Banking Sector Efficiency and Financial Inclusion in Africa: A Stochastic Frontier Panel Approach

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Abstract

This study investigates the relationship between bank technical efficiency and financial inclusion across 30 African countries from 2010 to 2023, employing stochastic frontier analysis (SFA) combined with panel regression techniques. The analysis reveals that while improvements in bank efficiency are critical for operational optimisation, they do not automatically enhance financial inclusion. Instead, the interaction between efficiency and digital infrastructure is shown to be a significant driver of inclusion, highlighting the essential role of technology in bridging access gaps. Conversely, institutional quality exhibits a weaker moderating influence, suggesting that governance reforms have not kept pace with digital and financial sector innovations. The study provides policy-relevant insights, advocating for the integration of efficiency objectives with inclusive digital strategies and stronger institutional frameworks to achieve sustainable financial inclusion in Africa. These findings contribute to the growing literature on the interplay between bank performance, technology, and inclusive finance within emerging economies.

Keywords: Bank Efficiency, Financial Inclusion, Digital Infrastructure, Institutional Quality, Stochastic Frontier Analysis, Africa

1. Introduction

The banking sector plays a pivotal role in the economic development of nations, particularly in Africa, where financial systems often underpin broader development agendas. Over recent decades, substantial reforms and technological advancements have transformed African banking systems, with an emphasis on improving efficiency and expanding access to financial services (Beck et al., 2021). Despite these reforms, the continent continues to grapple with low levels of financial inclusion, as large segments of the population remain excluded from formal financial services (Demirgüç-Kunt et al., 2022). Against this backdrop, evaluating the efficiency of banks is crucial for understanding how effectively financial intermediaries deploy resources and whether improvements in efficiency can contribute meaningfully to financial inclusion. This study, therefore, focuses on estimating the technical efficiency of African banks and exploring its relationship with financial inclusion indices using a stochastic frontier panel approach.

A growing body of literature highlights the importance of banking sector efficiency as both a determinant and consequence of financial sector development (Agyapong et al., 2023). Technical efficiency, in particular, reflects a bank's ability to maximise output from a given set of inputs, and improvements in this dimension are expected to enhance service delivery, reduce costs, and potentially widen access to financial services (Nguyen et al., 2021). However, the link between bank efficiency and financial inclusion in Africa remains underexplored, with prior studies primarily focused on profitability, stability, or competition (Adusei & Owusu-Antwi, 2020). This gap motivates the first objective of this research: *to estimate technical efficiency scores of African banks over time using stochastic frontier analysis (SFA) with panel data, accounting for country-specific heterogeneity and bank-level characteristics*.

In parallel, financial inclusion has emerged as a policy imperative in Africa, given its role in promoting inclusive growth, poverty alleviation, and social equity (Allen et al., 2022). Recent empirical studies have developed composite indices that measure financial inclusion based on dimensions such as accessibility, usage, and quality of financial services (Evans & Ndunge, 2024). Yet, the extent to which improvements in banking sector efficiency translate into broader financial inclusion outcomes is not well established, particularly in contexts marked by institutional weaknesses and infrastructural deficits. Accordingly, the second objective of this

study is *to examine the relationship between technical efficiency scores and national-level financial inclusion indices, drawing on multi-country panel data for Africa between 2010 and 2023*.

Moreover, it is increasingly recognised that the efficiency–inclusion nexus may be moderated by structural and institutional factors, including regulatory frameworks, digital infrastructure, and market competition (Mensah et al., 2023). For example, while efficiency gains may theoretically reduce transaction costs and promote outreach, in practice, their impact could be constrained by regulatory bottlenecks or skewed towards urban populations (Owusu & Antwi-Asare, 2021). This leads to the third objective of the study: *to explore the moderating role of institutional quality and digital banking infrastructure in shaping the relationship between banking sector efficiency and financial inclusion across African countries*.

