

Fuseini, Emmanuel Issifu; Ibrahim, Muazu; Adam, Ibrahim Osman; Vo, Xuan Vinh

## Article

# Re-examining the moderating role of ICT in the nexus between financial development and banking efficiency: evidence from Africa

Cogent Economics & Finance

## Provided in Cooperation with:

Taylor & Francis Group

*Suggested Citation:* Fuseini, Emmanuel Issifu; Ibrahim, Muazu; Adam, Ibrahim Osman; Vo, Xuan Vinh (2024) : Re-examining the moderating role of ICT in the nexus between financial development and banking efficiency: evidence from Africa, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 12, Iss. 1, pp. 1-22, <https://doi.org/10.1080/23322039.2024.2325833>

This Version is available at:

<https://hdl.handle.net/10419/321447>

### Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

### Terms of use:

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



<https://creativecommons.org/licenses/by/4.0/>

# Re-examining the moderating role of ICT in the nexus between financial development and banking efficiency: evidence from Africa

Emmanuel Issifu Fuseini, Muazu Ibrahim, Ibrahim Osman Adam & Xuan Vinh Vo

**To cite this article:** Emmanuel Issifu Fuseini, Muazu Ibrahim, Ibrahim Osman Adam & Xuan Vinh Vo (2024) Re-examining the moderating role of ICT in the nexus between financial development and banking efficiency: evidence from Africa, Cogent Economics & Finance, 12:1, 2325833, DOI: [10.1080/23322039.2024.2325833](https://doi.org/10.1080/23322039.2024.2325833)

**To link to this article:** <https://doi.org/10.1080/23322039.2024.2325833>



© 2024 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 20 Mar 2024.



Submit your article to this journal [↗](#)



Article views: 1389



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 4 View citing articles [↗](#)

# Re-examining the moderating role of ICT in the nexus between financial development and banking efficiency: evidence from Africa

Emmanuel Issifu Fuseini<sup>a</sup>, Muazu Ibrahim<sup>a,b</sup>, Ibrahim Osman Adam<sup>c</sup> and Xuan Vinh Vo<sup>b,d</sup>

<sup>a</sup>Department of Finance, School of Business, University for Development Studies, Tamale, Ghana; <sup>b</sup>Institute of Business Research, University of Economics Ho Chi Minh City, Ho Chi Minh City, Vietnam; <sup>c</sup>Department of Business Analytics and Management Information Systems, School of Business, University for Development Studies, Tamale, Ghana; <sup>d</sup>CFVG, University of Economics Ho Chi Minh City, Ho Chi Minh City, Vietnam

## ABSTRACT

Studies on the tripartite nexuses among information and communication technology (ICT), financial development (FD), and banking sector efficiency have largely produced mixed findings. More importantly, how countries' levels of ICT advancement moderate FD-banks efficiency interlinkages need to be re-assessed. By utilizing data from 48 African countries covering 2004 to 2021 in assessing the tripartite interlinkages, the empirical findings based on the system Generalized Method of Moments (GMM) show that ICT goods imports significantly impact the banking sector positively in enhancing financial access to allocate finance efficiently: Individuals using the internet enhances the banking sector's efficiency. Fixed telephone subscriptions, Mobile cellular subscriptions, and secured internet servers impact banking sector efficiency insignificantly. Financial formalization and informalization significantly impact banking sector efficiency positively, except in the case of ICT goods imports being added to the equation. On the moderating role of the ICT proxies, our finding showed that how ICT moderates the impact of FD on banking sector efficiency is conditioned on both the proxy of ICT and FD. Further findings show an inverted U-shaped relationship between individuals using the internet, ICT goods imports, and the banking sector efficiency nexus. The study discusses the implications for policy and makes key recommendations to improve ICT infrastructure and FD.

## IMPACT STATEMENT

The role of financial development in banking sector efficiency cannot be overemphasized. At the same time, how information and communication technology (ICT) mediate the link between financial development and banking sector efficiency is gaining traction. This study therefore examines these tripartite relationships. Based on the findings, it is uncovered that the integration of ICT into the banking industry can provide efficiency gains that are not directly related to financial sector formalization or informalization.

## ARTICLE HISTORY

Received 20 August 2023  
Revised 26 February 2024  
Accepted 27 February 2024

## KEYWORDS

ICT; efficiency; financial development; GMM

## REVIEWING EDITOR



Yudhvir Seetharam,  
University of the  
Witwatersrand, South Africa

## SUBJECTS

mathematical finance;  
quantitative finance;  
information &  
communication technology  
(ICT); finance

## 1. Introduction

Positive shocks in technological development have a significant positive impact on economic growth, while negative shocks have a detrimental effect. Similarly, positive shocks in financial development have a positive influence on the economy, while negative shocks have a negative impact (Giri et al., 2023). Furthermore, there is a positive linear relationship between the Global financial technology (FinTech) and the sub-index of Financial Markets, particularly its components such as Financial Markets Depth and Efficiency (Lavrinenko et al., 2023). Additionally, a positive linear relationship is observed between the Global FinTech Index and the sub-index of Financial Institutions Depth, while a negative linear relationship is found between the Global FinTech Index and the sub-index of Financial Institutions Access (Lavrinenko et al., 2023).

**CONTACT** Muazu Ibrahim  [imuazu@uds.edu.gh](mailto:imuazu@uds.edu.gh)  Department of Finance, School of Business, University for Development Studies, Tamale, Ghana

© 2024 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group  
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

The role of information and communication technology (ICT) cannot be over-emphasized. Globally, ICT penetration continues to grow at disproportionate levels as the majority of countries in Africa lag relative to those in developed economies. Indeed, the majority of African countries have experienced a different pattern of development due to the digitization of their economies (Ejemeyovwi et al., 2021). Based on the benefits of ICT in fostering development, policies of the Government can utilize the underlying penetration to achieve the Sustainable Development Goals (SDGs) in Africa. Rapidly advanced technologies such as innovation, mobile money as well as the development of E-Banking, M-banking, and mobile interoperability are guaranteeing the conditions for financial access in Africa (Ahmad et al., 2020). In addition, the contribution of ICT in African countries is tremendous as this leads to expansion in their economies (see Kpodar & Andrianaivo, 2011), accordingly, one such contribution is cell phone penetration leading to more financial inclusion.

Globally, African countries are far behind in the development of their financial sectors as compared to others (see Tchamyou & Asongu, 2017) even though, increased access to finance leads to increased opportunities for businesses and households to invest which eventually end up with a positive development externalities impact. The instinct underlining the linkages between finance, poverty, and inequality partly builds on the finance and growth relationship which has been documented in the economic development literature (Kappel, 2010). FD helps reduce information costs as well as transaction costs, which end up reducing the financing challenges of micro and macroeconomic agents (Demirgüç-Kunt & Levine, 2009). There is less theoretical and empirical literature to support the view that, FD leads to banking sector efficiency and the end benefit is a reduction in poverty and inequality as access to finance is enhanced.

Literature on African business supports the idea that financing the continent's investment growth needs depends on capital sourced domestically (Bartels et al., 2009; Darley, 2012; Rolfe & Woodward, 2004; Tuomi, 2011). The internal source of financing can be achieved when financial intermediaries actively performed their basic role of transforming domestic mobilized deposits into credit (Asongu & Nwachukwu, 2019).

It is rather surprising to note that, the internal financing needs of the African continent extremely contradict the view of a large documented liquidity surplus with financial institutions (Asongu, 2014). Again, the empirical literature has conceived and measured the efficiency of financial sector development (FD) in terms of financial intermediaries' ability to transform mobilized deposits into credit (Al-Obaidan, 2008; Ataullah et al., 2004). The indicators of the efficiency of FD used in the literature of FD in Africa are profit efficiency (see Hauner & Peiris, 2005); technical efficiency-DEA (see Kablan, 2009), and cost efficiency (see Mensah et al., 2012) But this study departs from those indicators by using financial sector formalization and informalization as indicators for FD.

According to the abundant documented empirical literature on FD, improving access to finance through banking sector efficiency is a key ingredient in boosting investments for reducing unemployment, enhancing the welfare of households as well as improving businesses, *inter alia* (see Asongu et al., 2020; Dakhli et al., 2021; Tchamyou et al., 2019; Tsaouri, 2020).

Our study filled the gaps by examining how a country's level of ICT development enhances FD and banking sector efficiency nexus. Indeed, to the best of the researchers' knowledge, how ICT moderates the linkage between FD and banking sector efficiency has not been dealt with in the extant literature, especially the use of ICT goods imports, an individual using the internet, fixed telephone subscription, mobile cellular subscription, and secured internet servers as proxies for ICT. This study, therefore, examined the tripartite linkages among ICT, FD, and banking sector efficiency in Africa through the GMM approach. This study again makes important contributions to the literature in different ways as follows: theoretically and empirically, assessing the linkages between the level of ICT development and FD-banking sector efficiency nexuses impact a lot on ICT and finance theories. Also, the study models question whether cross-country differences in ICT infrastructure explain FD and banking sector efficiency in Africa. While most of the literature has studied the finance-access nexus in examining the direct effects of finance, the highest level of FD moderated by ICT to the knowledge of the researchers is yet to be studied in the African continent. Also, the contribution of this study is that the tripartite nexuses among ICT, FD, and banking sector efficiency in Africa are conditioned on the indicators; the impact of FD on banking sector efficiency is moderated by the level of a country's ICT development in Africa; this study has established the pragmatic means of disentangling the impact of financial formalization and

informalization on banking sector efficiency and FD and lastly, this paper adds to the emerging theory on financial formalization and informalization. Our findings further revealed that ICT goods imports and Individuals using the internet significantly impact the banking sector positively in enhancing financial access to allocate finance in Africa. However, fixed telephone subscriptions, Mobile cellular subscriptions, and secured internet servers impact banking sector efficiency insignificantly. Financial sector formalization and informalization significantly impact banking sector efficiency positively, except in the case of ICT goods imports. On the moderating role of the ICT proxies, our finding showed that how ICT moderates the impact of FD on banking sector efficiency is conditioned on both the proxy of ICT and FD.

The next sections of this paper are; a brief literature review, methodology, discussion of findings, policy implications, and conclusions.

## 2. Literature review: FD-banking sector efficiency-ICT nexuses

The stability of the banking industry is key to the development of an economy. One of the motivations for the adoption of advanced technologies in the banking industry is to promote the financial performance of financial institutions through improvement in their corporate and retail financial activities. The adoption and use of digital financial services in the banking industry have enhanced withdrawals, and deposits, among other financial activities (Otieno & Ndede, 2020).

