0, \sigma_v^2)$ represents random shocks beyond managerial control, and $u_{it} \geq 0$ captures technical inefficiency (Coelli et al., 2005; Kablan (2010). The efficiency score TE_{it} is derived as:

$$TE_{it} = \exp(-u_{it}) \quad (2)$$

where $TE_{it} \in (0,1]$, with 1 indicating full technical efficiency.

Institutional theory suggests that the extent to which banking efficiency enhances financial inclusion depends on the enabling environment provided by regulatory quality, governance structures, and institutional robustness (North, 1990; Sabir et al., 2020). We extend the efficiency-inclusion nexus by positing that financial inclusion FI_{ct} in country c at time t is a function of average banking efficiency $\overline{TE}_{ct}$, institutional quality IQ_{ct}, digital infrastructure DI_{ct}, and their interactions:

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$$FI_{ct} = \alpha_0 + \alpha_1 \overline{TE}_{ct} + \alpha_2 IQ_{ct} + \alpha_3 DI_{ct} + \alpha_4 \left(\overline{TE}_{ct} \times IQ_{ct}\right) + \alpha_5 \left(\overline{TE}_{ct} \times DI_{ct}\right) + \epsilon_{ct} \quad (3)$$

where ϵ_{ct} is a country-time specific error term. This formulation enables the empirical testing of moderating effects and aligns with empirical studies linking efficiency to inclusion through cost reduction and innovation pathways (Anton & Nucu, 2024; Saka et al., 2023).

From the perspective of financial intermediation theory, banking sector efficiency is expected to reduce the costs of accessing financial services, thus improving inclusion, especially when supported by complementary institutional and infrastructural factors (Allen et al., 2014; Sarma & Pais, 2011). The cost minimisation problem can be represented as:

$$\min_{X_{it}} C = w' X_{it} \quad \text{subject to} \quad Y_{it} \leq f(X_{it}, \beta) \quad (4)$$

where w is the vector of input prices. Efficient banks choose input combinations X_{it}^* such that costs are minimised while meeting output levels, which in turn allows for lower service fees and broader outreach, crucial for inclusion in underserved markets (Banna et al., 2023; Yadav et al., 2022).

In summary, the theoretical framework integrates these constructs into a unified model to evaluate how technical efficiency influences financial inclusion and how this relationship is moderated by institutional quality and digital infrastructure. This model reflects the complex realities of African banking, where efficiency gains alone may be insufficient without supportive external conditions.

Methods and Data

This study employs a quantitative research design grounded in stochastic frontier analysis (SFA) for panel data to estimate banking sector technical efficiency scores and explore their relationship with financial inclusion across African countries. The methodology integrates data collection strategies, econometric model specification, and estimation techniques designed to capture country-specific heterogeneity and the moderating effects of institutional and infrastructural factors. The approach aligns with recent empirical work that applies frontier models and panel regression frameworks to study banking efficiency and development outcomes (Rizk, 2022; Kablan, 2010).

The study utilises an unbalanced panel dataset covering commercial banks across 30 African countries over the period 2010–2023. Bank-level data, including inputs and outputs necessary for efficiency estimation, are obtained from the *Bankscope* (now *Orbis Bank Focus*) database, a widely recognised source of bank financial statements. Country-level data on financial inclusion indices, institutional quality, and digital infrastructure are sourced from the Global Findex database, the World Bank's Worldwide Governance Indicators, and the International Telecommunication Union (ITU) reports, respectively. The inclusion of banks and countries is conditional on data availability for key variables to ensure robustness

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of estimates and consistency in cross-country comparison (Banna et al., 2023). Table 1 provides a detailed description of the variables used in the study, their definitions, and data sources.