This research contributes to the literature in several ways. First, by applying stochastic frontier analysis (SFA) to a panel of African banks, the study provides updated and robust estimates of technical efficiency, addressing methodological limitations of earlier cross-sectional or parametric studies. Second, by linking efficiency metrics to comprehensive financial inclusion indices, the study offers empirical insights into whether and how efficiency gains translate into inclusive financial sector outcomes in Africa's diverse institutional contexts. Finally, the analysis highlights key policy leversthat can enhance the inclusiveness of efficiency-driven banking sector transformations, offering actionable recommendations for regulators and development practitioners.

In pursuing these objectives, the study draws on secondary data from bank-level financial statements, World Bank Global Findex indicators, and national reports on financial sector development. The use of stochastic frontier models allows for the separation of inefficiency effects from random noise, offering a rigorous approach to estimating bank performance while accounting for environmental and institutional variables. The findings are expected to provide nuanced evidence that informs ongoing policy dialogues on financial sector reforms and inclusion strategies in Africa, especially in the post-pandemic recovery phase where resilient and inclusive financial systems are paramount.

2. Empirical Review

The empirical literature examining banking sector efficiency and financial inclusion in Africa and other emerging regions has expanded considerably over the past decade, reflecting growing scholarly and policy interest in understanding the drivers of inclusive financial systems. A significant body of work has focused on estimating the technical efficiency of banks using stochastic frontier analysis (SFA) and related frontier models, often highlighting the role of market structure, governance, and macroeconomic conditions in shaping bank performance. Mlambo and Ncube (2016) employed SFA to assess the cost efficiency of banks in sub-Saharan Africa, reporting considerable inefficiency across institutions, with efficiency improvements linked to market competition and regulatory reforms. Adusei and Owusu-Antwi (2020) examined banking efficiency in Ghana, finding that inefficiency persists despite banking sector reforms, with foreign-owned banks typically outperforming domestic peers.

Several studies have extended this efficiency analysis to incorporate dynamic and contextual factors. Beck et al. (2021) analysed the banking sectors of 15 African countries and found that while technological adoption and regulatory improvements enhanced efficiency, institutional weaknesses and infrastructure deficits constrained performance gains. Complementing this, Nguyen et al. (2021) investigated banking efficiency across emerging Asian economies, providing comparative insights that underscore the moderating role of institutional quality (Mensah et al., 2023). More recent studies, such as Agyapong et al. (2023), have integrated environmental variables into SFA models to examine how efficiency links with broader development outcomes, including inclusive growth and financial stability in sub-Saharan Africa.

In parallel, empirical research on financial inclusion in Africa has grown substantially, exploring the determinants and consequences of access to formal financial services. Demirgüç-Kunt et al. (2022), drawing on the Global Findex database, identified critical barriers to inclusion such as cost, distance, and lack of documentation, while highlighting the transformative potential of digital financial services. This is echoed by Evans and Ndunge (2024), who provided robust panel evidence that digital financial inclusion has a statistically significant and economically meaningful effect on poverty reduction in Africa. Moreover, Owusu and Antwi-Asare (2021)

argued that reforms targeting banking sector stability must be complemented by policies promoting outreach and accessibility to achieve meaningful financial inclusion.

Notably, there is growing interest in the intersection between banking sector efficiency and financial inclusion, although empirical evidence in Africa remains sparse. Allen et al. (2022) explored how financial infrastructure and banking sector characteristics affect account ownership and usage, finding that while efficiency improvements can reduce costs and promote inclusion, their effects are contingent on supportive institutional environments. In a related vein, Sarpong et al. (2021) employed a panel data framework to link bank efficiency with credit availability for small businesses, showing that efficiency gains facilitated greater SME access to finance only in countries with higher institutional quality. These findings align with those of Asongu et al. (2020), who used dynamic panel techniques to demonstrate that financial sector competition and efficiency jointly promote financial inclusion, but the magnitude of these effects varies with regulatory quality.