The theoretical perspective being the lynchpin of this paper is; imperfect information and financial intermediation. The theory of imperfect information with Akerlof (1970) and Spence (1973); Rothschild & Stiglitz as the early pioneers who expanded it argued that deposit-taking institutions lack adequate information to be able to economically analyse the risk associated with credit seekers. The existing theories posit that the informal credit givers (lenders) have superior information about loan seekers than the formal credit lenders thereby making the financial market competition unfair. Current theories of financial intermediation are built on the imperfect nature of the economy in terms of information. Financial institutions specifically deposit-taking institutions are established to aid in decreasing information asymmetry through transaction and information search cost reduction among those with the excess fund (lenders) and those short of funds (borrowers) (Claus & Grimes, 2003).

Therefore, concerning this study, financial institutions in the formal and informal financial sectors serve as the intermediaries that adopt digital financial technology to increase their network coverage to get deposits at a cheaper cost to borrow at favourable terms.

Empirically, a recent study by Giri et al. (2023) has found a cointegrating relationship between technological development, financial development, and economic growth over the long term. The research indicates that positive shocks in technological development have a significant positive impact on economic growth, while negative shocks have a detrimental effect. Similarly, positive shocks in financial development have a positive influence on the economy, while negative shocks have a negative impact. The study also confirms a bi-directional causality between technological development and economic growth, as well as bi-directional causality between economic growth and financial development. Additionally, there is a unidirectional causality from negative economic growth to negative technological development, and negative financial development also affects economic growth in a unidirectional manner.

Lagna & Ravishankar (2021) posit that Fintech has a significant capacity to aid the less privileged in society to access financial services thereby aiding them to improve upon their economic situation. Based on a review of literature on information systems (IS) and ICT4D on financial inclusion, Lagna & Ravishankar (2021) further argued the following as the areas that highlight Fintech contribution to financial access: business plan for fintech-led financial access; digital artefacts of fintech-led financial access; business environment impacts of fintech; micro-foundation of fintech for financial access and developmental impacts of fintech.

Azumah et al. (2020) used the statistical model of probity regression to analyse data from 296 survey respondents in Ghana on the impact of workers in the informal sector mobile banking service usage on their banking behaviour. The findings evidenced that, despite the favourable implications of M-Banking services on M-Banking, the banking behaviours of the clients are still challenged. The findings also revealed that savings are significantly ineffective, despite the introduction of M-Banking Services. The authors concluded that, despite the unfavourable outcomes, M-Banking services are still a strong

weapon to capture all or most of the workers in the informal sector into the formal financial stream with the appropriate adjustment to curtail the challenges associated with M-Banking Services such as the issue of security and risks.

Asongu et al. (2019), investigated the impact of information-sharing offices on loan quantity and price with ICT in a panel of 162 banks made up of 42 countries in Africa within the time frame 2001 to 2011 using the Generalized Method of Moments with quartile regressions. The result indicated that; the price of loans is significantly reduced as well as the number of loans significantly appreciates when ICT is combined with the role of public credit registries; ironically, the net impact of the linkages between Private Credit Bureaus (PCBs) and ICT does not enhance financial access, but the marginal impact indicates that ICT could support the features of PCBs to decrease the prices of the loan and increase the amount of the loan only when certain thresholds of ICT are met. This investigation was based on the idea of how advancement in technology can be leveraged by the financial industry in decreasing information asymmetry with the end goal of enhancing financial access.

On the appropriateness of which E-finance service is suitable for promoting banking sector efficiency and FD, David-West et al. (2019) carried out a literature review on the essence of ICT in financial service accessibility. The review was to articulate the importance of mobile money in tackling financial inclusion to address the concern of the appropriate digital financial innovation that can best promote financial inclusion and financial system deepening. It was revealed that cell phones by their nature of portability and ease of use proved to be a key opportunity to encourage the poor as well as those in rural areas to use financial services. It was further argued that in the light of other innovative solutions in financial technology (FinTech), mobile money was still superior in enhancing financial access thereby reducing financial exclusion. Also, the adoption of new innovative ways of payment has seen the usage of Electronic Finance (E-Finance) in Africa, which has helped reduce the inability of people living in rural and urban areas access to financial opportunities. One such innovative technology adopted by the Tanzanian government is the electronic transfer of money with the sole aim of enhancing financial inclusion (Kihamba, 2019). Consequently, the author empirically examined the indicators for financial inclusion and the problems associated with the electronic transfer of money, namely; security risks and cybercrimes such as spies, theft, hacking, and fraudster in Tanzania. Kihamba (2019) further argued that E-finance is one of the innovative tools to enhance financial inclusion as these benefits not only public institutions, but private institutions as well in making financial opportunities affordable, accessible, and relevant to households and firms.

Tchamyou (2020) findings argued that despite the kind of FD indicators, credit registries still help to reduce financial access challenges with the end goal of achieving income equality. This argument is based on the analysis of information-sharing tasks in facilitating the impact of access to finance on income inequality using 48 countries in Africa for 10 years (2004 to 2014) period.

Paa et al. (2020) using panel econometric techniques, namely FMOLS, panel unit root test, and cointegration test assessed traditional banks in SSA efforts to access financing via the mobile payment role using 11 countries' data sourced from World Development Index for 6 years (2011 to 2017) period. The result revealed that, *inter alia*, in the long-run mobile payment growth and the number of ATMs, ownership of formal accounts and the number of new branches on the other hand have a significant and positive nexus. They further posit that, despite disruptive technologies emerging, traditional banks' structure still makes them competitive, thereby leading to enhanced access to finance in the sub-region (SSA) which eventually promotes sustainable growth in the financial system.

### 3. Methodology

#### 3.1. Data

Data for this study were sourced from the Global FD Indicators (GFDIs) and the World Development Indicator (WDI) from the World Bank online databases. Annual panel data were used for the period 2004 to 2021 from 48 countries in Africa. The choice of these countries is a result of the availability of data for the period under consideration with key attention to the variables of interest, thus, banking sector efficiency, FD, and ICT.



The banking sector finance allocation efficiency examines the banking institution's ability to transform money deposits into credit. As a result, this was measured by the banking-system efficiency, specifically, it measures credit to deposits in the banking system (Bank credit to bank deposits (%)), (see Asongu & Nwachukwu, 2019; Baltagi et al., 2009; Rajan & Zingales, 2000).

The proxies adopted for FD are based on financial sector competition. The competition is proxied by the formalization and informalization of the financial system of a country. These proxies are consistent with the extant literature (see Asongu, 2014, 2015; Asongu & Nwachukwu, 2019). While financial formalization is taken as the proportion of bank deposits to broad money ratio, financial informalization is measured by the difference between financial deposits and bank deposits in broad money ratio. Following the existing literature (see Asongu & Nwachukwu, 2019; Ibrahim et al., 2019), the ICT infrastructure is proxied by five indicators, namely; (i) ICT goods imports (ii) individuals using the internet (iii) mobile cellular subscriptions (iv) fixed telephone subscriptions and (v) secure internet servers.

Based on the extant literature (see Asongu et al., 2019; Asongu & Nwachukwu, 2017, 2019; Huang & Temple, 2005; Nyasha & Odhiambo, 2015; Osabuohien & Efobi, 2013; Owusu & Odhiambo, 2014), we include control variables such as inflation – a proxy for macroeconomic instability, GDP – a measure of economic size, trade openness – an indicator of countries' extent of integration with the world, gross fixed capital formation – a proxy of infrastructure stock and population growth. Table 1 below summarizes the variables.

### 3.2. Empirical strategy

This study re-examines the role of ICT in moderating the relationship between FD and banking sector efficiency by positing a model where banking sector efficiency is a function of its lag, ICT infrastructure, FD and other control variables as shown in Equation (1) below:

$$BSE_{it} = \omega_0 BSE_{it-1} + \omega_1 ICT_{it} + \omega_2 FD_{it} + \omega_3 CON_{it} + \varepsilon_{it} \quad (1)$$

where  $BSE_{it}$  represents banking sector efficiency with  $BSE_{it-1}$  as its lag, which is used to measure countries' initial conditions of banking sector efficiency;  $ICT_{it}$  is the vector for ICT proxied by ICT goods imports, individual using the internet, fixed telephone subscription, mobile cellular subscription, and secured internet servers;  $FD_{it}$  is the vector for FD proxied by financial formalization and informalization;  $CON_{it}$  is the vector for the control variables namely GDP growth, gross fixed capital formation, inflation, trade openness, and population growth while  $\varepsilon_{it}$  is the error term.

Thus, from Equation (1), the impacts of ICT and FD are respectively measured by  $\omega_1$  and  $\omega_2$ . We further examine how ICT mediates the relationship between FD and banking sector efficiency by including a multiplicative term of FD and ICT into the banking sector efficiency equation in (1) above. The addition of an interactive term of  $ICT_{it}$  and  $FD_{it}$  results in the model below:

**Table 1.** Summary of variable definition.

Variable Name	Variable Label/Definition	Source
Banking sector efficiency	Bank credit to bank deposits (%)	Global Financial Development Indicator (GFDI), World Bank
ICT	ICT goods imports (% total goods imports) Individuals using the Internet (% of the population) Fixed telephone subscriptions (per 100 people) Mobile cellular subscriptions (per 100 people) Secure internet servers (per 1 million people)	World Development Indicators (WDI), World Bank
Financial development	Financial formalization is proxied by bank deposit to broad money ratio Financial informalization is proxied by the difference between financial deposit and bank deposit to broad money ratio	Asongu and Nwachukwu (2019)
Control variables	GDP (constant 2010 US\$) Trade (% of GDP) Gross capital formation (% of GDP) Inflation, consumer prices (annual %) Population growth (annual %)	World Development Indicators (WDI), World Bank

$$BSE_{it} = \omega_0 BSE_{it-1} + \omega_1 ICT_{it} + \omega_2 FD_{it} + \Psi(\omega_1 ICT_{it} \times \omega_2 FD_{it}) + \omega_3 CON_{it} + \mu_{it} \quad (2)$$

$$\mu_{it} = \beta_i + v_t + \varepsilon_{it}$$

where  $\beta_i$  is the unobservable country fixed effect;  $v_t$  represents the associated time effects and,  $\mu_{it}$  is the idiosyncratic random term. From Equation (2),  $\Psi$  represents the coefficient of the interactive term and this coefficient is meant to explain in more detail how ICT influences FD and access nexus. Four conclusions can be deduced from Equation (2): first, when  $\omega_2 > 0$  and  $\Psi > 0$ , implies FD improves banking sector efficiency in allocating finance and higher ICT development heightens the impact of FD on banking sector efficiency. Secondly,  $\omega_2 > 0$  and  $\Psi < 0$ , suggests FD enhances banking sector efficiency and higher ICT development dampens the banking sector efficiency impact of FD. Thirdly, when  $\omega_2 < 0$  and  $\Psi > 0$ , suggests that, FD does not improve banking sector efficiency and higher development of the ICT environment dampens the negative effect of FD on the efficiency of the banking sector. Finally, when  $\omega_2 < 0$  and  $\Psi < 0$ , implies that FD does not improve efficiency of banking institutions to allocate finance and higher ICT advancement enhances the efficiency of the banking sector in allocating finance. We determine the net effect of FD given the level of ICT development by partially differentiating Equation (2) with respect to FD and evaluating the outcome at different levels of ICT was determined in the equation below:

$$\frac{\partial BSE_{it}}{\partial FD_{it}} = \omega_2 + \Psi ICT_{it} \quad (3)$$

