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EMERGING MULTINATIONALS IN A DIGITAL ERA

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ICT adoption, innovation and financial development in a digital world: empirical analysis from Africa

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ABSTRACT

As a response to a digital era that is seen as a core element of global digitalisation, financial development in many countries including those in the African continent experienced varying patterns. These have made some countries to be categorised as relatively high and others relatively low in terms of their scale on digital economy. Thus, this study empirically investigates the interaction of information and communication technology (ICT) adoption and innovation, and the role of this digitalisation interaction on financial development in Africa, and across the sub-regions. It utilises the Bayesian Vector Auto-Regressive (BVAR) modelling to simulate the impulse response function and variance decomposition across Africa. The study finds that ICT-innovation interaction shock positively drives financial development across all of 6 datasets. This implies that for multinational corporations (MNCs) and other economic agents, ICT – innovation interaction should be strongly applied across all sectors to drive financial development since all sectors require finances to improve performance. Thus, contributes to the empirical testing of the theoretical reflections of digitalisation and digital economy interaction in African countries.

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1. Introduction

Firms operating in Africa are in need of capital finance for development purposes for which financial intermediaries play a major role in the transformation of mobilised deposits into credit (Asongu & Nwachukwu, 2017; Bartels, Alladina, & Lederer, 2009; Darley, 2012; Rolfe & Woodward, 2004) and at the same time, Africa is experiencing an uneven asymmetric development in ICT adoption. This is consistent with the view that ICT market in Africa presents considerable opportunities for doing business compared to North America, Europe and Asia; also documented in literature (e.g. Asongu, 2015; Penard, Poussing, Yebe, & Ella, 2012). A probable cause of the high adoption rate of ICT in Africa and the relatively low financial development in Africa could be attributed to the level of innovation and the ICT-innovation interaction attained by the region which implies that ICT alone might not be sufficient to mitigate financial underdevelopment (Ejemeyovwi, Osabuohien, Johnson, & Bowale, 2019).

Walsham and Sahay (2006) emphasised on the value and role of critical research in ICT for development. The emphasis brought to knowledge the need for a strong critical approach and argued that issues in developing countries are normally deeply intertwined with issues of power, politics institutional arrangements, and donor dependencies, which are the characteristics of most African countries. This calls for the more relevant theory building that will be better suited to researchers examining phenomena in complex non-Western domains (Avgerou, 2010; De', Pal, Sethi, Reddy, & Chitre, 2018; Walsham, 2012) rather than relying on the theories of technology diffusion and innovation that were originally developed in Western developed countries and do not have relevance when thoroughly adopted to the developing context.

ICT has been found to significantly contribute to financial development (Osabuohien, 2008), productivity, output, and reduction in the transportation cost (Ejemeyovwi, Osabuohien, Bowale, Abuh, & Adedoyin, 2019). This inclusive development is evident in their respective contributions not only to their countries but also to the world as a whole. The number of internet users, mobile technology users in West Africa has been experiencing an increase in the past decade (Ejemeyovwi, Adiat, & Ekong, 2019) but the issue being ignored is the necessity for

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ICT adoption to be complemented by innovation to significantly improve financial development in Africa which is a channel for inclusive development.

Healthy financial systems are characterised by high levels of financial development; hence, financial development is imperative for growth and, more importantly, inclusive growth (Papadavid, Rewilak, & Brighty, 2017). Countries with higher financial development experience faster reductions in income inequality (Beck, Demirgüç-Kunt, & Levine, 2007) and reduce growth volatility by alleviating liquidity constraints on firms and facilitating long-term investment (Aghion, Angeletos, Banerjee, & Manova, 2010). Hence, the development of financial intermediaries and financial markets are crucial to economic progress.

The study is motivated by the need to improve the relatively low financial development performance in Africa and the need to fill an apparent gap in extant literature by proposing a solution to the financial development issue in Africa. World Bank (2019a) statistics report that with regards to a measure of financial depth (private sector credit to gross domestic products-GDP ratio), 100 percent of African countries performed below selected advanced countries (as shown in Table A1 and Figure A1 in the Appendix). Also, 90 percent of African countries attained less than 50 percent and 64 percent of African countries performed below the Africa average (20 percent) as well as the regional averages. Furthermore, evidence from literature on financial development majorly focussed on its contribution to economic growth (Tayssir & Feryel, 2018); the determinants of financial development such as the role of institutions such as creditor rights protection (Adeleye, Osabuohien, & Bowale, 2017; Adeleye, Osabuohien, Bowale, Matthew, & Oduntan, 2018); the role of ICT adoption on financial deepening (Asongu & Nwachukwu, 2017); the role of ICT on Inclusive Growth (Ejemeyovwi & Osabuohien, 2020) and human development (Ejemeyovwi, Osabuohien, & Osabuohien, 2018) which all missed out the existence of ICT-innovation interaction and its relationship as a significant macro and micro determinant of financial development.

Having established the need to address the issue of relatively low financial development in Africa, it is expedient to note that for financial development to be achieved, an innovation-based economy is necessary as it is for achieving economic growth (Oluwatobi, 2014). The World Bank created a Knowledge Economy Index (KEI) that comprise of three components – education, information and communication technology (ICT) and innovation. Among the three components, ICT is likely to exert the highest impact on economic, human and financial development landscapes due to its tendency for wide spread, fast adoption and penetration (Asongu & Le Roux, 2016; Ekong, Adiat, Ejemeyovwi, Alalade, & Harnessing, 2019; Karakara & Osabuohien, 2019). Innovation-based economies (such as the Asian Tigers- South Korea, Singapore and China) have shown that economies have a higher chance of confronting the challenges posed to development through globalisation (Akinyemi, Efobi, Asongu, & Osabuohien, 2019; Johnson, 2016; Oluwatobi, 2014).

The research question being addressed by the study is: to what extent is the impact of ICT – innovation interaction shocks on financial development in Africa? This motivates the objective of the study, which examines how ICT – innovation interaction shocks affect financial development in Africa. To address this research issue, the study is structured as follows: a review of the related literature is carried out in the next section. Section Three discusses the methodological issues while Section Four presents the empirical results and discussion. The last section concludes.