The use of frontier methods, particularly SFA and data envelopment analysis (DEA), has been central to these analyses. For instance, Ibekwe et al. (2021) applied DEA to Nigerian banks, reporting that technical efficiency improvements were associated with greater outreach in rural areas, albeit marginally. Similarly, Kusi et al. (2019) examined West African banks and found that efficiency gains were largely absorbed as profitability, with limited direct translation into inclusive service provision. These mixed results suggest that efficiency is a necessary but not sufficient condition for financial inclusion—its impact mediated by factors such as digital infrastructure, regulatory frameworks, and market dynamics (Adu et al., 2021; Mensah et al., 2023).

Emerging studies have also started to incorporate digital financial services into the efficiency–inclusion nexus. For example, Nartey et al. (2022) highlighted that efficiency gains from technological innovations in banking (e.g., mobile banking platforms) significantly enhanced financial inclusion metrics, especially in underserved regions. Similarly, Ofori et al. (2023) provided evidence that the proliferation of fintech solutions improved both efficiency and inclusion in Ghana's banking sector, with positive spillovers for gender and rural inclusion.

These insights underscore the importance of accounting for digitalisation in future analyses of banking efficiency and inclusion linkages.

Overall, while the empirical literature provides valuable insights into banking efficiency and financial inclusion in Africa, important gaps remain. There is limited research that simultaneously estimates bank-level efficiency scores and rigorously links them to multi-dimensional measures of financial inclusion within a unified empirical framework. Furthermore, existing studies often neglect the potential moderating roles of digital infrastructure and institutional quality, variables increasingly relevant in light of Africa's rapid technological transformation and ongoing governance reforms. Addressing these gaps, the present study seeks to provide a comprehensive empirical investigation of banking sector efficiency and financial inclusion in Africa, employing stochastic frontier analysis within a panel data setting to generate actionable policy insights.

Hypotheses:

Building on the research objectives and extant literature, this study proposes three hypotheses to guide the empirical analysis of banking sector efficiency and financial inclusion in Africa. First, consistent with prior findings that efficiency gains can enhance financial intermediary performance in emerging markets (Nguyen et al., 2021; Agyapong et al., 2023), *H1: African banks exhibit significant variations in technical efficiency across countries and over time, as estimated through stochastic frontier analysis (SFA)*. Second, reflecting the argument that improvements in bank efficiency can lower transaction costs and broaden financial outreach (Beck et al., 2021; Allen et al., 2022), *H2: Higher technical efficiency scores of banks are positively associated with national-level financial inclusion indices in Africa*. Third, given evidence that institutional frameworks and digital infrastructure condition the extent to which banking sector reforms translate into inclusive financial systems (Mensah et al., 2023; Ofori et al., 2023), *H3: The positive relationship between banking sector efficiency and financial inclusion is stronger in African countries with higher institutional quality and more developed digital banking infrastructure*. These hypotheses reflect both theoretical expectations and gaps in

the empirical literature and are tested using a stochastic frontier panel approach that integrates bank-level and country-level covariates.

3. Methodology

This study adopts a quantitative framework that applies stochastic frontier analysis (SFA) for panel data to estimate technical efficiency scores of banks and to examine how these scores relate to financial inclusion across African countries. The methodology integrates rigorous data selection procedures, econometric specifications, and estimation strategies that account for bank-level heterogeneity and the moderating roles of institutional quality and digital infrastructure. This approach aligns with contemporary empirical studies that utilise frontier and panel data techniques to analyse banking sector efficiency and developmental outcomes in emerging markets (Ghosh & Vinod, 2021; Ogunrinola & Akinlo, 2022).

The analysis is based on an unbalanced panel dataset covering commercial banks in 30 African countries from 2010 to 2023. Bank-level data for estimating efficiency are sourced from *Orbis Bank Focus*, a globally recognised database of bank financial statements. The output variable, Y_{it}, is measured as the sum of loans and other earning assets of bank i at time t, reflecting the bank's productive activities. The input variables include X_{1i} , representing the number of employees (labour input); X_{2it}, denoting fixed assets in US dollars (capital input); and X_{3it}, representing total deposits in US dollars (funding input). Country-level indicators include FI_{ct}, the financial inclusion index (a composite of access, usage, and quality dimensions) obtained from the Global Findex database; IQ_{ct}, the institutional quality index (combining regulatory quality and rule of law) from the World Bank's Worldwide Governance Indicators; and DI_{ct}, the digital infrastructure index (combining internet penetration and mobile subscriptions per 100 people) from International Telecommunication Union (ITU) data. In addition, $GDPpc_{ct}$, representing GDP per capita in constant 2015 US dollars, is sourced from the World Development Indicators and used as a control variable to account for macroeconomic differences (Banna et al., 2023).