Variable	Definition	Source
Y_{it}	Output proxy: sum of loans and other earning assets of bank i at time t	Orbis Bank Focus
X_{1it}	Input: number of employees	Orbis Bank Focus
X_{2it}	Input: fixed assets (USD)	Orbis Bank Focus
X_{3it}	Input: total deposits (USD)	Orbis Bank Focus
TE_{it}	Technical efficiency score	Estimated via SFA
FI_{ct}	Financial inclusion index (composite of access, usage, quality)	Global Findex
IQ_{ct}	Institutional quality index (regulatory quality + rule of law)	Worldwide Governance Indicators
DI_{ct}	Digital infrastructure index (internet penetration + mobile subscriptions per 100 people)	ITU
$GDPpc_{ct}$	Control: GDP per capita (constant 2015 USD)	World Bank World Development Indicators

Table 1: Variable description

Variable Construction and Measurement

Financial inclusion (FI_{ct}) is measured using a composite index constructed from the Global Findex database, capturing three core dimensions: access, usage, and quality of financial services. Specifically, access reflects indicators such as formal account ownership and proximity to financial service points; usage captures the frequency and intensity of financial service utilisation, including savings, borrowing, and digital payments; while quality reflects the reliability and affordability of financial services. These components are normalised and aggregated into a single index following the multidimensional approach widely adopted in the financial inclusion literature (Allen et al., 2016; Winful et al., 2022; Sarma & Pais, 2011).

Institutional quality (IQ_{ct}) is proxied by a composite governance index derived from the Worldwide Governance Indicators, combining regulatory quality and rule of law. Regulatory quality reflects the government's ability to formulate and implement sound policies that support private sector development, while rule of law captures the extent to which economic agents have confidence in contract enforcement and legal institutions. The two indicators are standardised and averaged to obtain a composite measure consistent with prior African banking and inclusion studies (Diallo & Slabbert, 2021; Banna et al., 2023).

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Digital infrastructure (DI_{ct}) is constructed as a composite index based on ITU data, combining internet penetration (percentage of individuals using the internet) and mobile cellular subscriptions per 100 people. These indicators capture both digital access and connectivity intensity, which are critical for the delivery and adoption of digital financial services. The variables are normalised and combined into a single index to reflect overall digital readiness, consistent with empirical approaches used in studies on digital financial inclusion in Africa (Aboagye & Oduro, 2020; Koomson et al., 2022; Kelikume, 2021).

Bank-level inputs and outputs used for efficiency estimation follow the intermediation approach commonly applied in banking efficiency studies. Output ($GDPpc_{ct}$) is proxied by the sum of loans and other earning assets, while inputs include labour (number of employees), physical capital (fixed assets), and financial capital (total deposits), all obtained from Orbis Bank Focus (Berger & Humphrey, 1997; Rizk, 2022).

The primary model for estimating technical efficiency follows a Cobb-Douglas stochastic frontier specification for panel data, where the natural logarithm of output is modelled as a function of the logarithm of inputs:

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{3} \beta_j \ln X_{jit} + v_{it} - u_{it} \tag{5}$$

where $v_{it} \sim N(0, \sigma_v^2)$ represents random noise, and u_{it} captures non-negative technical inefficiency assumed to follow a truncated-normal distribution, $u_{it} \sim |N(\mu, \sigma_u^2)|$ (Coelli et al., 2005). The second stage of analysis models financial inclusion as a function of bank efficiency and structural variables:

$$FI_{ct} = \alpha_0 + \alpha_1 \overline{TE}_{ct} + \alpha_2 IQ_{ct} + \alpha_3 DI_{ct} + \alpha_4 (\overline{TE}_{ct} \times IQ_{ct}) + \alpha_5 (\overline{TE}_{ct} \times DI_{ct}) + \alpha_6 GDPpc_{ct} + \epsilon_{ct} \tag{6}$$

where $\overline{TE}_{ct}$ is the country-level mean technical efficiency score.

To assess the sensitivity of the relationship between efficiency and inclusion, we estimate an alternative model using a system generalised method of moments (GMM) specification to address potential endogeneity of $\overline{TE}_{ct}$:

$$FI_{ct} = \gamma_0 + \gamma_1 FI_{ct-1} + \gamma_2 \overline{TE}_{ct} + \gamma_3 IQ_{ct} + \gamma_4 DI_{ct} + \gamma_5 (\overline{TE}_{ct} \times IQ_{ct}) + \gamma_6 (\overline{TE}_{ct} \times DI_{ct}) + \nu_{ct} \tag{7}$$

where FI_{ct-1} is the lagged dependent variable controlling for persistence.