2. Issues in extant literature

According to Alexander and Baden (2000), the financial sector is the collection of institutions, instruments and regulatory frameworks that enable debt-incurring and debt-settlement transactions; that is, credit-extension. The financial system makes isolation of wealth ownership from physical capital control possible. The financial sector of an economy deepens, improves and widens as the economy grows, further implying that as an economy develops, the number and nature of financial instruments increase, the interrelationship and sophistication of financial institutions, as well as the geographical penetration and extent of financial markets, also increase. The financial sector performance of an economy could be measured empirically by the monetisation ratio (money supply to Gross domestic product ratio) as proposed by McKinnon (1973) and private sector credit to gross domestic products ratio (Adeleye et al., 2020; Osabuohien, Efobi, Odebiyi, Fayomi, & Salami, 2019; Osabuohien, Efobi, Odebiyi, Fayomi, & Seck, 2017). Thus, in this study, we conceptualise financial development as the improvement in the overall performance of a country's financial sector.

Judging from the review of statistics, financial development in Africa has been relatively low in terms of the private sector credit to GDP ratio. The average values for Africa trended below 30 percent at all the time-periods, 100 percent of the countries in Africa have values significantly less than the values of advanced countries such as the United Kingdom, United States (See Appendix), 90 percent of countries had figures below 50 percent and 64 percent of countries individually performed below the Africa average which is relatively poor. With regards to the regions, figure 2.2 shows that the private sector credit to GDP ratio for Southern Africa seemed to be the highest (ranging from 30 percent – 54.3 percent) which was followed by Northern Africa (ranging from 30 percent – 40 percent) then followed by West Africa (ranging from 19.5 percent – 34.8 percent). East Africa followed ranging within 15.1 percent – 23.2 percent and then lastly Central Africa (ranging from 4 percent – 20 percent). Also, in terms of the percentage of countries that performed below 50 percent (a benchmark for this study), 91 percent of countries within Africa performed below 50 percent: 91 percent of countries within West Africa performed below 50 percent; 67.26 percent of countries within North Africa performed below 50 percent. Furthermore, 77.80 percent of countries within Central Africa performed below 50 percent; 92 percent of countries within East Africa performed below 50 percent; 77.89 percent of countries within Southern Africa performed below 50 percent.

Developed and developing economies are characterised by differences in the level of financial development and there has been a serious omission in literature with regards to the controversy on the efficacy and impact of the financial infrastructure determinants on financial development. Furthermore, from observation, there seems to be a shortage on empirical literature analysing the role of ICT adoption, and innovation on financial development in Africa to the best of the researchers' knowledge. In light of this, the main issue addressed by this study is the assessment the interaction of ICT adoption and innovation, how it relates to the present Africa' financial landscape and what the future most probably holds for Africa in terms of the impact of shocks in ICT-innovation interaction on financial development and long run relationship between them.

The World Economic Forum's Global Competitiveness Report (2013) stated that the least competitive nations are those that depend on natural resources while the advanced economies are the innovation-driven economies. Ghani and Kharas (2010) emphasised that the knowledge economy path enables emerging economies to compete effectively with advanced economies where innovation drives the affairs of the economy. Some of the effects of such efficient competition include trade development (Osabuohien, Beecroft, & Efobi, 2018), emerging market development (Casanova & Miroux, 2018). The stream of literature capturing the knowledge economy (innovation, ICT, human capital and institutions) emphasised on its relationship with economic growth and development in Sub Saharan Africa (Asongu, 2013; Oluwatobi, Efobi, Olurinola, & Alege, 2014) without specifically acknowledging one of the major channels (notably financial development) and capturing empirically that channel in the designed model.

Literature on financial development majorly focussed on its contribution to economic growth (Okafor, Onwumere, & Chijindu, 2016; Tayssir & Feryel, 2018; Werigbelegha & Nwamaka, 2015), on trade flows and performance (Akinyemi et al., 2019; Osabuohien, Efobi, Odebiyi, & Fayomi, 2017; Osabuohien et al., 2019) without much emphasis on the determinants of financial development (Osuagwu & Nwokoma, 2017; Takyi & Obeng, 2013; Trinugroho, Agusman, Ariefianto, Darsono, & Tarazi, 2015) and these studies established the importance of financial development in achieving trade flows, economic growth, and inclusive growth for both advanced and emerging economies.

Another macro-categorisation of financial development literature focussed on the determinants of financial development such as the role of institutions such as creditor rights protection (Adeleye et al., 2017; Farla, 2014; Singh, & Huang, 2015), information sharing and financial deepening (Sahay et al., 2015); the role of ICT adoption on financial deepening in Africa (Asongu & Nwachukwu, 2017; Chithralega & Varalakshmi, 2016); outside Africa (Darrat & Al-Sowaldi, 2010; Iscan, 2012; Gadamsetty, 2013; Abosedra & Fakih, 2014; Bansal, 2014; Ho et al., 2017); which all missed out the existence of ICT-innovation interaction and its relationship as a significant macro and micro determinant of financial development.

Asongu and Nwachukwu (2017) investigated the role of internet and mobile phone penetration (ICT adoption measures) in complementing financial formalisation and 'in-formalisation' (financial sector development) in improving financial access in Africa using evidence based on generalised method of moments with 53 African countries for the period 2004 – 2011 to establish some findings. In establishing ICT, financial sector development and financial access linkage, a fourfold driver was identified, namely: the scope of ICT in that continent, the need

for alternative sources of finance for the continent's growing investment needs, rising concerns about surplus liquidity and gaps in the measurement of financial development and scarce literature on financial sector development.

The study pointed out some major issues. First, that Africa is experiencing an uneven asymmetric development in mobile phone (41 percent) and internet penetration (9.6 percent) as against the fact that developed economies had reached saturation levels as at 2010 in terms of their mobile phone and internet penetration which is consistent with the view that ICT market in Africa presents considerable opportunities for doing business compared to North America, Europe and Asia; also documented in literature by Penard et al. (2012); Asongu (2015). Second, businesses in Africa are in need of capital finance for development purposes for which financial intermediaries play a major role in the transformation of mobilised deposits into credit (Asongu & Nwachukwu, 2017; Bartels et al., 2009; Darley, 2012; Rolfe & Woodward, 2004) but contrastingly, there is the issue of surplus liquidity in the financial sector in Sub-Saharan Africa (Asongu, 2015).