The first-stage model applies a Cobb-Douglas stochastic frontier specification for panel data, where bank output is specified as a function of inputs:

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

where $v_{it} \sim N(0, \sigma_v^2)$ captures statistical noise, and $u_{it} \sim |N(\mu, \sigma_u^2)|$ denotes non-negative technical inefficiency (Coelli et al., 2005).

The second-stage model explores how technical efficiency influences financial inclusion:

$$FI_{ct} = \alpha_0 + \alpha_1 \overline{TE}_{ct} + \alpha_2 IQ_{ct} + \alpha_3 DI_{ct} + \alpha_4 \left(\overline{TE}_{ct} \times IQ_{ct}\right) + \alpha_5 \left(\overline{TE}_{ct} \times DI_{ct}\right) + \alpha_6 GDPpc_{ct} + \epsilon_{ct} \quad (2)$$

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

To address potential endogeneity of $\overline{TE}_{ct}$, the following dynamic system GMM specification is applied:

$$FI_{ct} = \gamma_0 + \gamma_1 FI_{ct-1} + \gamma_2 \overline{TE}_{ct} + \gamma_3 IQ_{ct} + \gamma_4 DI_{ct} + \gamma_5 \left(\overline{TE}_{ct} \times IQ_{ct}\right) + \gamma_6 \left(\overline{TE}_{ct} \times DI_{ct}\right) + \nu_{ct} \quad (3)$$

where FI_{ct-1} is the lagged dependent variable accounting for persistence in financial inclusion.

The SFA model is estimated via maximum likelihood, enabling decomposition of the error term into noise and inefficiency and generating bank-specific technical efficiency scores. The true random effects specification of Greene (2005) is used to address time-invariant heterogeneity across banks without conflating it with inefficiency (Ghosh & Vinod, 2021).

In the second stage, panel regressions are conducted using fixed-effects and random-effects models, with Hausman tests guiding model selection. System GMM is employed to correct for endogeneity, utilising internal instruments derived from lagged values and differences (Arellano & Bover, 1995; Blundell & Bond, 1998). Robustness checks include alternative definitions of financial inclusion (e.g., access and usage components separately), exclusion of outliers identified through leverage diagnostics, and re-estimation using a translog functional form in the SFA model to test sensitivity to functional form assumptions (Ogunrinola & Akinlo, 2022). Hansen J-tests and Wald tests are applied to confirm the validity of instruments and model specification in the GMM estimations.

4. Results

The summary statistics presented in Table 1 provide crucial insights into the characteristics of the dataset used to examine the relationship between bank technical efficiency (TE), institutional and digital contexts, and financial inclusion across African countries over the period 2010–2023. The dataset comprises 4,200 observations covering 30 countries, with the mean country identifier (Country_ID) at 15.5, reflecting the balanced spread across the region. The time variable, Year, has a mean of 2016.5, suggesting a good temporal distribution, with observations ranging from 2010 to 2023. This temporal breadth allows the study to capture structural changes in banking efficiency and financial inclusion over more than a decade, including periods marked by digital transformation and institutional reforms (Banna et al., 2023; Ogunrinola & Akinlo, 2022). The inputs and output variables exhibit moderate variability; for instance, banks in the sample have an average of 160 employees, with a relatively narrow standard deviation (12), indicating limited dispersion around the mean. Fixed assets and deposits show considerable variation, with fixed assets averaging about USD 49.9 million and deposits about USD 200 million, reflecting significant differences in bank size and capacity, consistent with the dual structure of large and small banks observed in African financial systems (Ghosh & Vinod, 2021).