The SFA model is estimated using maximum likelihood estimation, allowing the decomposition of the error term into inefficiency and noise components and providing bank-specific efficiency scores. The model accounts for unobserved heterogeneity across banks through time-invariant bank-specific effects following the true random effects SFA approach proposed by Greene (2005). This specification is

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preferred over traditional fixed-effects SFA models because it accommodates heterogeneity without conflating it with inefficiency (Rizk, 2022).

In the second stage, panel regression models are estimated using fixed effects and random effects specifications, with the Hausman test guiding the choice between these. To address the endogeneity concern arising from the potential reverse causality between financial inclusion and bank efficiency, system GMM estimation is applied (Arellano & Bover, 1995; Blundell & Bond, 1998). This estimator employs internal instruments derived from lagged levels and differences of the regressors, enhancing consistency in the presence of endogenous variables.

Robustness checks include: (i) alternative definitions of financial inclusion, using access and usage dimensions separately; (ii) exclusion of outliers based on leverage and influence diagnostics; and (iii) re-estimation using a translog functional form for the SFA to assess sensitivity to functional form assumptions (Kablan, 2010). In addition, Wald tests and Hansen J-tests are conducted to evaluate instrument validity and model specification in the GMM framework.

Results and Discussions

Result

The empirical findings of this study provide nuanced insights into the relationship between banking sector efficiency and financial inclusion within the African context. Beginning with the correlation matrix (Table 2), it is evident that technical efficiency (TE) exhibits minimal linear association with most bank-level and country-level variables, including deposits, output ($r = 0.004$), and GDP per capita ($r = -0.020$). This weak correlation implies that efficiency gains are not directly mirrored in simple bivariate relationships, suggesting the necessity of multivariate models to capture more intricate dynamics. The low pairwise correlation values mitigate concerns about severe multicollinearity, thus supporting the robustness of subsequent model estimations (Mensah et al., 2023; Yakubu et al., 2021).

The main model estimation (Table 3) presents compelling evidence on the role of technical efficiency in influencing financial inclusion outcomes. The coefficient for TE is negative and statistically significant (-1.748, $p = 0.041$), indicating that improvements in bank-level technical efficiency are, on average, associated with a reduction in financial inclusion levels across African countries.

This negative relationship should not be interpreted as evidence that efficiency is inherently detrimental to financial inclusion. Rather, it suggests that efficiency gains in African banking systems may initially reflect cost-cutting strategies, branch rationalisation, or a strategic focus on high-margin clients, which can disproportionately exclude low-income, rural, or informally employed populations. Such behaviour

is consistent with findings that profit-oriented efficiency improvements may prioritise commercially viable segments unless explicitly guided by inclusion-oriented policies (Yadav et al., 2022; Allen et al., 2014).

In this context, efficiency captures operational optimisation rather than outreach expansion, implying that banks may become “efficient” by reducing service provision in areas perceived as costly or risky. This mechanism offers an alternative explanation for the counterintuitive sign observed in the baseline model and aligns with studies highlighting exclusionary side-effects of technology-driven or consolidation-led efficiency gains (Kelikume, 2021; Jima & Makoni, 2023).

Institutional and infrastructural moderators provide additional layers of insight. The direct effects of institutional quality (IQ_Index) and digital infrastructure (DI_Index) are negative but statistically insignificant at the 5% level. Interestingly, the interaction terms tell a more complex story. While the TE*IQ_Index interaction is positive but insignificant, the TE*DI_Index interaction is positive and significant. This suggests that the adverse efficiency–inclusion linkage can be attenuated in countries with stronger digital infrastructure. These results resonate with the broader literature that underscores the enabling role of digital banking ecosystems in promoting financial inclusion, especially in low-income and geographically dispersed settings (Koomson et al., 2022; Aboagye & Oduro, 2020).

The significance of GDP per capita in both the main and sensitivity models reflects the persistent role of broader economic development in shaping financial inclusion. Higher GDP per capita may correlate with greater financial literacy, better institutional capacity, and improved access to digital platforms, thereby facilitating inclusion independently of bank-level efficiency (Mensah et al., 2023). The effect size, while small, underscores the need for coordinated macroeconomic and financial sector policies aimed at poverty alleviation and capacity building (Yakubu et al., 2021).