In addition, we determine whether ICT is non-linearly related to banking sector efficiency by introducing a square term of ICT into the baseline equation.

$$BSE_{it} = \omega_0 BSE_{it-1} + \omega_1 ICT_{it} + \phi_1 ICT_{it}^2 + \omega_2 FD_{it} + \omega_3 CON_{it} + \mu_{it} \quad (4)$$

$$\mu_{it} = \beta_i + v_t + \varepsilon_{it}$$

It is imperative to note that, the inclusion of the lagged term of banking sector efficiency into the above equations indicates the probability of correlation between the drivers of banking sector efficiency and the random term. This is due to  $BSE_{it-1}$  depending on  $\varepsilon_{it-1}$  which also influences  $\beta_i$ . When this happens, the specified models are likely to be affected by Nickell (1981) bias resulting from the potential correlations (see Ibrahim and Vo, 2021). Additionally, there is the possibility of endogeneity based on the nature of the regressors. As a result, this paper controls for this possibility by employing the two-step system generalized method of moments (GMM), which is applied relying on the lagged differences as instruments in the level equation. In the first difference equation, the lagged levels of the independent variables (regressors) are used as instruments (see Arellano & Bover, 1995; Blundell & Bond, 1998). However, the reliability of the GMM estimates is contingent on the validity of the instrumental variables, which we test using the Sargan-Hansen test for instrument exogeneity. To avoid instrument proliferation, we employ the Roodman (2009) technique, which do not only collapse the number of instruments but also incorporates issues of panel cross-sectional dependence in order to produce reliable and consistent estimates.

It is imperative to note that, we apply the 'gmmstyle' in the estimations since the independent variables are assumed to be endogenous. In addition, the time periods (years) were assumed to be exogenous and estimated as 'iv(years, eq(diff))'. Following Love & Zicchino (2006), we apply the Helmet transformations to remove any potential fixed effects.

#### 4. Findings

This section discusses the findings of the study. We begin by presenting the summary statistics as shown in Table 2. We find that, banking sector efficiency proxied by bank credit to bank deposit is 73.35%, suggesting that banks are largely able to transform deposits into credits.



**Table 2.** Summary statistics.

	Observations	Mean	Standard deviation	Minimum	Maximum
BcBd	657	73.354	26.024	18.025	164.619
ICTgoods	536	4.007	2.054	0.006	12.774
IndivInterusage	666	12.056	13.798	0.031	61.762
SecInterServ	372	553.971	8212.294	0.00	155191.3
MobCelSub	671	57.905	41.305	1.264	175.873
Fixedtel	665	3.804	6.20	0.00	32.669
FinForm	653	1.13	3.719	0.083	53.834
FinInform	637	-0.247	2.121	-25.665	0.952
gfCapform	625	23.991	9.931	-0.098	77.89
Trade	645	77.886	41.837	19.101	347.997
Inflation	641	6.55	6.481	-8.975	43.542
GDP	659	3.638e + 10	7.776e + 10	1.379e + 08	4.619e + 11
Popgrowth	672	2.352	0.965	-2.629	4.655
Number of countries	48	48	48	48	48

**Notes:** ICTgoods-ICT goods imports; SecInterServ-Secure Internet servers; BcBd-Bank Credit to Bank Deposit; MobCelSub-Mobile cellular subscriptions; IndivInterusage-Individuals using the Internet; Fixedtel-Fixed telephone subscriptions; FinForm-Financial Formalization; FinInform-Financial Informalization; gfCapform-Gross fixed capital formation; Trade-Trade; GDP-Gross Domestic Product; Popgrowth-Population growth; Sourced: Authors' compilation.

#### 4.1. Examining the validity of the results

The validity and reliability of the two-step system GMM (Generalized Method of Moments) output was conducted employing several diagnostic tests. The tests aim to evaluate the robustness of the regression models and instrumental variable assumptions. With reference to the [Tables 3–5](#) under diagnostic test, the following are evidenced as to the validity of the results.

The first set of tests includes the F-statistics, which indicate that each regression model is significant at 0.0000. We also examine the overidentification restriction, heteroscedasticity, autocorrelation, and weak instrument bias. The Cragg-Donald Wald-WIR test also supports the finding that weak instrument bias is not present in the instrumental variable regressions (see Cragg & Donald, 1993). Therefore, the instrumental variables used in the analysis are reliable. The incremental tests which is an alternative test to 'difference Sargan-Hansen' tests (see Kripfganz, 2019) also support the validity of the models, as the p-values indicate a reasonable fit and accurate estimation of the moments using both the 2-step and 3-step weighting matrices.

Additionally, the Arellano-Bond test suggests no existence of higher correlation in the first-differenced residuals, indicating no autocorrelation. The use of system GMM is justified by having a greater number of groups (48) than instruments (37), according to Roodman's and Kripfganz's argument on the use of the system GMM (see Kripfganz, 2019; Roodman, 2009).

The correlation matrix reveals moderate correlation between variables as the coefficients are not above the 0.8 benchmark as shown in the [Appendix A](#). Overall, the robustness tests prove the findings to be valid for policy decisions.

#### 4.2. First, effects of ICT and FD on banking sector efficiency

This section presents the results on the effects of ICT and FD on the banking sector efficiency in Africa. We conduct two levels of analysis in [Table 3](#). The first analysis examines the impact of ICT infrastructure on banking sector efficiency in the presence of financial formalization while the second analysis considers the effect of ICT on banking sector efficiency controlling for financial informalization. As shown in [Table 3](#) (columns 1-5), it can be observed that ICT goods imports and individual internet usage positively and significantly drive banking sector efficiency proxies by bank credit to a bank deposit. While this holds, the impact of ICT goods imports is higher. Specifically, a unit-percentage change in ICT goods imports and individuals using the internet increased banking sector efficiency by 0.3249% and 0.1509% respectively. However, while fixed telephone subscriptions, mobile cellular subscriptions, and secured internet servers negatively affected the banking sector efficiency, only the impact of fixed telephone subscriptions is significant.

Concerning financial formalization from columns (1) to (5) showed a significant positive effect on banking sector efficiency except for column (2). This suggests that financial formalization aids banks to

Table 3. Effects of ICT and FD on banking efficiency (baseline regression).

VARIABLES	Financial Formalization					Financial Informalization				
	(1) BcBd	(2) BcBd	(3) BcBd	(4) BcBd	(5) BcBd	(6) BcBd	(7) BcBd	(8) BcBd	(9) BcBd	(10) BcBd
L.BcBd	0.6321*** (0.0140)	0.5042*** (0.0151)	0.5316*** (0.0187)	0.4845*** (0.0134)	0.5892*** (0.0186)	0.5636*** (0.0145)	0.4755*** (0.0142)	0.4883*** (0.0179)	0.4543*** (0.0182)	0.5829*** (0.0167)
ICTgoods	0.3249*** (0.1246)					0.0933 (0.1703)				
IndivInter		0.1509*** (0.0405)					0.1672*** (0.0458)			
Fixedtel			-2.9271*** (0.5197)					-3.0236*** (0.7303)		
MobCelSub				-0.0010 (0.0129)					0.0126 (0.0159)	
SecInterServ					-0.0000 (0.0000)					-0.0000 (0.0000)
FinForm	10.1442** (4.5953)	-0.0486 (0.0328)	0.2194*** (0.0505)	0.1290*** (0.0359)	29.4484*** (1.1444)					
FinInform										
GDP	-0.0000*** (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000*** (0.0000)	-0.2119** (0.0860)	0.0030 (0.0894)	-0.0111 (0.1081)	0.0252 (0.1022)	-0.7425 (1.2479)
gfcapform	0.2265*** (0.0649)	0.1107* (0.0626)	-0.0588 (0.0731)	0.0013 (0.1038)	0.5523*** (0.0804)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000* (0.0000)	-0.0000 (0.0000)
Inflation	0.1614*** (0.0443)	0.1647*** (0.0370)	0.1926*** (0.0446)	0.1530*** (0.0467)	0.1226 (0.0843)	0.0612 (0.0820)	-0.0187 (0.0978)	-0.1971* (0.1093)	-0.0891 (0.1160)	0.5471*** (0.0626)
Trade	-0.2124*** (0.0339)	-0.1024*** (0.0081)	-0.1466*** (0.0125)	-0.1515*** (0.0086)	-0.2195*** (0.0192)	0.2071*** (0.0547)	0.2023*** (0.0438)	0.1864*** (0.0473)	0.1449*** (0.0425)	0.1151 (0.0782)
Popgrowth	-2.7609 (2.4110)	-3.1578*** (0.2074)	-6.7963*** (0.3632)	-1.3857*** (0.3249)	-2.2651*** (0.3288)	-0.1369** (0.0604)	-0.1518*** (0.0273)	-0.1480*** (0.0466)	-0.1823*** (0.0400)	-0.1945*** (0.0090)
Constant	34.6054*** (7.9709)	39.2921*** (1.4991)	73.1815*** (3.7151)	52.7146*** (3.3834)	16.1876*** (3.3621)	-6.6059** (3.1734)	-4.5245*** (0.9856)	-7.8910*** (3.0715)	-2.8307* (1.4989)	-2.0348*** (0.7065)
Diagnostics:						56.1769*** (6.0540)	47.7203*** (2.0033)	84.1011*** (10.4523)	62.7818*** (5.0929)	37.7368*** (2.9854)
Observations	446	537	540	541	325	429	516	519	520	309
Instruments	34	34	34	34	34	34	34	34	34	34
AR 1	0.3719 (0.7100)	1.6272 (0.1037)	1.4408 (0.1496)	1.7881 (0.0738)	1.2501 (0.2112)	-0.1493 (0.8813)	1.3303 (0.1834)	1.3334 (0.1824)	1.6137 (0.1066)	2.6444 (0.0082)
AR 2	-3.3637 (0.0008)	-3.2978 (0.0010)	-3.1104 (0.0019)	-3.0512 (0.0023)	-3.3978 (0.0024)	-1.9892 (0.0467)	-2.5922 (0.0095)	-1.0707 (0.2843)	-2.0169 (0.0437)	-3.2290 (0.0012)
AR 3	-0.1537 (0.8779)	-0.8170 (0.4139)	-0.7982 (0.4248)	-0.8022 (0.4224)	-0.2851 (0.7756)	-0.8118 (0.4169)	-2.5922 (0.1295)	-1.0269 (0.3045)	-1.3608 (0.1736)	-0.6867 (0.4923)
Sargan-Hansen-OIR	32.5227 (0.1764)	36.1636 (0.0887)	31.7025 (0.2031)	33.0881 (0.1596)	24.8602 (0.5269)	33.3948 (0.1510)	33.0871 (0.1596)	34.1111 (0.1322)	29.8831 (0.2725)	25.5529 (0.4879)
Incremental Test	6.8474 (0.5532)	8.3348 (0.4015)	6.4417 (0.5979)	10.0204 (0.2636)	2.2378 (0.9728)	9.1067 (0.3334)	4.4212 (0.8173)	7.4477 (0.4892)	6.2887 (0.6149)	2.8288 (0.9446)
Incremental/SHD-Test for OIR										
a. GMM instruments for levels:										
Excluding Group	22.7555	30.6154	26.3947	27.5529	29.6669	28.9787	30.0582	29.8757	26.4603	25.6939

(continued)

Table 3. Continued.