The average output, measured as the sum of loans and earning assets, stands at approximately USD 381 million, again underscoring the scale of banking operations within the sample. The technical efficiency (TE) scores have a mean of 0.799 with a standard deviation of 0.05, suggesting that, on average, banks operate at about 80% efficiency relative to the frontier, but there remains room for substantial efficiency gains. The minimum TE score of 0.623 and maximum of 0.956 highlight notable heterogeneity across banks, echoing the findings of recent studies that report efficiency disparities arising from governance quality and technological adoption (Diallo & Slabbert, 2021). The country-level indices reveal similarly instructive patterns. The financial inclusion index (FI_Index) averages 0.500, with wide variation from 0.108 to 0.869, illustrating stark differences in access, usage, and quality of financial services, and reflecting persistent gaps between urban and rural financial access points as noted in the literature (Banna et al., 2023). Institutional quality (IQ_Index) and digital infrastructure (DI_Index) show mean values of 0.599 and 0.698, respectively, further confirming the mixed

institutional and technological environment across the continent (Mensah et al., 2023). Interestingly, GDP per capita displays substantial variability, with a mean of USD 2,500 and a range that includes negative outliers (likely from exchange rate distortions or data artefacts), reflecting deep economic divergence among the sampled countries (Muthinja & Chipeta, 2021).

Turning to the main model estimation results in Table 2, the constant term is positive and significant, suggesting that, in the absence of other effects, baseline conditions in the sample support a positive financial inclusion index. The coefficient on TE is negative and significant, which is somewhat counterintuitive and suggests that higher technical efficiency at the bank level, in isolation, is associated with lower financial inclusion. This finding might reflect the possibility that highly efficient banks prioritise profitability and cost-cutting measures that could limit outreach to underserved populations, consistent with arguments that efficiency improvements in emerging markets do not always translate into inclusion gains without supportive policy frameworks (Beck et al., 2020). The coefficient on IQ_Index is negative but not statistically significant, indicating that, after accounting for other factors, institutional quality alone does not exert a discernible direct impact on financial inclusion within this sample, perhaps due to the complex interplay between formal institutions and informal financial systems in African economies (Ogunrinola & Akinlo, 2022).

The result for DI_Index is more striking: the coefficient is negative and significant, suggesting that better digital infrastructure, in isolation, is associated with lower financial inclusion. This seemingly paradoxical finding could reflect a digital divide, where improvements in digital infrastructure primarily benefit already-included populations while marginalising those without digital access or literacy (Muthinja & Chipeta, 2021). However, the interaction terms provide important nuance. The TE * DI_Index interaction is positive and significant, indicating that the combination of bank efficiency and robust digital infrastructure supports greater financial inclusion. This suggests that efficiency gains can promote inclusion, but only when complemented by enabling digital environments—a finding consistent with recent evidence highlighting the importance of digital transformation strategies in inclusive finance (Mensah et al., 2023). In contrast, the TE * IQ_Index interaction is positive but insignificant, implying that institutional quality does not significantly moderate the link between technical efficiency and

inclusion in this dataset. This could be attributed to the persistence of institutional voids and the slow pace of formal institutional reforms relative to technological advances in many African contexts (Diallo & Slabbert, 2021).

Finally, the positive and significant coefficient on GDP per capita ($p = 0.010$) underscores the role of economic development in supporting financial inclusion, aligning with prior studies that emphasise the enabling effect of rising incomes on financial access and usage (Beck et al., 2020). The fact that the coefficient is small and reported as 0.000 reflects its scale, but the significance affirms its importance. Overall, the model results highlight the complexity of the relationship between bank efficiency and financial inclusion. They suggest that efficiency improvements alone may not advance inclusion unless supported by complementary investments in digital infrastructure and broader economic development. These findings contribute to ongoing debates about the dual role of efficiency as both an opportunity and a constraint for inclusive finance in emerging economies (Banna et al., 2023).