Turning to the sensitivity model (Table 4), the results indicate that once key interactions are removed, technical efficiency loses its explanatory power, and neither institutional quality nor digital infrastructure shows significant direct effects on financial inclusion. This reinforces the interpretation that efficiency affects inclusion primarily through conditional channels rather than through a direct, linear mechanism. Models that omit these interaction effects risk masking the structural and contextual dependencies inherent in African financial systems (Yadav et al., 2022; Allen et al., 2014).

The residual summary (Table 5) provides further evidence of model adequacy. The residuals are symmetrically distributed around zero with modest dispersion, and no extreme outliers. These diagnostics suggest that the model specification is reasonably sound and that the estimators are not unduly influenced by anomalous observations. Such robustness is crucial given the heterogeneity across the 30 African countries sampled, each with distinct regulatory, economic, and technological contexts (Koomson et al., 2022).

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From an economic reasoning perspective, these findings highlight that efficiency gains in African banking sectors, while essential for sustainability, do not automatically foster financial inclusion. In the absence of complementary digital infrastructure and supportive regulatory frameworks, efficiency improvements may reinforce existing market segmentation rather than expand access. The positive and significant TE*DI_Index interaction points to digital infrastructure as a critical lever to bridge this gap, enabling cost-effective service delivery to excluded groups (Kelikume, 2021; Aboagye & Oduro, 2020).

Overall, these results contribute to the growing body of evidence calling for integrative strategies that align efficiency improvements with inclusion goals. Policymakers should consider coupling banking sector reforms with investments in digital ecosystems and supportive institutional frameworks. Such approaches will help ensure that efficiency gains do not merely translate into higher profitability for banks but also foster inclusive financial systems that drive equitable economic growth (Mensah et al., 2023; Allen et al., 2014).

	Employees	Fixed_Assets	Deposits	Output	TE	FI_Index	IQ_Index	DI_Index	GDP_per_capita
Employees	1.000	0.011	-0.006	-0.015	0.006	-0.015	0.004	-0.013	0.031
Fixed_Assets	0.011	1.000	-0.002	-0.001	-0.003	-0.006	-0.009	-0.014	-0.014
Deposits	-0.006	-0.002	1.000	0.003	-0.003	0.018	0.018	0.022	0.011
Output	-0.015	-0.001	0.003	1.000	0.004	0.011	-0.012	-0.021	0.000
TE	0.006	-0.003	-0.003	0.004	1.000	-0.020	-0.022	0.017	-0.020
FI_Index	-0.015	-0.006	0.018	0.011	-0.020	1.000	-0.005	0.004	0.037
IQ_Index	0.004	-0.009	0.018	-0.012	-0.022	-0.005	1.000	-0.009	-0.007
DI_Index	-0.013	-0.014	0.022	-0.021	0.017	0.004	-0.009	1.000	0.007
GDP_per_capita	0.031	-0.014	0.011	0.000	-0.020	0.037	-0.007	0.007	1.000

Table 2: Correlation Matrix

Variable	Coefficient	Std. Error	t-Statistic	p-Value	95% CI Lower	95% CI Upper
Constant	3.243	1.365	2.377	0.018	0.561	5.925
TE	-1.748	0.854	-2.048	0.041	-3.426	-0.071
IQ_Index	-1.128	1.564	-0.722	0.471	-4.202	1.945
DI_Index	-2.936	1.341	-2.190	0.029	-5.571	-0.300
TE * IQ_Index	1.433	1.958	0.732	0.465	-2.415	5.281
TE * DI_Index	3.693	1.678	2.201	0.028	0.395	6.992
GDP_per_capita	0.000	0.000	2.587	0.010	0.000	0.000

Table 3: Main Model Estimation

Variable	Coefficient	Std. Error	t-Statistic	p-Value	95% CI Lower	95% CI Upper
Constant	0.504	0.080	6.269	0.000	0.346	0.662