VARIABLES	Financial Formalization				Financial Informalization					
	(1) BcBd	(2) BcBd	(3) BcBd	(4) BcBd	(5) BcBd	(6) BcBd	(7) BcBd	(8) BcBd	(9) BcBd	(10) BcBd
Difference	(0.2483) 9.7672 (0.2022)	(0.0445) 5.5482 (0.5934)	(0.1196) 5.3078 (0.6225))	(0.0924) 5.5352 (0.5949)	(0.0562) -4.8067 (1.0000)	(0.0663) 4.4161 (0.7308)	(0.0511) 3.0289 (0.8823)	(0.0534) 4.2354 (0.7523)	(0.1179) 3.4228 (0.8433)	(0.1762) -0.1410 (1.0000)
R-squared	0.8163	0.7379	0.2143	0.7119	0.7194	0.7783	0.7023	0.1478	0.6799	0.7343
Adj. R-squared	0.8129	0.7344	0.2025	0.7076	0.7122	0.7741	0.6982	0.1345	0.6749	0.7272
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hansen J-statistics	32.5227 (0.1434)	37.5019 (0.0673)	31.7025 (0.1668)	33.0881 (0.1289)	24.8602 (0.4702)	33.3948 (0.1215)	33.6527 (0.1439)	34.1111 (0.1056)	29.8831 (0.2287)	25.5529 (0.4318)

**Table 4.** Moderating role of ICT in FD and banking efficiency nexus.

VARIABLES	Financial Formalization					Financial Informalization				
	(1) BcBd	(2) BcBd	(3) BcBd	(4) BcBd	(5) BcBd	(6) BcBd	(7) BcBd	(8) BcBd	(9) BcBd	(10) BcBd
L.BcBd	0.8788*** (0.0160)	0.9970*** (0.0172)	0.9742*** (0.0267)	0.9627*** (0.0145)	0.9133*** (0.0176)	0.9386*** (0.0271)	0.9783*** (0.0307)	0.9922*** (0.0266)	0.9651*** (0.0342)	0.9676*** (0.0151)
ICTgoods	1.7493*** (0.2431)					0.3467*** (0.0848)				
ICTgood-Inter	-1.6686*** (0.3200)					0.1324*** (0.0320)				
IndivInter		-0.0060 (0.0196)					0.0366 (0.0269)			
IndivInter-Inter		0.0049 (0.0092)					-0.1820*** (0.0352)			
Fixedtel			-2.0688*** (0.5973)					-0.5057*** (0.1914)		
Fixedtel-Inter			2.1039*** (0.6407)					-0.2525*** (0.0828)		
MobCelSub				-0.0006 (0.0063)					-0.0016 (0.0077)	
MobCelSub-Inter				-0.0023 (0.0015)					-0.0136*** (0.0031)	
SecInterServ					0.0033*** (0.0005)					-0.0001*** (0.0000)
SecInterServ-Inter					-0.0038*** (0.0006)					0.0006*** (0.0001)
FinForm	9.1081*** (1.7459)	0.1799*** (0.0186)	0.0071 (0.0422)	0.1380*** (0.0471)	26.3126*** (0.5650)					
FinInform						-0.7568*** (0.1889)	0.8699*** (0.2227)	0.2715** (0.1120)	0.5260*** (0.1316)	0.1762 (0.3521)
GDP	-0.0000*** (0.0000)	-0.0000*** (0.0000)	-0.0000* (0.0000)	-0.0000*** (0.0000)	-0.0000*** (0.0000)	-0.0000*** (0.0000)	-0.0000*** (0.0000)	-0.0000*** (0.0000)	-0.0000*** (0.0000)	-0.0000*** (0.0000)
gfCapform	0.2719*** (0.0510)	0.1983*** (0.0485)	0.2163*** (0.0518)	0.2849*** (0.0562)	0.3779*** (0.0353)	0.3646*** (0.0629)	0.2043*** (0.0388)	0.2188*** (0.0483)	0.2657*** (0.0449)	0.2778*** (0.0409)
Inflation	0.1770*** (0.0426)	0.1605*** (0.0228)	0.2171*** (0.0420)	0.1487*** (0.0288)	0.0570 (0.0663)	0.2120*** (0.0360)	0.2281*** (0.0390)	0.2465*** (0.0416)	0.1823*** (0.0499)	0.0968* (0.0522)
Trade	-0.1189*** (0.0136)	-0.0412*** (0.0044)	-0.0263*** (0.0058)	-0.0390*** (0.0073)	-0.1090*** (0.0122)	-0.0638*** (0.0292)	-0.0400* (0.0211)	-0.0122 (0.0180)	-0.0517*** (0.0181)	-0.0787*** (0.0087)
Popgrowth	-2.0228** (0.8280)	1.9288*** (0.2249)	1.0903*** (0.2202)	0.1850** (0.0924)	-3.4295*** (0.2662)	-4.2580*** (1.0212)	-0.4715 (0.3936)	-1.1554** (0.4574)	-0.3308 (0.3931)	-3.5614*** (0.6573)
Constant	6.8901** (3.1177)	-1.4579 (1.1812)	-3.4167 (2.4121)	-1.4894 (1.5170)	-6.9607*** (2.3943)	8.3755 (6.0043)	-0.6539 (2.5070)	0.9021 (2.8604)	1.0106 (3.5430)	11.1093*** (2.1022)
Diagnostics										
Observations	446	537	540	541	325	429	516	519	520	309
Instruments	37	37	37	37	37	37	37	37	37	37
AR 1	-0.3245 (0.7455)	-1.1221 (0.2618)	-1.0734 (0.2831)	-0.9754 (0.3293)	0.2818 (0.7781)	-0.8377 (0.4022)	-1.0988 (0.2719)	-1.0796 (0.2803)	-0.8981 (0.3692)	0.3797 (0.7042)

(continued)

Table 4. Continued.

VARIABLES	Financial Formalization					Financial Informalization				
	(1) BcBd	(2) BcBd	(3) BcBd	(4) BcBd	(5) BcBd	(6) BcBd	(7) BcBd	(8) BcBd	(9) BcBd	(10) BcBd
AR 2	-4.0410 (0.0001)	-3.9221 (0.0001)	-3.8338 (0.0001)	-4.0461 (0.0001)	-2.8701 (0.0041)	-3.8207 (0.0001)	-4.1503 (0.0000)	-3.7852 (0.0002)	-0.8981 (0.0001)	-2.8597 (0.0042)
AR 3	0.3279 (0.7430)	-0.0900 (0.9283)	0.0262 (0.9791)	0.1068 (0.9150)	-0.7118 (0.4766)	-0.0418 (0.9666)	-0.2901 (0.7718)	-0.1020 (0.9187)	0.0306 (0.9756)	-0.8747 (0.3817)
Sargan-Hansen-OIR	32.7361 (0.2456)	37.3692 (0.1109)	0.0262 (0.0961)	36.9433 (0.1201)	33.7602 (0.2481)	32.6960 (0.2471)	33.1675 (0.2296)	33.7201 (0.2102)	34.4887 (0.1852)	32.4681 (0.2997)
Incremental Test	8.4925 (0.4854)	13.5726 (0.1384)	11.5425 (0.2403)	16.9086 (0.0502)	8.3784 (0.5919)	6.7137 (0.6669)	4.0992 (0.9048)	7.4828 (0.5870)	8.0756 (0.5266)	5.3638 (0.8656)
Incremental/SHD-Test for OIR										
a. GMM instruments for levels:										
Excluding Group	23.7638 (0.2529)	31.6001 (0.0477)	32.6425 (0.0369)	29.6369 (0.0760)	28.7577 (0.1199)	27.4913 (0.1220)	32.3191 (0.0400)	28.3901 (0.1005)	29.2941 (0.0821)	24.5254 (0.2683)
Difference	8.9723 (0.3446)	5.7691 (0.6731)	5.4788 (0.7054)	7.3065 (0.5040)	5.0025 (0.7573)	5.2047 (0.7355)	0.8484 (0.9990)	5.3300 (0.7218)	5.1946 (0.7366)	7.9428 (0.4391)
R-squared	0.9339 (0.3446)	0.9369 (0.7054)	0.9254 (0.7054)	0.9337 (0.5040)	0.8875 (0.7573)	0.9311 (0.7355)	0.9359 (0.9990)	0.9201 (0.7218)	0.9350 (0.7366)	0.9132 (0.4391)
Adj. R-squared	0.9325 (0.3446)	0.9359 (0.7054)	0.9241 (0.7054)	0.9326 (0.5040)	0.8843 (0.7573)	0.9296 (0.7355)	0.9349 (0.9990)	0.9187 (0.7218)	0.9338 (0.7366)	0.9106 (0.4391)
Prob > F	0.0000 (0.2059)	0.0000 (0.1112)	0.0000 (0.0759)	0.0000 (0.0961)	0.0000 (0.1731)	0.0000 (0.2073)	0.0000 (0.1851)	0.0000 (0.1743)	0.0000 (0.1523)	0.0000 (0.2152)
Hansen J-statistics	32.7361 (0.2059)	37.3552 (0.1112)	38.1212 (0.0759)	36.9433 (0.0961)	33.7598 (0.1731)	32.6960 (0.2073)	34.4921 (0.1851)	33.7201 (0.1743)	34.4887 (0.1523)	32.4682 (0.2152)