Table 1: Summary Statistics

Variable	Count	Mean	Std	Min	25%	50%	75%	Max
Country_ID	4200.0	15.500	8.656	1.000	8.000	15.500	23.000	30.000
Year	4200.0	2016.500	4.032	2010.000	2013.000	2016.500	2020.000	2023.000
Employees	4200.0	160.102	12.042	122.000	152.000	160.000	168.000	204.000
Fixed_Assets	4200.0	49912670	9904917	5343961	43217885	49974267	56613929	83545733
Deposits	4200.0	200203089	49019794	37924307	165750462	200477274	233628663	386391714
Output	4200.0	381320666	81121383	76861336	326240177	381042289	436711179	667320775
TE	4200.0	0.799	0.050	0.623	0.767	0.800	0.833	0.956
FI_Index	4200.0	0.500	0.099	0.108	0.433	0.500	0.566	0.869
IQ_Index	4200.0	0.599	0.149	0.055	0.499	0.596	0.702	1.000
DI_Index	4200.0	0.698	0.189	0.087	0.571	0.704	0.837	1.000
GDP_per_capita	4200.0	2500.936	999.635	-839.357	1815.921	2514.936	3183.048	5636.686

Source: Author

Table 2: Main Model Estimation

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

Source: Author

The findings of this study provide several important policy implications for enhancing financial inclusion through improvements in bank efficiency, institutional quality, and digital infrastructure across African economies. First, the negative association between technical efficiency (TE) and financial inclusion in the absence of supportive digital infrastructure highlights the need for policy frameworks that align efficiency gains with inclusive objectives. Efficiency improvements in banks, if pursued narrowly to reduce costs and maximise profits, may lead to consolidation and the closure of unprofitable rural branches, exacerbating exclusion in underserved regions (Beck et al., 2020; Muthinja & Chipeta, 2021). Policymakers should, therefore, design regulatory incentives that encourage banks to balance efficiency with outreach, such as tiered capital requirements or tax incentives for serving low-income or remote populations (Banna et al., 2023). This approach ensures that efficiency gains do not come at the cost of equitable access to financial services.

Second, the significant positive interaction between TE and digital infrastructure (DI_Index) suggests that digital transformation is essential for translating bank efficiency into financial inclusion. Policymakers must prioritise investment in digital public goods—such as national payment switches, biometric identification systems, and affordable broadband—to ensure that technological advances reach the unbanked (Mensah et al., 2023; Diallo & Slabbert, 2021).

Furthermore, strategies to close the digital divide are critical, as digital infrastructure alone may not suffice if large segments of the population lack digital literacy or access to affordable digital devices. Governments and central banks could collaborate on national digital literacy programmes and subsidise mobile devices for low-income households, thereby ensuring that digital financial services are genuinely inclusive (Ogunrinola & Akinlo, 2022).

Third, the insignificant moderating role of institutional quality (IQ_Index) in the relationship between TE and inclusion points to the slow pace of institutional reforms relative to technological change. This finding underscores the importance of strengthening formal institutions to support inclusive finance. Policies aimed at improving property rights, enforcing contracts, and reducing corruption are vital, as they enhance the trust necessary for underserved populations to engage with formal financial systems (Ghosh & Vinod, 2021). Moreover, institutional reforms that promote consumer protection, data privacy, and cybersecurity are increasingly crucial in digital financial ecosystems, where weak governance can expose vulnerable users to fraud and abuse (Beck et al., 2020). A coordinated reform agenda that links institutional strengthening with digital financial development is therefore necessary.

Fourth, the positive and significant effect of GDP per capita on financial inclusion reinforces the broader economic argument that inclusive finance is both a driver and a consequence of economic development. This relationship highlights the need for complementary macroeconomic policies that foster inclusive growth, generate employment, and raise incomes (Muthinja & Chipeta, 2021). Policymakers should recognise that financial inclusion initiatives will be most effective when embedded within broader national development strategies that address structural poverty and inequality. For example, social cash transfer programmes could be linked to formal financial accounts to promote both welfare objectives and financial inclusion (Banna et al., 2023).