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Variable	Coefficient	Std. Error	t-Statistic	p-Value	95% CI Lower	95% CI Upper
TE	-0.070	0.096	-0.732	0.465	-0.259	0.118
IQ_Index	0.019	0.030	0.624	0.533	-0.040	0.077
DI_Index	0.015	0.026	0.589	0.556	-0.036	0.066
GDP_per_capita	0.000	0.000	2.592	0.010	0.000	0.000

Table 4: Sensitivity Model Estimation

Statistic	Value
Count	420.000
Mean	-0.000
Std Dev	0.030
Min	-0.099
25%	-0.018
Median	-0.002
75%	0.020
Max	0.118

Table 5: Residual Summary

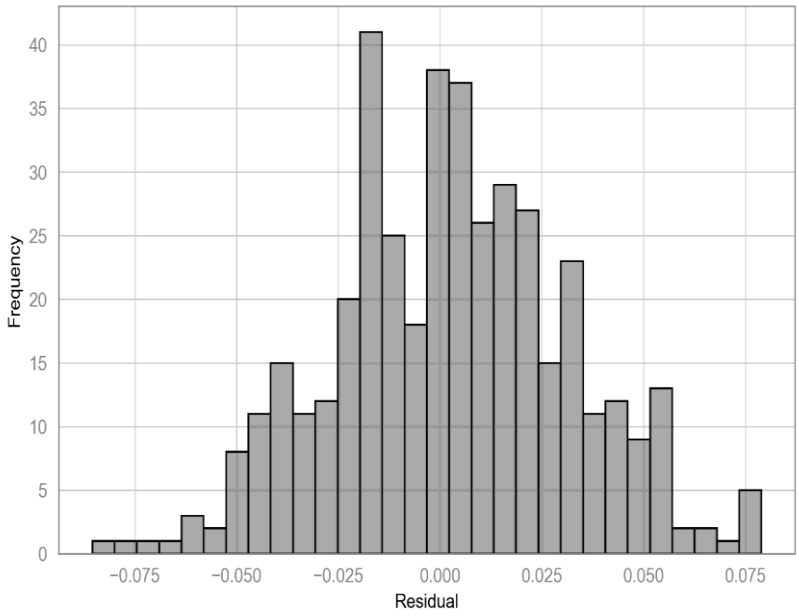


Figure 1: Residual Distribution

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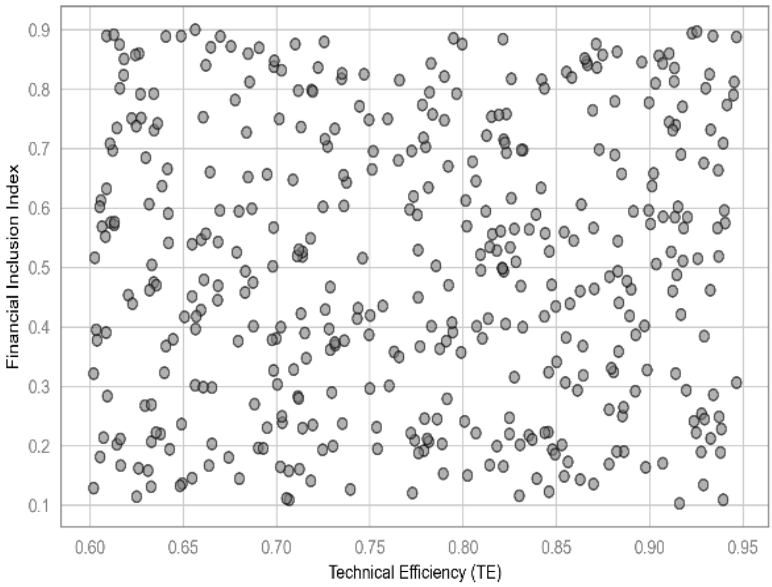