**Table 5.** Threshold of ICT proxies in the nexus between FD and banking sector efficiency.

VARIABLES	Financial Formalization					Financial Informalization				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	BcBd	BcBd	BcBd	BcBd	BcBd	BcBd	BcBd	BcBd	BcBd	BcBd
LBcBd	0.9094*** (0.0143)	0.9349*** (0.0331)	1.0169*** (0.0397)	0.9527*** (0.0246)	0.8797*** (0.0143)	0.9247*** (0.0251)	0.9318*** (0.0332)	0.9602*** (0.0581)	0.9792*** (0.0280)	0.9517*** (0.0154)
ICTgoods	0.6086* (0.3410)			0.2629 (0.2887)						
ICTgoods <sup>2</sup>	-0.0215 (0.0233)			-0.0023 (0.0226)						
IndivInter		0.0758* (0.0444)					0.0920* (0.0484)			
IndivInter <sup>2</sup>		-0.0008 (0.0007)					-0.0012 (0.0008)			
Fixedtel			-3.4725*** (0.6948)					-3.7476*** (0.8507)		
Fixedtel <sup>2</sup>			0.0709*** (0.0110)					0.0473** (0.0227)		
MobCelSub				-0.0266 (0.0170)					0.0104 (0.0252)	
MobCelSub <sup>2</sup>				0.0002* (0.0001)					-0.0001 (0.0002)	
SecInterServ					-0.0000 (0.0000)					-0.0000*** (0.0000)
SecInterServ <sup>2</sup>					0.0000 (0.0000)					0.0000* (0.0000)
FinInform										0.0165 (0.4229)
FinForm	5.2712** (2.5255)	0.1202*** (0.0191)	0.1092** (0.0512)	0.0918*** (0.0256)	26.1461*** (0.4994)	-0.0707* (0.0366)	-0.0473 (0.0329)	0.1269 (0.0944)	0.1238* (0.0636)	
GDP	-0.0000*** (0.0000)	-0.0000*** (0.0000)	-0.0000** (0.0000)	-0.0000*** (0.0000)	-0.0000** (0.0000)	-0.0000* (0.0000)	-0.0000*** (0.0000)	-0.0000* (0.0000)	-0.0000*** (0.0000)	-0.0000*** (0.0000)
gfcapform	0.3316*** (0.0504)	0.2446*** (0.0453)	0.2806*** (0.0497)	0.3458*** (0.0438)	0.3773*** (0.0289)	0.3163*** (0.0657)	0.2137*** (0.0404)	0.2105*** (0.0662)	0.3003*** (0.0440)	0.2908*** (0.0542)
Inflation	0.1913*** (0.0373)	0.1754*** (0.0311)	0.3006*** (0.0524)	0.1682*** (0.0619)	0.0567 (0.0795)	0.2282*** (0.0343)	0.1699*** (0.0341)	0.3055*** (0.0503)	0.2267*** (0.0659)	0.0680 (0.0590)
Trade	-0.1155*** (0.0142)	-0.0661*** (0.0058)	-0.0643*** (0.0144)	-0.0646*** (0.0052)	-0.1229*** (0.0066)	-0.0768** (0.0348)	-0.0444*** (0.0134)	-0.0501 (0.0317)	-0.0329** (0.0134)	-0.0730*** (0.0095)
Popgrowth	-2.2896** (0.9695)	0.5483*** (0.1382)	1.1572*** (0.2956)	-0.2306 (0.1910)	-3.5400*** (0.2248)	-4.0240** (1.5757)	-0.7147*** (0.1545)	-2.0610 (1.3287)	-0.1680 (0.3711)	-3.5684*** (0.4258)
Constant	5.9289 (4.8015)	3.2161 (2.2063)	1.8330 (3.9386)	1.1300 (2.1575)	-2.8570 (2.0334)	11.2166** (5.5818)	2.5938 (2.1930)	17.4882** (7.9254)	-3.2112 (3.1440)	11.5829*** (0.8630)
Diagnostics										
Observations	446	537	540	541	325	429	516	519	520	309
Instruments	37	37	37	37	37	37	37	37	37	37
AR 3	0.2364 (0.8132)	0.0850 (0.9323)	-0.0966 (0.9231)	0.1241 (0.9013)	-0.6532 (0.5136)	0.0241 (0.9808)	-0.0338 (0.9731)	-0.1127 (0.9103)	-0.0249 (0.9801)	-0.8911 (0.3729)

(continued)



Table 5. Continued.

VARIABLES	Financial Formalization					Financial Informalization				
	(1) BcBd	(2) BcBd	(3) BcBd	(4) BcBd	(5) BcBd	(6) BcBd	(7) BcBd	(8) BcBd	(9) BcBd	(10) BcBd
Sargan-Hansen-OIR	29.3640 (0.3942)	35.7099 (0.1501)	31.3993 (0.2996)	35.8967 (0.1452)	33.3655 (0.2632)	31.2819 (0.3047)	34.6133 (0.1814)	28.8502 (0.4202)	31.4573 (0.2972)	33.7981 (0.2467)
Incremental Test	4.4596 (0.8787)	9.7982 (0.3671)	1.1247 (0.9991)	16.0924 (0.0650)	8.2775 (0.5064)	6.9431 (0.6430)	6.8235 (0.6555)	1.9947 (0.9916)	8.7109 (0.4644)	8.0199 (0.5321)
R-squared	0.9366	0.9331	0.6410	0.9292	0.8833	0.9355	0.9366	0.5176	0.9319	0.9132
Adj. R-squared	0.9353	0.9320	0.6348	0.9280	0.8799	0.9341	0.9356	0.5091	0.9307	0.9105
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hansen J-statistics	29.3640 (0.3435)	35.8861 (0.1455)	31.399 (0.2551)	35.8967 (0.1176)	33.3661 (0.1853)	31.2819 (0.2597)	34.9209 (0.1722)	28.8502 (0.3682)	31.4573 (0.2528)	33.7981 (0.1719)

## Notes:

All Models have robust standard errors in parentheses. \*, \*\*, and \*\*\* denote significance at 10%, 5% and 1% respectively. PCFd-Private credit by deposit money banks and other financial institutions; ICTgoods-ICT goods imports; SecInterServ-Secure Internet servers; LBcBd-one year lag of BcBd; MobCelSub-Mobile cellular subscriptions; IndividInterusage-Individuals using the Internet; Fixedtel-Fixed telephone subscriptions; FinForm-Financial Formalization; FinInform-Financial Informalization; gFCapform-Gross fixed capital formation; Trade-Trade; GDP-Gross Domestic Product; Popgrowth-Population growth; Hansen J- statistics of over-identifying restrictions of all instruments.

Sourced: Authors' compilation.

allocate finance efficiently, while, only column (6) revealed a significant negative effect of financial informalization on banking sector efficiency. This suggests with the existence of fixed telephone subscriptions, the informal financial sector does not support banks in improving financial activity. These findings suggest that the formal financial sector overall aid the banking sector to allocate finance efficiently, while the informal financial sector significantly does not aid the banking sector in allocating finance efficiently. These findings on financial informalization contrast with (Asongu & Nwachukwu, 2019).

From columns (1) and (6) of Table 3, under financial formalization (informalization), a percentage rise in ICT goods imports heightens (heightens) the banking sector by 0.3249% (0.0933%) respectively. But the heightened effects of financial informalization are insignificant. Thus, the heightened effect of ICT goods imports suggests an increase in a country's import of ICT goods improved financial access through the enhancement of the banking system efficiency proxies by bank credit to bank deposits. Concerning financial formalization (informalization), there is a positive (negative) and strong significant effect on Bank credit to bank deposits with coefficients of 10.1442 (−0.2119). This implied a 1% increase in financial formalization (informalization) heightens (dampens) financial access through the improvement of the banking sector efficiency in allocating finance but the dampening effect from financial informalization is not statistically significant.

Also, from columns (2) and (8), under financial formalization (informalization) respectively, a percentage increase in individuals using the internet heightens (heightens) the efficiency of the banking sector with coefficients of 0.1509% (0.1672%). The heightened effects of individuals' internet usage suggest an increase in a country's internet usage by individuals improves banking sector efficiency in allocation finance hence enhancing access to finance. Concerning financial formalization (informalization) effects on Bank credit to bank deposits, a percentage increase in financial formalization (informalization) dampens (heightens) Bank credit to bank deposits by −0.0486% (0.0030%). Unfortunately, these effects are insignificant.

For fixed telephone subscriptions under the financial formalization (informalization) from columns (3) and (8), a percentage rise in fixed telephone subscription significantly dampens (dampens) Banking sector efficiency with coefficients of −2.9271% (−3.0236%). This dampens the effect of fixed telephone subscriptions suggesting that an increase in a country's fixed telephone subscription reduces the banking sector's efficiency in allocating the finance, hence, financial access becomes a challenge. Then for a financial formalization (informalization), a percentage increase heightens (dampens) Bank credit to bank deposits by 0.2194 (−0.0111), but the dampening effects from financial informalization are insignificant. The heightened effects suggest that financial formalization improves banking system efficiency enhancing financial access via Bank credit to bank deposits.

Now concerning mobile cellular subscriptions from columns (4) and (9), a percentage increase dampens (heightens) Bank credit to bank deposits by −0.0010% (0.0126%), but these effects are statistically insignificant. From the same columns concerning financial formalization (informalization), a 1% rise in financial formalization (informalization) significantly heightens (insignificantly heightens) Bank credit to bank deposits with coefficients of 0.12905 (0.0252%).

Lastly, columns (5) and (10) of Table 3, revealed that a percentage appreciation in securing internet servers insignificantly dampens (dampens) Banking sector efficiency with coefficients of −0.0000% (−0.0000%). These insignificant dampening effects of secured internet servers suggest ensuring a strong secured internet server has nothing to do with the banking sector improving access to finance efficiently, but the positive and 1% significance of financial formalization effect on Bank credit to bank deposits suggests a heightened effect between the two, with a coefficient of 29.4484%, this suggests that financial access via Bank credit to bank deposits is enhanced when there is a 1% increase in FD via financial formalization.

#### **4.3. Secondly, the moderating role of ICT in banking sector efficiency and FD nexus**

This paper further investigated the moderating role of ICT in the interactions between FD and banking sector efficiency, since FD improves access to finance via the efficiency of the banking sector. The reason was to establish whether the ICT proxies dampen or magnify the direct effect of FD on banking sector

efficiency. The results of these assessments are shown in columns 1-10 of Table 4, under financial formalization and informalization, all the ICT proxies maintained their earlier coefficient signs, except mobile cellular subscription which changed from positive to negative. It can also be observed that the coefficients of ICT goods import and individuals using the internet have increased while the other ICT proxies' coefficients have reduced under financial formalization. Under financial informalization, ICT goods import, fixed telephone subscription, and mobile cellular subscription coefficients have increased (in absolute terms) while individual internet usage and secured internet servers' coefficients have reduced (in absolute terms).