Though there has been attempts on the empirical linkages between ICT adoption and financial development, the connection between ICT-innovation interaction and financial development in Africa is yet to be understood. This research issue points out that financial development may be influenced by a knowledge- driven economy (ICT-innovation interaction) and hence, introduces ICT-innovation interaction as an omitted determinant in literature which plays a role in the outcome of the financial development in African economies. Also, this study acknowledges that financial development has no definite generally agreed measure and hence, comprises of government sector based and private sector based financial development that are captured empirically in the study.

3. Analytical framework and methodology

3.1. Analytical framework

The concept behind this study lies in the process of how the interaction between information and communication technology (ICT) adoption and innovation (research and development) interrelate to drive financial development. This is based on the postulation that ICT adoption cannot operate alone. The interdependency is crucial because (i) ICT in itself is a product of innovation, (ii) the ICT could be used as the medium through which information about other innovations are made popular, (iii) ICT adoption also contributes significantly in the research and development process which is about finding solutions to problems in the financial sector. It is therefore expected that ICT and innovation significantly affect financial development.

This study therefore, designed a framework: the ICT adoption - innovation matrix framework, which highlights the picture of the inter-relationship between ICT adoption and innovation that is useful for an economy to know the level of ICT adoption – innovation interaction. This framework is similar to the knowledge economy framework of Oluwatobi (2014) and Johnson (2016). Oluwatobi (2014) explored the inter-relationship between human capital, institutions, (knowledge economy) and economics growth while Johnson (2016) designed the ICT – inclusive growth pyramid framework categorising countries according to the level of ICT adoption in relation with inclusive growth. The role of ICT adoption in the achievement of inclusive growth and the Remittance utilisation framework was also designed by Osabuohien and Efobi (2013; 2014) and explored by this study.

The ICT – Innovation matrix shows the various possibilities in terms of the classification of economies with respect to the level of ICT – innovation interaction. Notably, the level of ICT – innovation interaction is greatly influenced by the level of ICT adoption, innovation (research and development) and the level at which the former and the later are utilised together. The four segments of ICT – innovation matrix framework include the high ICT– innovation interaction class (Panel A), low ICT – innovation interaction class (Panel B1 and B2) and the average ICT – innovation interaction class (Panel C). The matrix is shown in Figure 1.

Panel A is an ideal model of an ICT – innovation interaction driven economy which has constantly engaged in information and communication technology adoption overtime, engaged in lots of innovative activities (university and non-university-based research and development). Furthermore, and most importantly, engaged in the synergy between innovation and ICT adoption, which has translated into financial development, which is an arm of inclusive growth. Countries that fall into this category are advanced economies with some exceptions based on the levels of financial development and inclusive growth. The countries that fall into this category are usually relatively small compared to the countries that fall into the categories of average ICT – innovation interaction class (Panel B1 and B2) and the average ICT – innovation interaction class (Panel C).

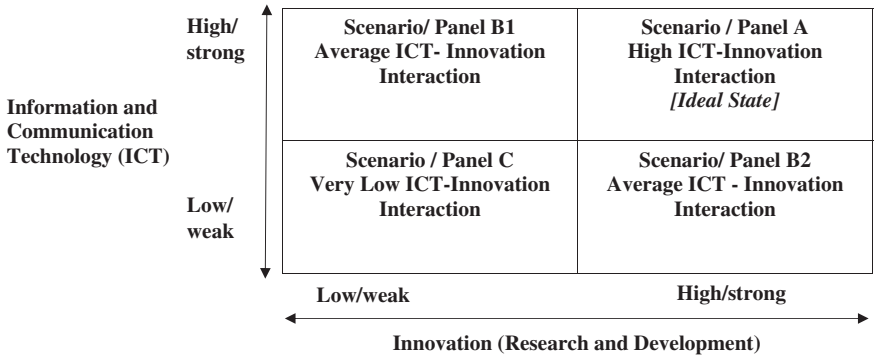

Figure 1. ICT – innovation interaction matrix. Source: The Authors'.

Panel B1 and B2 indicates the average model of ICT – innovation interaction driven economies which (i) have invested relatively lesser than the high interaction economies in ICT and innovation (ii) are yet to have high interaction between ICT and innovation (university and non-university-based research and development). Furthermore, be engaged in the synergy between innovation and ICT adoption which has translated into financial development which is an arm of inclusive growth and (iii) have not fully reaped the benefits of the ICT – innovation interaction engaged in information and communication technology adoption overtime. Countries that fall into this category are some advanced economies, some emerging economies and with some exceptions based on the levels of financial development and inclusive growth. The countries that fall into this category are usually relatively more compared to the countries that fall into the category of high ICT – innovation interaction class (Panel A) and small compared to the countries that fall into the category the low ICT – innovation interaction class (Panel C).

Panel C shows the least class and is expected to be the most populated class within the ICT – innovation interaction matrix framework. The class contains economies, which (i) have invested in ICT and innovation relatively lesser than the average ICT – innovation interaction economies (ii) are yet to attain the level of interaction between ICT and innovation (university and non-university-based research and development). (iii) importantly, must be engaged in the synergy between innovation and ICT adoption which is yet to translate into financial development (a dimension of inclusive growth). (iv) May have not fully reaped the benefits of the ICT – innovation interaction engaged in information and communication technology adoption overtime. The countries that fall into this category are usually relatively large compared to the countries that fall into the categories of high ICT – innovation interaction class (Panel A) and the average ICT – innovation interaction class (Panel B1 and B2).

3.2. Theoretical framework

The theoretical framework is bound within the Gurley and Shaw (1960) financial intermediation hypothesis and the asymmetric information theory (Hannig & Jansen, 2010), which posit that financial intermediation ensures efficient allocation of financial resources when financial intermediaries overcome the problem of information asymmetry. Hence, symmetric information passage in the financial system leads to financial development. Nothing that asymmetric information refers to the difference in the information available to different parties in a financial contract (Brealey, Leland, & Pyle, 1977; Hannig & Jansen, 2010; Sharpe, 1990). The assumptions of the theoretical framework being proposed by this study are stated herewith.