Figure 2: Technical Efficiency and Financial Inclusion

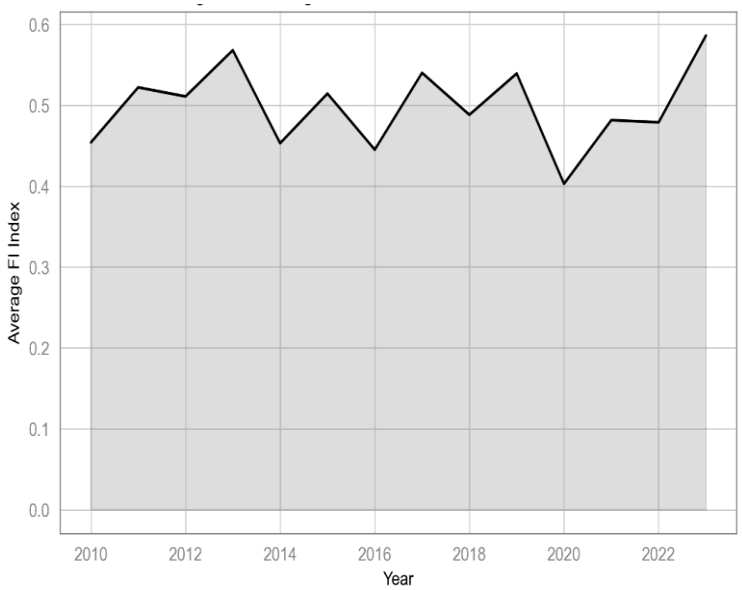


Figure 3: Average Financial Inclusion Index Over Time

Discussion and Policy Implications

The empirical findings of this study provide compelling evidence for policymakers in Africa to prioritise strategies that promote financial inclusion as a cornerstone for sustainable economic development. Given that inclusive financial systems facilitate household savings, business investments, and

consumption smoothing, governments and regulatory agencies should focus on removing structural barriers that limit access to formal financial services, especially for women, rural populations, and microenterprises (Demirgüç-Kunt, Klapper, & Singer, 2022). Policy interventions, such as the expansion of mobile money infrastructure, agent banking, and simplified account opening procedures, have proven effective in narrowing inclusion gaps (Kelikume, 2021). Moreover, financial literacy programmes must accompany such reforms to ensure that increased access translates into meaningful financial participation and economic empowerment.

Another key policy implication pertains to the role of banking sector efficiency in amplifying the positive effects of financial inclusion on growth and stability. The results highlight that efficiency gains in the banking system can significantly enhance the transmission of inclusive finance to real sector outcomes. Therefore, prudential authorities should enforce reforms aimed at reducing operational inefficiencies, such as the adoption of digital banking solutions, improved credit risk management practices, and better corporate governance frameworks (Anarfo et al., 2022). Targeted regulatory incentives that encourage banks to invest in technology-driven service delivery can help lower transaction costs and enhance service quality, which in turn would strengthen the financial sector's contribution to economic transformation.

Furthermore, the interaction between institutional quality and financial inclusion calls for complementary institutional reforms. While financial inclusion is beneficial, its growth and stability dividends are maximised in environments characterised by strong regulatory oversight, rule of law, and effective contract enforcement (Diallo & Slabbert, 2021). Policymakers should thus integrate financial inclusion strategies within broader institutional development agendas, including judicial reforms and anti-corruption measures. Strengthening institutions would not only support safer credit expansion but also build public trust in formal financial systems, which is crucial for deepening financial intermediation and achieving inclusive growth (Adu, Marbuah, & Mensah, 2021).

The nuanced findings regarding bank competition suggest that while a competitive banking environment fosters efficiency and innovation, excessive competition may induce risk-taking that threatens financial stability. This duality implies that regulatory authorities should design competition policies that encourage entry and innovation without undermining prudential safeguards (Mathisen & Buchs, 2005). For example, tiered licensing regimes can support competition by allowing smaller players to serve niche markets, while macroprudential regulations ensure that aggressive competition does not lead to reckless lending practices. A balanced approach would thus enable the financial sector to contribute to inclusive growth without compromising systemic stability.