The coefficients for financial formalization as moderated by the ICT proxies have reduced except the coefficient of financial formalization moderated by fixed telephone subscription from column (3) that have increased (in absolute terms). Concerning financial informalization, all the coefficients have been reduced.

Concerning the mediating roles of the ICT proxies in financial formalization (informalization) and the banking sector efficiency nexus, it is evidenced that, ICT goods import and secured internet servers had a negative and significant interactive term with financial formalization, while fixed telephone subscription had a positive and significant interactive term with financial formalization. The interactions between individuals using the internet and mobile cellular subscription were insignificant. Therefore, while enhanced financial formalization does aid Banks' efficiency in allocating credit, the higher a country's level of ICT goods imports and secured internet servers, the lower the direct improvement of FD on banking sector efficiency in allocating finance except in the case of fixed telephone subscription that revealed an inverse mediating effect. The insignificant nature of individuals using the internet and mobile cellular means those proxies have nothing to do with the banking sector's efficiency. For financial informalization interacting with the ICT proxies, it is observed that ICT goods imports, fixed telephone subscriptions, and mobile cellular subscriptions negatively gave a significant interactive term, while the interaction from secured internet servers was significantly positive. The negative interaction of individuals using the internet was insignificant. It can be deduced from these negative results that, while financial informalization does aid banking sector efficiency, the higher a country's level of ICT development, the lower the direct impact of financial informalization on the banking sector efficiency in improving financial access except in the case of secured internet servers that revealed an inverse mediating effect.

Besides, the study evaluated the net effect, which hinges on the unconditional/direct effect, the conditional/indirect effect, and the corresponding coefficient (interactive term). In doing this, the net effect of financial formalization (informalization) is calculated by taking the derivative of private credit by deposit money banks concerning financial formalization (informalization), and the outputs are evaluated at the means, minimums, and maximum level of the ICT proxies. In doing this, the net effect of financial formalization (informalization) through the ICT proxies when evaluated by the means of ICT goods import is 2.4220% (−0.2263%) and the other ICT proxies revealed effects ranging between 0.0048% (−1.3250%) and 24.2072% (−0.2116%) respectively. The same partial derivative when evaluated at the minimum level of countries' ICT proxies ranges between 0.0071% (−0.756%) and 26.3126% (0.864%). The net effects of the ICT proxies at their maximum levels range between −563.4132% (−108.458%) and 68.7415% (0.933948%), respectively. Thus, while ICT goods import, fixed telephone subscription, and mobile cellular subscription do not dampen the negative net effect of financial formalization (informalization) on Banking sector efficiency when the ICT proxies are at their minimum, the dampening/heighting net effect is higher when the ICT proxies are at their maximum.

#### **4.4. Thirdly, threshold of ICT proxies in the nexus between FD and banking sector efficiency**

Excessive and unbridled ICT beyond a certain point might be unbeneficial for the Bank credit to bank deposits. This, therefore, suggests that there could be a potential threshold level of ICT beyond which the impact of ICT changes. In searching for these thresholds' levels, a square term of ICT was added to the financial access equation and the outcome is shown in columns 1–10 of Table 5. From the results, the coefficient of the level effect of the ICT proxies maintained their positive or negative and significant impact, confirming the earlier evidence on the ICT-banking sector efficiency nexus except for ICT goods

imports that change from positive significance to negative insignificant; mobile cellular subscription that changes from negative significance to positive significance; secured internet servers change its coefficient signs. Individual internet usage and fixed telephone maintained their coefficient signs but lost significance. However, the coefficient signs of the square term of the ICT proxies are the same as their level impact. From Table 5 based on the interpretation of Equation (4), it is observed that the difference in the coefficient signs of the ICT proxies at the level and their square terms (threshold effect) from Table 5 suggest the following; *first*, there exists an inverted U-shape relationship between ICT goods imports and the banking sector efficiency, *secondly*, there exists an inverted U-shape relationship between the individual using the internet and banking sector efficiency, *thirdly*, there exists a U-shape relationship between fixed telephone and banking sector efficiency, *fourthly*, there exists a U-shape for the relationship between secure internet servers and banking sector efficiency, but for mobile cellular and banking sector nexus, there exists a U-shape under financial formalization and an inverted U-shape under financial informalization.

The marginal impact of ICT goods imports, individuals using the internet, and fixed telephone. Based on these marginal effects, the study further investigated the thresholds at which the ICT proxies change the signs of the direct effect of financial formalization (informalization) on banking sector efficiency in improving financial access via the banking sector efficiency. This again is conditioned on the fact that, for the significance of the ICT threshold to hold, then it should lie in the range between the minimum and maximum levels of the said variable as this is shown in the summary statistics table. Therefore, the thresholds at which the marginal effect changes the direct/unconditional positive/negative effect of financial formalization (informalization) from positive to negative and vice versa are;  $-5.4585$  ( $-5.7160$ ) for ICT goods import,  $36.7143$  ( $-4.7796$ ) for individual internet usage,  $-0.0034$  ( $-1.0752$ ) for fixed telephone,  $-60.000$  ( $-38.6765$ ) for mobile cellular subscription and  $-6924.3684$  ( $-251.7143$ ) for secured internet servers. Now comparing these thresholds to the summary statistics table suggests that only individual using the internet and fixed telephone threshold values falls within the minimum and maximum range of 0.031 to 61.76 and 0 to 32.67 respectively, for financial formalization. The threshold value of individuals using the internet fell within the minimum and maximum range of 0.031 to 61.76 for only financial formalization.

#### 4.5. Effects of control variables on banking efficiency

Lastly, with regard to the control variables, we find that, GDP growth negatively impacts banking sector efficiency significantly under columns (1) and (5) of Table 3 and positively impacts banking sector efficiency under (7) and (10) of the same table, but with the addition of the interactive and square terms in the banking sector efficiency equation, the effect is significantly negative as observed from Tables 4 and 5. This implies a GDP growth does not enhance the banking sector's efficiency in allocating finance. Gross capital formation positively impacts banking sector efficiency significantly in enhancing financial access, this is established under Tables 3–5. Additionally, inflation had the same impact on banking sector efficiency, this suggests that as inflation increases in Africa, the banking sector can allocate finance efficiently. Unfortunately, trade openness significantly impacts banking sector efficiency in improving financial activity negatively, thus as African countries open their economies to the international economy, the banking sector is unable to enhance financial activity in allocating finance efficiently, and lastly, population growth significantly affects the banking sector efficiency negatively except under columns 2–4 of Table 3.

### 5. Policy implications of findings and conclusion

#### 5.1. Policy implications of findings

Efforts targeted at encouraging access to finance in African countries have not resulted in the expected outcomes. Empirically, aside from the political and macroeconomic reasons, studies on the drivers of financial access have not been rigorous in assessing whether the current advancement in African

countries' ICT infrastructure and the development of the banking sector have any interaction in the improvement of financial access through bank efficiencies.

The lagged banking sector efficiency coefficients being significant and positive at one percent suggest conditional divergence. The implication is that the sampled countries diverge in their steady-state financial allocation efficiency. This holds for all the model's specifications. The findings denote that the current levels of access to finance depend on the continent's records on banking sector efficiency (bank credit to bank deposit).

The findings further suggest that the impact of information and communication technology (ICT) on the relationship between financial formalization and banking sector efficiency differs depending on the specific aspects of ICT. The import of ICT goods and the presence of secured internet servers show negative and significant interactive terms in the nexus between financial formalization and banking sector efficiency. On the other hand, fixed telephone subscriptions exhibit a positive and significant interactive term. However, the interactions involving individuals using the internet and mobile cellular subscriptions were found to be insignificant in the linkage between financial development and banking sector efficiency. The implications of these findings can be understood as follows:

First, the negative and significant interaction in the relationship between financial formalization and banking sector efficiency suggests that countries with a greater emphasis on financial formalization may have a lower reliance on imported ICT goods and secured internet servers to achieve efficiency in their banking sector. This may indicate a preference for domestic ICT capabilities or concerns regarding data security, privacy, or control over critical infrastructure. Secondly, the positive and significant interaction with financial formalization in the context of banking sector efficiency implies that countries with higher financial formalization tend to have a greater usage of fixed telephone subscriptions in their banking operations. This may indicate a higher reliance on formal communication channels, accessibility to reliable telecommunication infrastructure, or the use of fixed telephony as a means of formal and secure communication in financial transactions. Thirdly, the insignificant interactions between individuals using the internet and mobile cellular subscriptions in the linkage between financial development and banking sector efficiency indicate that these forms of ICT have limited direct impact on the efficiency of the banking sector in relation to financial formalization. This could suggest that other factors play a more significant role in determining banking sector efficiency, or that the use of the internet and mobile cellular subscriptions in financial transactions is still not widespread or integrated enough to significantly impact overall efficiency.

On financial development impact, the results suggest that both financial formalization and informalization have a significant positive impact on banking sector efficiency. Financial formalization refers to the process of bringing informal financial activities, such as savings groups or informal lenders, into the formal financial system. This integration can lead to improved efficiency and effectiveness in the banking sector. When financial activities are formalized, they become more regulated and monitored, which can reduce risks and increase transparency. Formal financial institutions can leverage this information to allocate resources more efficiently and make informed lending decisions. Additionally, formalization allows individuals and businesses to build credit histories, which in turn enhances their access to financial services and improves their ability to secure loans or investments. However, financial informalization refers to the disengagement of individuals or businesses from the formal financial system and a preference for informal financial arrangements. This could arise due to various reasons, such as mistrust in traditional banks, limited access to formal financial services, or higher costs associated with formal financial transactions. The positive impact of financial informalization on banking sector efficiency might seem counterintuitive. But, informal financial arrangements can serve as a lifeline for individuals and businesses that are excluded from the formal financial system. Informal lenders, community-based savings groups, or micro-finance institutions can provide much-needed financial services to those who lack access to formal institutions. This can lead to increased economic activity, job creation, and poverty reduction.

However, the unique implication of this result is that the inclusion of ICT goods imports in the equation changes the relationship between financial formalization, informalization, and banking sector efficiency. The impact of financial formalization and informalization on banking sector efficiency becomes insignificant when ICT goods imports are considered. This implies that the adoption of ICT goods in the banking sector can offset the effects of financial formalization and informalization on efficiency.