One major assumption of the asymmetric information framework is the existence of four economic agents as actors: The households, the firms, the government, and the rest of the world. The household consists of identical consumers of various goods and services with optimisation goals of maximising utility and minimising cost given certain resource constraints such as income, time, and cost. The firms consist of identical producers of various goods and services with optimisation goals of maximising profit and minimising costs given resource constraints such as labour, capital, and time. The government as the regulator is assigned the responsibility of efficient allocation of resources as well as the social planner of the economy overseeing every sector. The rest of the world is

characterised by the many individual economies with goals to maximise international returns given the constraints of resources and other international economies.

Other assumptions include: (i) that the economy and the economic actors last for 'T' periods: Where$T = \infty$; that is the economy lasts forever till infinity. (ii) Financially developed economies are countries with lots of financial activities and could be indicated by the volume of financial activities that enable the real sector of each economy. (iii) Expected value of information and communication technology (ICT) is a function of ICT investments, level of ICT available. Other assumptions being added to these theories to form the theoretical frame work of this study include (iv) Innovation (knowledge from research and development) is not only the responsibility of the universities but also the research arm of every producing firm (v) ICT -innovation interaction is a function of the individual levels of ICT adoption, innovation and the interaction level between former and the later.

The financial intermediation and the asymmetric information theories are justifiable as the theoretical framework of this stud given that the financial intermediation theory emphasises the importance of the financial intermediation and their efficiency which implies the need for financial sector development, while the asymmetric information theory is relevant as the theory indicates the need for symmetric information for the development of the financial sector. This study attempts to firstly, merge these two theories and further extend the merged theory by the inclusion of innovation. The rest is explained in the course of the study.

3.3. Empirical model

The model specification provides a general overview of the basic variables utilised during the empirical analysis. The study adapts existing models of Asongu and Nwachukwu (2017); and Asongu, Anyanwu, and Tchamyou (2017) where the determinants of financial development were expressed with adjustments such as the introduction of the ICT – innovation interaction variable as a significant determinant of financial development (the thesis of the study). The functional form of the model is given as follows:

$$FD = f(A, S, X, Z) \tag{1}$$

Where A, S, X and Z are the independent variables of interest.
A represents information and communication technology adoption
S represents innovation
X represents the interaction between information and communication technology adoption and innovation.
Z represents the control variables (necessary for the model from literature and theory)
The model is stated in its implicit form as follows:

$$FD_{it} = f_{=}(INN_{it}, ICT_{it}, ICTINit, INST_{it}, GDPGR_{it}) \tag{2}$$

Where:

FD_{it}: Financial development of country 'i' at time 't'; ICT_{it}: Information and communication technology adoption of country 'i' at time 't'; INN_{it}: Innovation of country 'i' at time 't'; $ICTIN_{it}$: ICT – innovation interaction variable of country 'i' at time 't'; $INST_{it}$: Institutional quality of country 'i' at time 't'; $GDPGR_{it}$: Gross domestic product growth rate of country 'i' at time 't'; The model is stated explicitly as follows:

$$FD_{it} = \beta_0 + \beta_1 ICT_{it} + \beta_2 INN_{it} + \beta_3 ICTIN_{it} + \beta_4 INST_{it} + \beta_5 GDPGR_{it} \tag{3}$$

FD represents the financial intermediation process - as discussed in the Gurley and Shaw (1960) financial development hypothesis - which entails the various aspects of financial development. This study utilises the principal component analysis (PCA) to derive financial development index as seen in literature for holistic capturing of the various components of financial development which include: financial depth, financial access, financial activity, financial size, financial stability and financial efficiency. The variables utilised include: Private sector credit to GDP (financial depth), Depositors with commercial Bank (financial access), private domestic credit from financial institutions (financial activity), deposit money bank assets on Central Bank assets (financial size), Banks Z Score (financial stability) and Bank Credit to Bank Deposit (financial efficiency).

Information and communication technology-innovation (ICT-innovation) interaction variable is the crux of the study. The interaction as modelled by the researcher captures the value of the existing level of ICT adoption and innovation interaction, which is a function of the individual values, as well as the level of harmony between ICT adoption and innovation. Information and communication technology (ICT) adoption is a measured by mobile

technology variable as in literature and supplemented by internet usage variable which is consistent with African knowledge economy (Asongu, 2015; Tchamyou, 2017). Innovation is measured by scientific and technical journal articles because (i) profitable ideas that emanate from non-engineering disciplines can easily be stored for easy retrieval and use instead of being side-lined due to their non-patent-worthy nature, hence, journal articles are veritable platforms for the expression of such innovations. (ii) The motivation for patenting is usually profit driven but the profit driven patenting may leave out innovative ideas that may not reflect immediate potential for profit. The a-priori expectation for ICT-innovation interaction is positive, which implies a significant relationship is expected between ICT-innovation interaction and financial development.

$$\text{Effect} = \beta_1, \beta_2, \beta_3 > 0 \tag{4}$$

3.4. Technique of analysis

To examine the effect of ICT-innovation interaction shocks on financial development in Africa, the BPVAR methodology is utilised. The BPVAR's usage is justifiable given that the hypothesis of the study is concerned with the examination of the transmision effect of a shock from a variable to another. Furthermore, the BPVAR tends to be advantageous over the other possible types of VAR for looking at the issue of shocks given that it considers the statistical properties of the data for a more reliable policy estimate. The BPVAR have the same structures with the Vector autoregression (VAR) models with regards to the endogeneity and interdependency assumptions of the variables. However, the difference is the addition of a cross sectional dimension which is a more suitable tool in addressing issues relating to transmissions of shocks across countries (Amu, 2018). Canova and Ciccarelli (2013), Amu (2018) further pointed out that BPVAR are suited to capture both static and dynamic interdependencies, treat the links across units in an unrestricted fashion, and easily incorporate time variations in the coefficients and in the variance of the shocks and account for cross sectional dynamic heterogeneities. VARs are flexible statistical models that include many free parameters and, in that respect, the BVAR deals with the problem of over-parameterisation by treating the model parameters as random variables and prior probabilities

The BPVAR methodology utilises the Bayesian theorem applied to the standard VAR models in order to overcome the limitations of the unrestricted VAR (UVAR) method (the benchmark estimation method) for dynamic economic problems. An identified limitation of the UVAR includes the representation of the autoregressive components of the model in a generalised form without restrictions (Ballabringa, Gonzalez, & Janero, 2000). Ciccarelli and Rebucci (2003) pointed out the effects of the generalised modelling of the UVAR and they include (i) The unrestricted model structure usually results in the problem of overfitting which is derived from the lack of prior beliefs leading to coefficients that are not reliable (ii) The analysis tends to provide a simple description of the data. In sum, such results could be misleading.