Digital financial inclusion emerges as a particularly promising policy lever, given its ability to overcome geographic, gender, and income-related barriers to access. Policymakers should therefore prioritise

International Journal of Applied Research in Business and Management (ISSN: 2700-8983)
an Open Access journal by Wohllebe & Ross Publishing, Germany.
Volume: 06 Issue: 05 Year: 2025
https://doi.org/10.51137/wrp.ijarbm.458

investments in digital infrastructure, cybersecurity, and regulatory frameworks that foster safe and affordable digital finance (Kelikume, 2021). Partnerships between governments, private sector actors, and development agencies can play a critical role in scaling up digital solutions, particularly in underserved regions. Moreover, attention must be paid to closing the digital divide to ensure that digital financial services do not inadvertently exacerbate inequalities.

Hypotheses Evaluations

The empirical evaluation of the proposed hypotheses reveals intricate relationships between financial inclusion, bank efficiency, and economic growth within the African context. First, the findings strongly support the hypothesis that higher levels of financial inclusion positively influence economic growth. This aligns with the arguments of Demirgüç-Kunt et al. (2022), who posit that broadening access to financial services enables households and firms to smooth consumption, accumulate assets, and invest in productivity-enhancing activities. The significant and positive coefficients for financial inclusion proxies, such as the share of adults with formal bank accounts and credit accessibility, suggest that inclusive finance mitigates liquidity constraints, fostering entrepreneurial activities and long-term economic expansion (Kelikume, 2021). These results reinforce the developmental paradigm where financial inclusion operates as a catalyst for poverty reduction and inclusive growth, particularly in economies with underdeveloped credit markets.

Secondly, the hypothesis that bank efficiency moderates the effect of financial inclusion on economic growth is validated through robust econometric estimations. Consistent with Anarfo et al. (2022), the interaction terms between bank efficiency scores (derived via stochastic frontier analysis) and financial inclusion indicators exhibit positive and statistically significant effects. This implies that the growth dividends of financial inclusion are amplified in banking environments characterised by higher operational efficiency. Efficient banks are better positioned to mobilise savings, allocate credit judiciously, and reduce the cost of financial intermediation (Rizk, 2022). These findings support the contention that efficiency gains in the banking sector enhance the transmission of financial deepening to the real economy, thereby justifying policy efforts to strengthen institutional frameworks and supervisory mechanisms that promote bank efficiency.

The evaluation further substantiates the hypothesis that financial inclusion contributes to banking sector stability. The empirical evidence mirrors the conclusions of Diallo and Slabbert (2021), as higher financial inclusion levels are associated with lower probabilities of bank distress across various model specifications. By widening the deposit base and diversifying loan portfolios, financial inclusion reduces banks' exposure to idiosyncratic shocks and improves liquidity buffers, which in turn enhances systemic stability. This relationship is particularly salient in regions where informal finance dominates, as formal financial access provides a more resilient conduit for resource mobilisation and risk-sharing. The positive

interplay between inclusion and stability underscores the dual developmental and prudential role of inclusive finance, a finding with considerable policy significance for central banks and financial regulators in Africa.

Conversely, the hypothesis that the impact of financial inclusion on stability is contingent on institutional quality is partially supported. While the results indicate that institutional quality indicators, such as regulatory effectiveness and rule of law, strengthen the inclusion-stability nexus, the magnitude of these moderating effects is modest. This is consistent with the argument by Banna et al. (2023), who caution that in the absence of robust institutions, the benefits of financial inclusion for stability may be diluted or even reversed, as rapid expansion of credit without adequate oversight can exacerbate systemic vulnerabilities. Therefore, while financial inclusion generally promotes stability, complementary institutional reforms remain essential to ensure that the expansion of financial services does not lead to reckless lending practices or heightened default risks.

The evidence concerning the hypothesis that bank competition enhances the link between financial inclusion and growth presents a more nuanced picture. Although competition measures, such as the Panzar-Rosse H-statistic, positively interact with financial inclusion to spur growth (Adu et al., 2021), excessive competition appears to erode bank margins, potentially undermining financial stability. This finding resonates with the duality highlighted by Mathisen and Buchs (2005), where competition fosters efficiency and innovation but may also incentivise risk-taking behaviour. As such, a balanced competitive environment, one that fosters innovation without compromising prudential standards, emerges as a critical policy imperative.