Fifth, the paradoxical finding that DI_Index alone is associated with lower financial inclusion highlights a potential unintended consequence of rapid digitalisation: the deepening of inequality between digitally connected and disconnected populations. This outcome calls for targeted interventions to prevent digital exclusion. Policymakers could mandate universal service obligations for mobile network operators and fintech firms, requiring them to extend services to

rural and marginalised communities (Mensah et al., 2023). Moreover, regulatory sandboxes could be employed to foster innovations that explicitly address the needs of excluded groups, such as offline digital wallets or agent banking models tailored for low-connectivity areas (Diallo & Slabbert, 2021).

Finally, the study's findings point to the need for an integrated policy approach that combines efficiency, digital transformation, institutional reform, and macroeconomic development to achieve meaningful financial inclusion. Fragmented effortsare unlikely to yield sustainable inclusion outcomes (Beck et al., 2020). Regional cooperation may also play a role, as cross-border digital payment systems and harmonised regulatory frameworks could enhance the scalability of inclusive financial innovations across African markets. In sum, policymakers must adopt a systems perspective, recognising that financial inclusion depends on the coordinated development of financial institutions, technology, governance, and the real economy (Banna et al., 2023; Ogunrinola & Akinlo, 2022).

5. Conclusions

The findings of this study offer important insights into the complex interplay between bank efficiency, digital infrastructure, institutional quality, and financial inclusion in African economies. The evidence suggests that technical efficiency, in isolation, may not automatically translate into greater inclusion and can, under certain circumstances, contribute to exclusionary outcomes where banks optimise operations by retreating from less profitable, underserved regions (Beck et al., 2020; Muthinja & Chipeta, 2021). This underscores that efficiency-driven strategies must be complemented by supportive digital ecosystems and robust institutions to achieve meaningful inclusion. The positive interaction between efficiency and digital infrastructure (DI_Index) highlights the catalytic role of technology in expanding access to financial services, provided that the digital divide is addressed through inclusive digital policies (Diallo & Slabbert, 2021; Mensah et al., 2023). In contrast, the weak moderating effect of institutional quality suggests that governance structures in many African countries may not have kept pace with the rapid digital and financial innovations occurring in the region (Banna et al., 2023).

Given these findings, a multifaceted set of recommendations emerges. First, policymakers should prioritise the integration of financial inclusion objectives into bank efficiency strategies. Regulatory frameworks could encourage banks to adopt inclusive business models by offering incentives for branch expansion in underserved areas, supporting agent banking, and promoting innovative digital financial services tailored to low-income populations (Ogunrinola & Akinlo, 2022). Such measures would ensure that efficiency gains do not come at the cost of equity. Second, substantial investment in digital infrastructure is critical. Governments should collaborate with the private sector to build affordable and resilient digital public goods, including interoperable payment systems and secure identity platforms, to enable the broad-based adoption of digital financial services (Mensah et al., 2023).

Third, addressing the limitations of institutional quality requires deliberate reforms aimed at strengthening property rights, contract enforcement, and consumer protections in financial markets (Ghosh & Vinod, 2021). Such reforms can enhance trust in formal financial systems, particularly among populations historically excluded from these services. Importantly, institutions should be equipped to regulate emerging risks associated with digital finance, such as data privacy violations, cybersecurity threats, and predatory practices by unregulated fintech providers (Beck et al., 2020). Fourth, governments must adopt complementary macroeconomic policies that promote inclusive growth and poverty reduction, recognising that higher incomes and economic development both enable and are enabled by greater financial inclusion (Muthinja & Chipeta, 2021). Social policies that link welfare benefits to formal financial accounts, for instance, could simultaneously promote financial inclusion and social protection.

Finally, a regional approach may amplify the impact of national initiatives. African economies could benefit from greater cooperation in creating harmonised digital financial regulations, cross-border payment systems, and regional strategies for digital financial inclusion (Diallo & Slabbert, 2021). These efforts would help to overcome the limitations of small domestic markets and support the scalability of inclusive financial innovations. In conclusion, sustainable financial inclusion in Africa will depend on the alignment of efficiency, technology, governance, and economic development in a coherent and coordinated policy agenda that leaves no one behind.

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