Given the variables' variations in VAR models are accounted for by their own lags, coefficients other than the dependent ones are assigned smaller relative variance. Also, the variance – covariance matrix of the error term is assumed to be fixed. The model of the panel VAR presented in this study is adapted by Alege and Osabuohien (2013); and Amu (2018), which is of the form:

$$Y_{it} = A_{it} + B_{it}(L)\, Y_{it-1} + \mu_{it} \tag{5}$$

$$\text{Where } Y_{it} = \begin{bmatrix} FD_{it} \\ ICT_{it} \\ INN_{it} \\ ICTIN_{it} \\ INST_{it} \\ GDPGR_{it} \end{bmatrix}; A_i = \begin{bmatrix} \beta_{FD} \\ \beta_{ICT} \\ \beta_{INN} \\ \beta_{ICTIN} \\ \beta_{INST} \\ \beta_{GDPGR} \end{bmatrix}; \mu_{it} = \begin{bmatrix} \mu_{FD} \\ \mu_{ICT} \\ \mu_{INN} \\ \mu_{ICTIN} \\ \mu_{INST} \\ \mu_{GDPGR} \end{bmatrix} \tag{6}$$

Y_{it} presents a vector of endogenous variables as defined in equation (5) for time, t = 1, … 16 and individual countries, = 1 to 54. The vector Y_{it} consist of the logarithms of the specified variables (FD_{it}, ICT_{it}, INN_{it}, $ICTIN_{it}$, $INST_{it}$, INF_{it}, $GDPGR_{it}$), as defined in equation (5). A_i is a (10×1) vector of the individual country's intercept parameters. $B_i(L)$ is a (10×10) matrix of the lag polynomials with L identifying as the lag operator. The elements are typically presented as: for n: $\sum_{j=1}^{n} \alpha_{ixyj}\, L$, where n is the number of lags in the model, x and y are indexes over the endogenous variables. The residual μ_{it} is a (10×1) vector of error terms having a variance σ_i^2 for each country, indicating a normal distribution. The residuals are assumed contemporaneously correlated across equations,

but serially uncorrelated, for each country. For the estimation of the panel BVAR, the equation for an individual country is written as:

$$Y_{it} = \beta_{yi} + \sum_{j=1}^{n} \alpha_{1FDj} FD_{i-j} + \sum_{j=1}^{n} \alpha_{1ICTj} ICT_{i-j} + \sum_{j=1}^{n} \alpha_{1INNj} INN_{i-j} + \sum_{j=1}^{n} \alpha_{1ICTINj} ICTIN_{i-j} + \sum_{j=1}^{n} \alpha_{1INSTj} INST_{i-j} + \sum_{j=1}^{n} \alpha_{1GDPGRj} GDPGR_{i-j} + \mu_{it} \quad (7)$$

Equation 7 represents the Panel VAR model for an individual country for financial development (FD_{it}). The other endogenous variables (ICT_{it}, $INN_{it,}$ $ICTIN_{it}$, $INST_{it,}$ $GDPGR_{it,}$) have similar equations as shown in equation 3. The panel VAR reduced form equations for the 16 individual countries considered for the study are consequent from arranging the system of equations in equation (7) above.

3.5. Data, variables, and data sources

The scope of this study covers a period of 54 African countries over a period of 18 years, 2000 to 2017. The time and cross section (panel) period is considered to be sufficient enough to analyse the dynamic nature of the variables considered. The countries considered include Algeria, Angola, Burundi, Benin, Burkina Faso, Botswana, Central African Republic, Chad, Cote d'Ivoire, Cameroon, Congo Republic, Comoros, Cape Verde, Democratic Republic of Congo (DRC), Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Ghana, the Gambia and Guinea. Others are: Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Malawi, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe.

The study complements the continental dataset with sub-regional and selected country specific datasets as informed by certain criteria which include paucity of data and the performance of the selected individual countries among the countries in each region. The selected time period (2000 to 2017) was informed by (i) paucity of data (ii) the fact that this period witnessed the introduction, commercialisation of ICT and ICT sector deregulation in most African countries like Nigeria, various financial sector reforms in Africa and similarly, significant increase in research and development in Africa. The choice of selected countries was informed by the significant performance of these countries in terms of their financial development well as their innovation, ICT adoption and institutional development among their sub regional counterparts. Table 1 shows the variable description and the corresponding data sources.

4. Results and discussion

This section displays the empirical results of the study, which address the study's objectives. Preliminary analyses are carried out before the econometric results are presented.

4.1. Financial development index computation

The PCA is a technique that reduces a set of highly correlated variables to a smaller set of uncorrelated indicators called principal components, which represent a substantial proportion of information or variability in the constituent indicators (Asongu & Tchamyou, 2018). Asongu and Tchamyou (2018) furthermore emphasised that the criterion utilised to determine which information to retain is from Jolliffe (2002) and Kaiser (1974) who recommended that PCs with an eigenvalue greater than the mean or one should be retained. The eigenvalues and corresponding difference (variation) of retained first PCs, consistent with the criterion highlighted above are displayed in Table 2.

Table 1. Description of variables and data sources.

Variable	Identifier	Data Source	Measurement
Financial development Index	FDEV	Researcher's computation; World Bank, 2019a	Index Point
Number of mobile cell subscribers	ICT	World Bank, 2019a	Unit
Number of internet users			
Innovation	INN	World Bank, 2019a	Unit
ICT – innovation interaction	ICTINN	World Bank, 2019a	Unit
Institution (Government Effectiveness)	INST	World Bank, 2019b	Unit
Gross Domestic Products growth rate	GDPGR	World Bank, 2019a	Percent

Source: Compiled by the authors.