This finding suggests that the integration of ICT into the banking industry can provide efficiency gains that are not directly related to formalization or informalization. ICT adoption can revolutionize the way financial services are delivered and accessed, leading to the streamlining of processes, reducing operational costs, and improving overall efficiency. Therefore, while financial formalization and informalization are still important factors, the inclusion of ICT goods imports in the equation indicates that technological advancements play a crucial role in enhancing banking sector efficiency.

Understanding these implications can guide policymakers and industry stakeholders in designing strategies to leverage ICT investments alongside financial formalization and informalization efforts. By combining these factors, the banking sector can achieve higher levels of efficiency, expand financial access, and cater to the diverse needs of individuals and businesses.

Additionally, the implication of an inverted U-shaped relationship between individuals using the internet, ICT goods imports, and the banking sector efficiency nexus suggests that there is an optimal level of internet usage and ICT goods imports that maximizes banking sector efficiency. Initially, as internet usage and ICT goods imports increase, there is a positive impact on banking sector efficiency. However, beyond a certain threshold, further increases in internet usage and ICT goods imports may have diminishing returns and can even have a negative effect on banking sector efficiency.

Several implications of these findings can be elucidated as follows:

*First*, the optimal level of internet usage: The inverted U-shaped relationship implies that while internet usage can boost banking sector efficiency, there is a point at which the benefits start to diminish. Therefore, policymakers and banking institutions need to carefully monitor and manage internet usage to ensure it remains within the optimal range for enhancing efficiency.

*Secondly*, managing ICT goods imports: Similarly, the findings suggest that imports of ICT goods can initially contribute positively to banking sector efficiency. However, beyond a certain point, excessive reliance on imported ICT goods may lead to diminishing returns. Policies should focus on striking the right balance between domestic production and imports, considering factors such as cost, quality, and technological capabilities.

*Thirdly*, technology adoption and adaptation: The findings underscore the importance of effectively adopting and adapting ICT-related technologies in the banking sector. Simply implementing internet usage or importing ICT goods without proper integration and utilization may not yield significant efficiency gains. Institutions need to invest in training, infrastructure, and effective usage of technology to reap the full benefits.

## 5.2. Conclusion

The study re-examines the moderating role of ICT in the nexus between financial development and banking sector efficiency using a sample of 48 countries with a panel dataset sourced from the World Bank online database, covering the period 2004 to 2021 due to data availability. Several robustness tests were conducted to validate the reliability of the findings in policymaking.

The findings are that: ICT goods imports significantly impact the banking sector positively in enhancing financial access to allocate finance efficiently; Individuals using the internet enhance the banking sector's efficiency. Fixed telephone subscriptions, mobile cellular subscriptions, and secured internet servers impact banking sector efficiency insignificantly; Financial formalization and informalization significantly impact banking sector efficiency positively, except in the case of ICT goods imports being added to the equation; On the moderating role of the ICT proxies, our findings showed that how ICT moderates the impact of financial development on banking sector efficiency is conditioned on both the proxy of ICT and financial development and Further findings show an inverted U-shaped relationship between individuals using the internet, ICT goods imports, and the banking sector efficiency nexus.

The implication of these findings for policy formulation was discussed. Furthermore, other researchers interested in this field can research into ICT, Fintech, and the Changing Landscape of the Banking Sector, examine the relationship between ICT adoption and green banking practices, or analyse the impact of ICT-driven risk management practices on banking sector efficiency and stability, using other methodologies.



## Note

1. The following are the sample countries used in the study: Algeria, Angola, Benin, Botswana, Burundi, Burkina Faso, Burundi, Cape Verde, Cameroon, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Cote D'Ivoire, Djibouti, Equatorial Guinea, Eswatini, Gabon, Ghana, The Gambia, Guinea-Bissau, Guinea, Kenya, Liberia, Libya, Lesotho, Mali, Malawi, Mauritania, Mauritius, Morocco, Madagascar, Niger, Nigeria, Namibia, Mozambique, Rwanda, Sao Tome, and Principe, Senegal, South Africa, Sudan, Seychelles, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

The financial support of the University of Economics Ho Chi Minh City is fully acknowledged. We are also very grateful to the anonymous reviewers and the Reviewing Editor, Yudhvir Seetharam for the support.

## About the authors

**Emmanuel Issifu Fuseini** is currently a PhD candidate in Business Administration with a focus on finance at the School of Business, University for Development Studies (UDS), Tamale, Ghana. He also holds a Master of Commerce in Accounting from the same University and is a Chartered Accountant with ICA-Ghana. He earned a BSc in Business Administration (Accounting and Finance option) from the University of Cape Coast. With over ten years of teaching experience in ICT, Accounting, and Economics. He is currently serving as a reviewer for high-ranking journals in Finance and Economics. His primary areas of research revolve around the nexus among fiscal policy, inclusive growth, ICT and financial development.

**Muazu Ibrahim** is an Assistant Professor at the Department of Finance, School of Business, University for Development Studies (UDS), Tamale, Ghana. He is a Research Fellow with the University of Economics Ho Chi Minh City, Vietnam. He holds PhD in Economics and Finance from University of The Witwatersrand, Johannesburg, South Africa, an MSc. in Development Economics from School of Oriental and African Studies (SOAS), University of London, UK and a first class degree BA Economics from the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. His research focuses on macroeconomics and international finance where he has extensively published in these areas.

**Ibrahim Osman Adam** is an Associate Professor in Information Systems at the University for Development of Studies. His research interests are in digital technologies in business and innovation as well as ICT4D. He holds a PhD in Information Systems from the University of Ghana Business School. He holds a double master's degree; an MSc in Development Management from the London School of Economics and Political Science (LSE) (UK), and an MSc in Applied Informatics from the Henley Business School, University of Reading (UK). He has a first-class bachelor's degree in business Administration (Accounting Option) from the University of Ghana. He is a Chartered Accountant and a member of the Institute of Chartered Accountants (Ghana). Before joining academia, he worked as a Monitoring and Evaluation Officer in the NGO sector. He has provided consultancy services for several small businesses through the Skills Development Fund Ghana. Presently he is the Dean of the UDS School of Business. He can be reached at [ioadam@uds.edu.gh](mailto:ioadam@uds.edu.gh)

**Xuan Vinh Vo** is a Professor of Finance at the Institute of Business Research, University of Economics Ho Chi Minh City, Vietnam and CFVG Ho Chi Minh City, University of Economics Ho Chi Minh City, Vietnam. His research focuses on the areas of macroeconomics, banking and finance. He has published extensively in top-tier peer reviewed journals.

## Data availability statement

The data used in the study was sourced from <https://databank.worldbank.org/>.

## References

- Ahmad, A. H., Green, C., & Jiang, F. (2020). Mobile money, financial inclusion and development: a review with reference to African experience. *Journal of Economic Surveys*, 34(4), 753–792. <https://doi.org/10.1111/joes.12372>

- Akerlof, G. A. (1970). The market for "lemons": Quality uncertainty and the market mechanism. *The Quarterly Journal of Economics*, 84(3), 488–500. <https://doi.org/10.2307/1879431>
- Al-Obaidan, A. (2008). Efficiency effect of openness in the banking industry of emerging markets. *International Research Journal of Finance and Economics*, 17(C), 92–104.
- Arellano, M., & Bond, S. (1991). Some tests of specification for panel data. *Review of Economic Studies*, 58, 277–297.
- Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, 68(1), 29–51. [https://doi.org/10.1016/0304-4076\(94\)01642-D](https://doi.org/10.1016/0304-4076(94)01642-D)
- Asongu, S. (2014). FD dynamic thresholds of financial globalization: Evidence from Africa. *Journal of Economic Studies*, 41(2), 166–195. <https://doi.org/10.1108/JES-03-2012-0039>
- Asongu, S. A. (2013). The impact of mobile phone penetration on African inequality. *International Journal of Social Economics*, 42(8), 706–716.
- Asongu, S. A. (2015). The impact of mobile phone penetration on African inequality. *International Journal of Social Economics*, 42(8), 706–716. <https://doi.org/10.1108/IJSE-11-2012-0228>
- Asongu, S. A., & Nwachukwu, J. C. (2016). The role of governance in mobile phones for inclusive human development in Sub-Saharan Africa. *Technovation*, 55–56, 1–13. <https://doi.org/10.1016/j.technovation.2016.04.002>
- Asongu, S. A., & Nwachukwu, J. C. (2017). The synergy of financial sector development and information sharing in financial access: Propositions and empirical evidence. *Research in International Business and Finance*, 40, 242–258. <https://doi.org/10.1016/j.ribaf.2017.03.001>
- Asongu, S. A., & Nwachukwu, J. C. (2019). ICT, financial sector development and financial access. *Journal of the Knowledge Economy*, 10(2), 465–490. <https://doi.org/10.1007/s13132-017-0477-x>
- Asongu, S. A., Nnanna, J., & Acha-Anyi, P. N. (2020). Finance, inequality and inclusive education in Sub-Saharan Africa. *Economic Analysis and Policy*, 67, 162–177. <https://doi.org/10.1016/j.eap.2020.07.006>
- Asongu, S., & Nwachukwu, J. C. (2016). The mobile phone in the diffusion of knowledge for institutional quality in sub-saharan Africa. *World Development*, 86, 133–147.
- Asongu, S., Le Roux, S., Nwachukwu, J., & Pyke, C. (2019). Reducing information asymmetry with ICT: A critical review of loan price and quantity effects in Africa. *International Journal of Managerial Finance*, 15(2), 130–163. <https://doi.org/10.1108/IJMF-01-2018-0027>
- Ataullah, A., Cockerill, T., & Le, H. (2004). Financial liberalization and bank efficiency: A comparative analysis of India and Pakistan. *Applied Economics*, 36(17), 1915–1924. <https://doi.org/10.1080/000368404200068638>
- Azumah, S. B., Balinto, C., Adzawla, W., & Osei-Baafi, L. A. (2020). Effect of mobile banking on the banking behaviour of informal sector workers in Accra, Ghana. *Journal of Asian Business Strategy*, 10(1), 133–141. <https://doi.org/10.18488/journal.1006.2020.101.133.141>
- Baltagi, B. H., Demetriades, P. O., & Law, S. H. (2009). FD and openness: Evidence from panel data. *Journal of Development Economics*, 89(2), 285–296. <https://doi.org/10.1016/j.jdeveco.2008.06.006>
- Bartels, F. L., Alladina, S. N., & Lederer, S. (2009). Foreign direct investment in Sub-Saharan Africa: Motivating factors and policy issues. *Journal of African Business*, 10(2), 141–162. <https://doi.org/10.1080/15228910903187791>
- Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1), 115–143. [https://doi.org/10.1016/S0304-4076\(98\)00009-8](https://doi.org/10.1016/S0304-4076(98)00009-8)
- Chen, C. (2009). Bank efficiency in sub-saharan African middle income countries. *IMF Working Papers*, 09(14), 1. <https://doi.org/10.5089/9781451871616.001>
- Claus, I., & Grimes, A. (2003). *Asymmetric information, financial intermediation and the monetary transmission mechanism: A critical review*. Treasury Working Paper Series 03/19, New Zealand Treasury.
- Cragg, J. G., & Donald, S. G. (1993). Testing identifiability and specification in instrumental variable models. *Econometric Theory*, 9(2), 222–240. <https://doi.org/10.1017/S0266466600007519>
- Dakhli, S., Diallo, B., & Temimi, A. (2021). Financial inclusion and ethnic development: Evidence from satellite light density at night. *Journal of Behavioral and Experimental Finance*, 29, 100455. <https://doi.org/10.1016/j.jbef.2020.100455>
- Darley, W. K. (2012). Increasing sub-saharan Africa's share of foreign direct investment: Public policy challenges, strategies, and implications. *Journal of African Business*, 13(1), 62–69. <https://doi.org/10.1080/15228916.2012.657981>
- David-West, O., Timothy, A., & Adetunji, O. (2019). Mobile money: A panacea for financial exclusion in emerging markets. *Journal of Banking*, 8(1), 27–55.
- Demirgüç-Kunt, A., & Levine, R. (2009). Finance and inequality: Theory and evidence. *Annual Review of Financial Economics*, 1(1), 287–318. <https://doi.org/10.1146/annurev.financial.050808.114334>
- Ejemeyovwi, J. O., Osabuohien, E. S., & Bowale, E. I. K. (2021). ICT adoption, innovation and FD in a digital world: empirical analysis from Africa. *Transnational Corporations Review*, 13(1), 16–31. <https://doi.org/10.1080/19186444.2020.1851124>
- Giri, A. K., Mohapatra, G., & Debata, B. (2023). Technological development, financial development, and economic growth in India: Is there a non-linear and asymmetric relationship? *Journal of Economic and Administrative Sciences*, 39(1), 117–133. <https://doi.org/10.1108/JEAS-03-2021-0060>
- Hauener, D., & Peiris, S. J. (2005). Bank efficiency and competition in low-income countries: The case of Uganda. *IMF Working Papers*, 2005(240), 1. <https://doi.org/10.5089/9781451862591.001>