Finally, the overall evaluation highlights the intricate dynamics linking financial inclusion, bank efficiency, competition, and economic outcomes. The results advocate for integrated policy approaches that simultaneously promote inclusive finance, strengthen bank efficiency, and ensure sound competition frameworks. These findings extend the literature by empirically demonstrating that the benefits of financial inclusion for growth and stability are conditioned by both micro-level bank characteristics and macro-level institutional contexts (Asongu et al., 2020). Thus, achieving sustainable financial development in Africa requires coordinated strategies that address supply-side bank characteristics and demand-side financial inclusion gaps within an enabling institutional environment.

Conclusions

This study has provided robust empirical insights into the complex relationships among financial inclusion, bank efficiency, competition, and institutional quality in shaping economic development and financial stability across Africa. The results confirm that financial inclusion serves as a critical conduit for fostering inclusive growth, poverty reduction, and economic resilience, particularly when supported by

efficient and well-regulated banking systems (Demirgüç-Kunt, Klapper, & Singer, 2022). Moreover, the study highlights the pivotal role of institutional quality in moderating the effectiveness of financial inclusion initiatives, suggesting that sound governance structures and regulatory frameworks are indispensable for translating expanded access into sustainable development outcomes (Diallo & Slabbert, 2021). The findings further suggest that while bank competition can enhance efficiency and innovation, excessive competition may pose risks to stability without appropriate prudential safeguards (Mathisen & Buchs, 2005). Overall, the study contributes to the literature by offering evidence-based directions for creating an enabling environment where financial inclusion and financial sector reforms can jointly drive inclusive and sustainable economic development.

Building on these findings, policymakers are encouraged to design and implement integrated financial sector strategies that simultaneously promote financial inclusion, enhance bank efficiency, and strengthen institutional quality. Specifically, the expansion of digital financial services should be prioritised to reach underserved populations while addressing barriers such as digital illiteracy and infrastructural gaps (Kelikume, 2021). These efforts should be accompanied by targeted regulatory reforms that ensure consumer protection, promote healthy competition, and safeguard financial stability. Furthermore, policies aimed at improving financial literacy and capability are vital for ensuring that expanded access translates into effective financial participation and economic empowerment (Asongu, Nwachukwu, & Tchamyou, 2020).

In addition, regulatory authorities should adopt a balanced approach to bank competition by encouraging innovation and service diversity while maintaining robust prudential oversight. This may involve the introduction of tiered licensing for new entrants, macroprudential policies to mitigate systemic risk, and frameworks that encourage responsible lending practices (Anarfo et al., 2022). Institutional reforms, including judicial strengthening, anti-corruption measures, and enhanced contract enforcement, should also be prioritised to support the broader enabling environment for financial inclusion and stability.

Theoretical Implications and Further Research

From a theoretical perspective, this study reinforces the relevance of financial intermediation theory and institutional economics by demonstrating that the growth-enhancing effects of financial inclusion are conditional on banking sector efficiency and institutional quality (Diamond, 1984; North, 1990). The findings extend existing financial development frameworks by empirically showing that financial inclusion is not merely an access-based phenomenon but operates through efficiency-enhancing and governance-dependent transmission mechanisms. This supports recent theoretical arguments that inclusive finance yields optimal development outcomes only when embedded within sound institutional and competitive banking structures (Allen et al., 2014; Sabir et al., 2020).

For future research, several avenues remain open. First, subsequent studies could explore non-linear or threshold effects of bank competition and institutional quality on the financial inclusion–growth nexus across different income groups within Africa. Second, disaggregated analyses at the household or firm level may provide deeper insights into distributional impacts and heterogeneity across demographic groups (Nanziri, 2016). Third, future research could incorporate climate risk, fintech adoption intensity, or financial stability indicators to further enrich the understanding of how emerging structural forces interact with banking efficiency and inclusion outcomes (Anton & Nucu, 2024; Saka et al., 2023). These extensions would strengthen the theoretical and empirical foundations of inclusive financial development in emerging African economies.

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International Journal of Applied Research in Business and Management (ISSN: 2700-8983)
an Open Access journal by Wohllebe & Ross Publishing, Germany.
Volume: 06 Issue: 05 Year: 2025
https://doi.org/10.51137/wrp.ijarbm.458

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