In the computation of the financial development index for all samples were selected based on the criterion earlier discussed. The PC for the Africa sample with the highest eigenvalue (2.82) was selected, having a difference of 1.67 as against the second component having the 1.15 and a difference of 0.23. For North Africa, the PC with the highest eigenvalue (3.83) was selected, having a difference of 1.96 as against the second component having the 1.85 and a difference of 1.64. For West Africa, the PC with the highest eigenvalue (3.33) was selected, having a difference of 1.71 as against the second component having the 1.62 and a difference of 0.96. For Central Africa, the PC with the highest eigenvalue (2.32) was selected, having a difference of 0.77 as against the second component having the 1.54 and a difference of 0.15. For East Africa, the PC with the highest eigenvalue (2.64) was selected, having a difference of 1.30 as against the second component having the 1.33 and a difference of 0.29. For South Africa, the PC with the highest eigenvalue (3.26) was selected, having a difference of 1.98 as against the second component having the 1.26 and a difference of 0.46.

4.2. Correlation test

Multicollinearity (perfect collinearity) is an issue to be avoided because of its ability to give rise to biased estimates, hence violating the best linear unbiased estimator' (BLUE) assumption (Ejemeyovwi, 2017). Adeleye et al. (2018) noted that 'there is no consensus on the exact level of dependence for one to become weary of the presence of multicollinearity, but it is usually agreed that any figure from 0.8 and above should be cautiously looked at'. The correlation results shown in Tables 3 and 4 reveal the relationships existing between and among the variables. Furthermore, the correlation result between the variables shows that among all the independent variables in the model, the coefficients lie below 0.5. Notably, the outstanding correlation coefficients in Table 3 that lie above 0.5 are below 0.8 and are focussed on the relationship between the dependent variable and the independent variables, which is allowed.

Table 2. PCA and Eigen vectors.

Principal Indicator	Index	PCA Eigenvalue (highest)	Difference	Proportion
Panel A: Africa				
Financial Development Index	fdev	2.82	1.67	0.47
Panel B: North Africa (NAC)				
Financial Development Index	fdev	3.82	1.97	0.64
Panel C: West Africa (WAC)				
Financial Development Index	fdev	3.33	1.71	0.55
Panel D: Central Africa (CAC)				
Financial Development Index	fdev	2.31	0.77	0.38
Panel E: East Africa (EAC)				
Financial Development Index	fdev	2.64	1.30	0.44
Panel F: Southern Africa (SAC)				
Financial Development Index	fdev	3.25	1.98	0.54

Fdev: Financial Development Index.
Source: Authors' Computation.

Table 3. Correlation matrix, Africa.

VAR	GDPGR	INST	ICTIN	FDEV	GDPGR	INST	ICTIN	FDEV
Africa						North Africa		
GDPGR	1.000				1.000			
INST	0.002	1.000			−0.088	1.000		
ICTIN	−0.019	−0.060	1.000		−0.151	0.239	1.000	
FDEV	−0.004	0.002	0.009	1.000	0.028	−0.168	−0.224	1.000
West Africa						Central Africa		
GDPGR	1.000				1.000			
INST	0.051	1.000			0.307	1.000		
ICTIN	−0.086	−0.030	1.000		0.059	0.275	1.000	
FDEV	−0.133	−0.032	0.171	1.000	−0.122	0.080	0.005	1.000
East Africa						Southern Africa		
GDPGR	1.00				1.00			
INST	0.05	1.00			0.06	1.00		
ICTIN	−0.01	0.04	1.00		0.20	−0.13	1.00	
FDEV	0.02	0.04	−0.01	1.00	−0.06	−0.04	0.01	1.00

GDPGR: Gross Domestic Product Growth Rate. INST: Institution (Government Effectiveness). ICT: information and communication Technology Adoption. INN: Innovation. ICTIN: ICT-Innovation Interaction. FDEV: Financial Development Index.
Source: Authors' computation.

Table 4. BVAR stability results.

Root	Modulus	Root	Modulus	Root	Modulus
Africa		North Africa		West Africa	
0.960244	0.960244	0.432976	0.432976	0.715110	0.715110
−0.624194	0.624194	−0.418194	0.418194	−0.287011	0.287011
0.141003	0.141003	0.017812 − 0.015754i	0.023779	−0.088596	0.088596
−0.109957	0.109957	0.017812 + 0.015754i	0.023779	0.074885	0.074885
No root lies outside the unit circle		No root lies outside the unit circle		No root lies outside the unit circle	
VAR satisfies the stability condition		VAR satisfies the stability condition		VAR satisfies the stability condition	
Central Africa		East Africa		Southern Africa	
0.738628	0.738628	0.402498	0.402498	−0.115727 − 0.010244i	0.116179
−0.294969	0.294969	−0.208003	0.208003	−0.115727 + 0.010244i	0.116179
0.002975 − 0.011438i	0.011819	−0.106582	0.106582	0.084201	0.084201
0.738628	0.738628	0.402498	0.402498	−0.115727 − 0.010244i	0.116179
No root lies outside the unit circle		No root lies outside the unit circle		No root lies outside the unit circle	
VAR satisfies the stability condition		VAR satisfies the stability condition		VAR satisfies the stability condition	

Source: Authors' computation.

Table 5. Response of ICT-innovation shocks on financial development in Africa.

Period	Africa	North Africa	West Africa	Central Africa	East Africa	Southern Africa
1	−0.0050	−0.0110	−0.0068	−0.0087	−0.0040	−0.0008
2	0.0012	−0.0057	−0.0002	−0.0003	−0.0112	0.0018
3	0.0021	−0.0021	−0.0021	−0.0010	−0.0038	−0.00003
4	0.0020	−0.0010	−0.0010	0.0002	−0.0008	0.00002
5	0.0020	−0.0003	−0.0009	0.0002	−0.0002	−0.000002
6	0.0019	−0.0002	−0.0060	0.0003	−0.00005	0.0000004
7	0.0019	−0.00007	−0.00045	0.0002	−0.00001	−0.00000004
8	0.0018	−0.00003	−0.00033	0.0002	−0.00004	0.0000000007

Source: Authors' computation.