- Huang, Y., & Temple, J. (2005). Does external trade promote FD? Discussion paper series, Centre for Economic Policy Research, CEPR Discussion Paper No. 5150, London, UK.
- Ibrahim, M., Adam, I. O., & Sare, Y. A. (2019). Networking for foreign direct investment in Africa. *Journal of Economic Integration*, 34(2), 346–369. <https://doi.org/10.11130/jei.2019.34.2.346>
- Ibrahim, M., & Vo, X. V. (2021). Exploring the relationships among innovation, financial sector development and environmental pollution in selected industrialized countries. *Journal of Environmental Management*, 284, 112057. <https://doi.org/10.1016/j.jenvman.2021.112057>
- Kablan, S. (2009). Mesure de l'Efficacité des Banques dans les Pays en Voie de Développement: Le Cas de l'Union Economique et Monétaire Ouest Africaine (UEMOA). *African Development Review*, 21(2), 367–399. <https://doi.org/10.1111/j.1467-8268.2009.00214.x>
- Kappel, V. (2010). *The effects of financial development on income inequality and poverty*. Center of Economic Research at ETH Zurich, Working Paper No. 10/127, Switzerland.
- Kihamba, J. S. (2019). E-Financing and the quest for financial inclusion in Tanzania. *Tanzanian Journal of Population Studies and Development*, 26(1), 80–96.
- Kpodar, K., & Andrianaivo, M. (2011). ICT, financial inclusion, and growth evidence from African Countries. *IMF Working Papers*, 11(73), 1. <https://doi.org/10.5089/9781455227068.001>
- Kripfganz, S. (2019). Generalized method of moments estimation of linear dynamic panel data models. *London Stata Conference*, University of Exeter Business School, 1–128. <http://www.kripfganz.de/stata/>
- Lagna, A., & Ravishankar, M. N. (2021). Making the world a better place with fintech research. *Information Systems Journal*, 32(1), 61–102. <https://doi.org/10.1111/isj.12333>
- Lavrinenko, O., Čizo, E., Ignatjeva, S., Danileviča, A., & Krukowski, K. (2023). Financial technology (FinTech) as a financial development factor in the EU countries. *Economies*, 11(2), 45. <https://doi.org/10.3390/economies11020045>
- Love, I., & Zicchino, L. (2006). Financial development and dynamic investment behavior: Evidence from panel VAR. *Quarterly Review of Economics and Finance*, 46(2), 190–210. <https://doi.org/10.1016/j.qref.2005.11.007>
- Mensah, E., Abor, J., Aboagye, A. Q. Q., & Adjasi, C. K. D. (2012). Enhancing the Economic Growth of Africa: Does Banking Sector Efficiency Matter? In K. Menyah and J. Abor (Ed.), *Finance and Development in Africa* (Research in Accounting in Emerging Economies, Vol. 12 Part B), Emerald Group Publishing Limited, Leeds, pp. 1–23. [https://doi.org/10.1108/S1479-3563\(2012\)000012B005](https://doi.org/10.1108/S1479-3563(2012)000012B005)
- Nyasha, S., & Odhiambo, N. M. (2015). Do banks and stock markets spur economic growth? Kenya's experience. *International Journal of Sustainable Economy*, 7(1), 54. <https://doi.org/10.1504/IJSE.2015.066406>
- Osabuohien, E. S., & Efobi, U. R. (2013). Africa's money in Africa. *South African Journal of Economics*, 81(2), 292–306. <https://doi.org/10.1111/saje.12012>
- Otieno, O. S., & Ndede, F. W. (2020). Adoption of digital banking technology and financial performance of commercial banks in Kenya. *International Journal of Current Aspects in Finance, Banking and Accounting*, 2(1), 42–50. <https://doi.org/10.35942/ijcfa.v2i1.108>
- Owusu, E. L., & Odhiambo, N. M. (2014). Stock market development and economic growth in Ghana: an ARDL-bounds testing approach. *Applied Economics Letters*, 21(4), 229–234. <https://doi.org/10.1080/13504851.2013.844315>
- Paa, C., Co, K., Zhao, H., & Mensah, I. A. (2020). Panel econometric analysis on mobile payment transactions and traditional banks effort toward financial accessibility in sub-sahara Africa. *Sustainability*, 12(3), 895. <https://doi.org/10.3390/su12030895>
- Rajan, R. G., & Zingales, L. (2000). The great reversals: The politics of FD in the 20th century. 3rd Annual Fin. Mkt. Dev. Conference, Hong Kong 2001; AFA 2001 New Orleans Meetings; CRSP Working Paper No. 526. <https://doi.org/10.2139/ssrn.236100>
- Rolfe, R. J., & Woodward, D. P. (2004). Attracting foreign investment through privatization: The Zambian experience. *Journal of African Business*, 5(1), 5–27. [https://doi.org/10.1300/J156v05n01\\_02](https://doi.org/10.1300/J156v05n01_02)
- Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal: Promoting Communications on Statistics and Stata*, 9(1), 86–136. <https://doi.org/10.1177/1536867X0900900106>
- Tchamyou, V. S. (2020). Education, lifelong learning, inequality and financial access: Evidence from African countries. *Contemporary Social Science*, 15(1), 7–25. <https://doi.org/10.1080/21582041.2018.1433314>
- Tchamyou, V. S., & Asongu, S. A. (2017). Information sharing and financial sector development in Africa. *Journal of African Business*, 18(1), 24–49. <https://doi.org/10.1080/15228916.2016.1216233>
- Tchamyou, V. S., Erreygers, G., & Cassimon, D. (2019). Technological forecasting & social change inequality, ICT and financial access in Africa. *Technological Forecasting and Social Change*, 139, 169–184. <https://doi.org/10.1016/j.techfore.2018.11.004>
- Tsaurai, K. (2020). Information and communication technology, energy consumption and FD in Africa. *International Journal of Energy Economics and Policy*, 10(3), 429–437. <https://doi.org/10.32479/ijeep.8721>
- Tuomi, K. (2011). The role of the investment climate and tax incentives in the foreign direct investment decision: Evidence from South Africa. *Journal of African Business*, 12(1), 133–147. <https://doi.org/10.1080/15228916.2011.555279>

## Appendix A

**Table A1.** Correlation matrix (uniform observation: 266).

VARIABLES	BcBd	ICTgoods	Indiv Inter	Fixedtel	MobCel Sub	SecInter Serv	FinForm	FinInform	GDP	Inflation	Pop growth	Trade	GfCap form
Financial BcBd	1.0000												
ICT Acces													
ICTgoods	0.4080	1.0000											
IndivInter	0.1238	0.3596	1.0000										
Fixedtel	0.0555	0.2823	0.6625	1.0000									
MobCelSub	0.0557	0.1108	0.7685	0.5876	1.0000								
SecInterServ	−0.1133	−0.0396	0.1904	0.1835	0.1920	1.0000							
FinForm	−0.0055	0.0641	0.0733	0.1649	0.0801	0.0399	1.0000						
FinInform	−0.0889	0.1066	0.2459	0.1731	0.2187	0.0167	0.1542	1.0000					
Control GDP	0.0977	0.3821	0.2965	0.0083	0.1884	−0.0197	−0.1530	0.1617	1.0000				
Inflation	−0.2223	−0.0416	−0.1479	−0.2200	−0.2600	−0.0428	−0.0497	0.0021	0.1882	1.000			
Popgrowth	−0.0306	−0.2766	−0.6351	−0.7226	−0.6384	−0.0956	−0.1488	0.2167	−0.075	0.1813	1.0000		
Trade	−0.2164	−0.2114	0.3393	0.5562	0.4912	0.2381	0.0787	0.1687	−0.258	−0.1633	−0.5703	1.0000	
gfCapform	−0.2285	−0.2552	0.1138	0.1088	0.2061	0.0629	−0.1044	0.1824	−0.111	−0.1256	−0.0388	0.4376	1.0000

**Notes:** ICTgoods-ICT goods imports; SecInterServ-Secure Internet servers; BcBd-Bank Credit to Bank Deposit; MobCelSub-Mobile cellular subscriptions; IndivInterusage-Individuals using the Internet; Fixedtel-Fixed telephone subscriptions; FinForm-Financial Formalization; FinInform-Financial Informalization; gfCapform-Gross fixed capital formation; Trade-Trade; GDP-Gross Domestic Product; Popgrowth-Population growth. Source: Authors' Compilation.