4.3. BVAR stability test

The BVAR autoregressive roots results for the Africa datasets, sub-regional datasets and selected -countries datasets in Table 4, respectively, meet the criteria for a stationary BVAR model after taking the first difference and hence, are considered stable and permissible for the estimation of the hypotheses. The results of the estimation of the BVAR model are considered valid if the model is stable (stationary) and the results are considered invalid if the model is unstable (non-stationary). The autoregressive (AR) roots analysis is utilised by this study to determine the stability of the model for the various datasets. In addition, the rule of thumb for deciding the AR roots stability condition state that for a stable/stationary model, the BVAR model must have roots in which the modulus is less than one and must lie within the unit.

4.4. BVAR empirical estimates

The IRF captures the reaction of any dynamic system in response to shocks or impulse to the system. The IRF describes the reaction of the system as a function of time and other independent variables that parameterises the dynamic behaviour of the system since the variables in the model are assumed to be endogenously determined (Ucheagha, 2017).

As can be seen in Table 5 (column 2), financial development in Africa responds to a one standard deviation shock from ICT-innovation interaction positively from the first period to the third period at an increasing rate and from about the fourth period to the eighth period, the response slightly decreased but still having a significant positive impact. Furthermore, one standard deviation shock in ICT-innovation interaction will lead to a positive increase in financial development in Africa from −0.005 at the initial time period to about 0.002 at the third time period and as at the eighth time period, 0.018 index points.

Financial development in North Africa as shown in Table 5 (Column 3) responds to a one standard deviation shock from ICT-innovation interaction positively from the first period to the third period at an increasing rate and from about the fourth period to the eighth period, the response increased but at a decreasing rate. Furthermore, one standard deviation shock in ICT-innovation interaction will lead to a positive increase in financial

Table 6. Validity of hypothesis one (result summary across the sample datasets).

S/N	Sample dataset	Theoretical/Apriori expectation	Result realisation
1.	Africa	Positive	Positive
2.	East Africa Countries (EAC): Rwanda	Positive	Positive
3.	North Africa Countries (NAC)	Positive	Positive
4.	West Africa Countries (WAC)	Positive	Positive
5.	Central Africa Countries (CAC)	Positive	Positive
6.	Southern Africa Countries (SAC)	Positive	Positive

Source: Authors' computation.

development in North Africa from −0.011 at the initial time period to about 0.002 at the third time period and as at the eighth time period, 0.0003 index points.

Financial development in West Africa as shown in Table 5 (Column 4) responds to a one standard deviation shock from ICT-innovation interaction positively from the first period to the third period at an increasing rate and from about the fourth period to the eighth period, the response decreased at a decreasing rate. Furthermore, one standard deviation shock in ICT-innovation interaction will lead to a positive increase in financial development in West Africa from −0.0068 at the initial time period to about −0.0021 at the third time period and as at the eighth time period, 0.0003 index points.

Financial development in Central Africa as shown in Table 5 (column 5) and Figure 4.6 responds to a one standard deviation shock from ICT-innovation interaction positively from the first period to the second period at an increasing rate. A temporary fall from the second to the fourth period is experienced, and from about the fourth period to the eighth period, the response increased but at a slow and almost infinitesimal rate. Furthermore, one standard deviation shock in ICT-innovation interaction will lead to a positive increase in Central Africa's financial development from −0.0087 index point at the initial time period to about −0.0010 at the third time period and as at the eighth time period, 0.0002 index points.

Financial development in East Africa as shown in Table 5 (column 6) responds to a one standard deviation shock from ICT-innovation interaction negatively from the first period to the second period at an increasing rate. However, from about the second period to the eighth period, the response became positive. Furthermore, one standard deviation shock in ICT-innovation interaction leads to a decrease in East Africa's financial development from −0.004 index point at the initial time period to about −0.001 index point at the second time period and as at the eighth time period, −0.00004 index points.

Financial development in Southern Africa (Table 5, column 7) responds to a one standard deviation shock from ICT-innovation interaction positively from the first period to the second period at an increasing rate while from the second period to the third period, a decline is experienced. From the third period to the eighth period, an infinitesimal change is experienced. More specifically, one standard deviation shock in ICT-innovation interaction will lead to a positive increase in financial development in Southern Africa from −0.0008 at the first-year time period to about 0.0018 at the second year, −0.00003 at the third year and as at the eighth year, 0.0000000007 financial development index points.

4.5. Implication of findings

The empirical findings as well as the implications of the ICT-innovation interaction shock - impact vary depending on the related sample of interest. For Africa, financial development is affected significantly and furthermore positively and this follows the theoretical (apriori expectation) as confirmed in Table 6. This is expected as although not all but some countries in Africa are already implementing the idea. This reflects the relevance of ICT adoption (as noted by Asongu & Nwachukwu, 2017), innovation and also their interaction in Africa's financial development process which include the usefulness of ICT-innovation interaction in the store of value, reducing information asymmetry and surplus liquidity as well as implications for a quiet life.

ICT-innovation interaction implies the constant working-together of innovation (research & development) and information & communication technology to enable financial solutions as applicable to all the economic sectors to spur financial development as well as economic growth (Kumar & Kuman, 2017). ICT-innovation interaction is a template for financial institutions in Africa to follow and one of the ways to ensure ICT-innovation interaction is by the University – Industry linkage and partnership model (Oluwatobi, 2015) being applied to the financial sector for financial sector development. This model entails bank and non-bank financial institutions (financial

industry) having consistent interaction with academic (innovators) to ensure that realistic and industry-applicable solutions are proffered to existing problems real-time hence, ensuring a better working financial system.

ICT-innovation interaction has implications with regards to its contribution to the store of value and increasing financial activity as pointed out by Asongu and Nwachukwu (2017). The interaction enables financial products which (i) provides users with the option of storing currency in mobile phones connected to the internet through pseudo bank accounts from the user's mobile operators and formalised bank accounts (ii) enable the instant and stress-free conversion of cash 'to' and 'out' of stored value in formalised bank accounts. (iii) enable specialised industry tailored product services such as the Kenyan M-PESA, Malawi's Kwacha and Ghana's M-Farms. (iv) enable transactions and communications with relevant financial institutions through point of sale (POS) terminals (Omran, Van Horne, & Huang, 2013).

ICT-innovation interaction also has implications of reducing information asymmetry and surplus liquidity through (i) tailoring financial instruments that facilitate contingency-oriented interbank borrowing to mitigate issues related to transportation that mat oblige banks in remote areas to hold surplus cash and (ii) easing bond markets investments, boosting of lending competition among banks. (iii) matching investors (supply) with institutions-in-need (demand), hence, increasing financial access, financial size, stability, financial depth, financial activity and financial efficiency.

5. Conclusion

The study examined the response of financial development to ICT-innovation interaction shock. Stability tests were carried out and the results showed that the model was stable. The Bayesian Vector Autoregressive (BVAR) technique of estimation was further utilised to test out the hypothesis and the result indicated that there exists a positive and significant effect of ICT-innovation interaction shock on financial development in Africa. The positive significant relationship was observed in all of the 6 datasets. As a result, we reject the null hypothesis of 'ICT – innovation interaction shocks do not have significant influence on financial development in Africa'. More specifically, the estimation result affirmed that ICT-innovation interaction shock positively explains variations in financial development, implying that financial development in Africa is determined by the ICT-innovation interaction.

Based on the empirical findings, which affirmed that ICT-innovation interaction shock positively impacts financial development in most of the sample datasets. The study therefore rejects the null hypothesis and makes two recommendations. First, for the sample countries with positive ICT-innovation interaction shock on financial development result, ICT – innovation interaction should be strongly applied across all sectors by all firms to drive financial development since all sectors require finances to perform.

As a suggestion for further studies, African country representatives should be selected to test out the hypothesis posited by this study. The issue of ICT-institution intraction on financial development should also be considered for the African region. This can be the birth of another outstanding idea for empirical research. Furthermore, regular static and dynamic panel data analyses could be considered to address the issues brought out by the study.

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Appendix

Table A1. Domestic Credit to Private Sector Ratio and Money Supply-GDP Ratio in Economies.

Year	United Kingdom	United States	Africa Average	West Africa Average	North Africa Average	Central Africa Average	East Africa Average	Southern Africa Average
1999	106.87	171.09	16.7	19.5	31.3	4.9	15.6	42.5
2000	115.93	162.09	16.8	21.6	31.5	4.0	15.9	41.9
2001	121.89	170.21	16.7	21.2	31.6	5.4	15.1	43.6
2002	126.09	161.69	17.6	22.0	32.1	5.4	15.4	38.7
2003	130.66	176.56	17.5	22.9	30.9	6.1	16.6	39.7
2004	138.45	183.94	17.1	23.9	30.4	6.4	16.2	43.1
2005	144.40	187.85	18.1	26.1	30.5	7.0	16.5	46.6
2006	155.01	197.71	18.4	27.2	31.0	7.8	16.3	50.4
2007	171.26	206.30	19.6	28.5	31.8	8.7	16.3	52.3
2008	193.74	188.02	20.5	29.9	32.4	9.0	18.4	48.5
2009	194.86	191.84	21.3	32.6	33.6	11.6	17.1	51.0
2010	187.95	187.21	21.9	33.3	34.2	12.0	18.7	51.1
2011	173.23	177.85	22.8	34.8	37.1	12.8	19.6	50.1
2012	163.47	179.06	23.0	34.3	35.2	13.6	19.5	52.6
2013	152.01	192.53	23.6	34.2	35.6	14.4	20.6	53.7
2014	137.39	194.62	24.2	36.4	37.5	14.5	21.0	54.3
2015	132.79	188.20	25.1	35.1	39.1	16.4	21.9	56.6
2016	134.41	192.17	24.6	33.5	40.0	20.0	23.2	30.5
2017			20.9	33.0	36.5	13.3	16.9	30.0

Source: Authors' computation using data from World Bank (2019a).

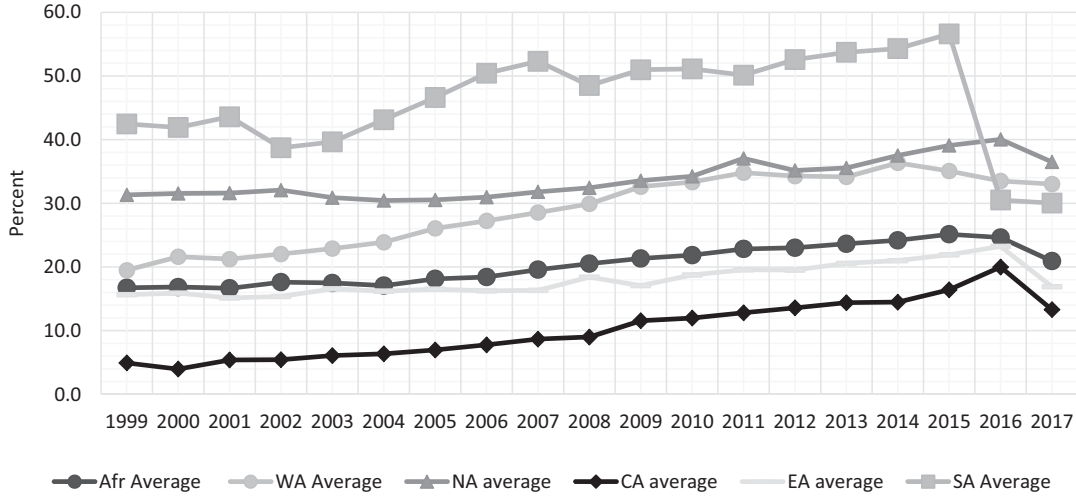

Figure A1. Domestic private sector credit contribution to GDP Ratio in Africa. *Note: AFR = Africa; CA = Central Africa; NA = North Africa; WA = West Africa; SA = Southern Africa; EA = East Africa. Source: Authors' computation using data from World Bank (2019a).