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Do Information and Communications Technology (ICT) and financial development contribute to economic diversification? Evidence from sub-Saharan Africa

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Abstract

This study based on a panel of 37 sub-Saharan Africa countries over the period of 2000–2019 explores the effect of a number of Information and Communications Technology variables namely fixed broad band, fixed line telephone, Information and Communications Technology good imports, internet, mobile, and secure internet servers, and financial development measured by private sector domestic credit to GDP on economic diversification as measured by a computed Herfindahl–Hirschman Index of economic diversification. Model estimation was performed using pooled ordinary least squares regression, panel data fixed effects regression, and generalized method of moments regression. The results from findings indicated that the Information and Communications Technology variables: fixed-line telephone, and ICT imports significantly reduced economic diversification, while internet and mobile were, respectively, insignificant for boosting economic diversification, and fixed broadband and secure internet servers were insignificant in adversely affecting economic diversification. As regards financial development, it was insignificant in boosting economic diversification of sub-Saharan Africa countries. The study recommended amongst others that individuals in sub-Saharan Africa countries should have improved access to Information and Communications Technology infrastructure and governments should ensure adequate provision of quality Information and Communications Technology infrastructure.

Keywords: Information Communication Technology (ICT), Financial development, Economic diversification, Sub-Saharan Africa, Generalized method of moments

JEL Classifications: C23, G10, G21, O11, O33, O55

1 Introduction

Low levels of economic development despite rapidly increasing levels of Information and Communication Technology (ICT) penetration, prevalent in sub-Saharan Africa (SSA) countries as highlighted by development statistics of the World Bank, suggest that the anticipated new economy following ICT diffusion to the countries in line with the digital

economy literature (such as Al-Roubaier et al. 2020) remains elusive. Low levels of economic development are highlighted broadly by high poverty, unemployment and income inequality according to development literature (Todaro and Smith 2020), On the other hand, mobile phone, internet, broadband, secure servers, fixed telephones, computers, are collectively referred to as ICT infrastructure that may play a role in economic development as their respective penetration levels increase in SSA countries. This is more so as the leap-frogging hypothesis of Steinmueller (2001). Relating ICT to economic growth highlights the invaluable contribution of ICT to aiding less developed countries scale difficult hurdles on their path to the achievement of economic growth and development.

Related to economic development is economic diversification whose popular emphasis by development organizations as the World Bank may be traced to the advent of structural adjustment in developing countries in the late 1980s to early 1990s when it was anticipated that following successful reforms, developing country economies will be diversified. Economic diversification defined as the process of shifting an economy from a single source of income towards multiple sources from a growing range of sectors and markets has gradually overtime emerged as a pursuit of many of the developing economies of the world today, including SSA countries. Borne out of its many significant benefits including positioning ailing economies for progress as erstwhile productive sectors as well as other sectors of the domestic economy previously under-developed are regenerated, economic diversification results in the achievement of an economically transformed nation reflected by incomes being realized by the country from a diversity of sources. Further reduced exposure of the domestic economy to adverse external economic influences, increased standards of living, increased employment, reduced poverty, reduced external dependence are features of an economically transformed economy following economic diversification and hence high levels of economic development may result.

Economists in countries across the world are generally in agreement that while there exists variation in the levels of economic development across SSA countries evidenced by the varied levels of indicators, the bulk of the countries including major economies as Nigeria, Cote D'Ivoire, Kenya, South Africa are hindered from realizing their enormous economic potential on account of their inability to achieve economic diversification. This may consequently explain the lack of competitiveness of such economies in global markets.

Economic diversification holds significant promise at boosting Africa's resilience, and aiding the achievement of economic development as well as its sustainment over the longer term on the African continent (OECD 2011). Robust and sustainable growth may be better generated by economies that have a wide array of sectors undertaking a broad range of activities. The sectors working together may influence each other in the sectors individually and collectively contributing to economic diversification thus making a much more sizeable contribution to the achievement of economic diversification by countries. One of such sectors with the potential to influence every other sector of the economy as well as having the potential to be influenced by sectors of the economy it influences, is the financial sector.

The financial sector is inextricably linked with most other sectors of the local economy as it finances development activity and contributes positively to the economy through

financial intermediation activity. A functional financial sector promotes investment in productive sectors of the economy which may be potentially risky but have the potential of providing high returns to investment. Consequently, as the financial sector achieves progress it will inevitably realize development overtime. The importance of a developed financial sector has been highlighted by a number of studies (Rajan and Zingales 2003; Levine 1997). Better mobilization of savings, dissemination of information about investment, optimizing the allocation of capital, mobilizing and pooling savings, and facilitating and encouraging foreign capital inflows are some of the outcomes of improved financial development (Kasekende 2010). Thus financial development is appealing and from that perspective may be argued as a sine quo non for economic diversification of countries in general, and SSA countries in particular challenged with low levels of financial development due to low but relatively better developed banking sectors than capital markets.

A further driving force of economic diversification and indeed having a potential to drive progress in financial sector development is Information and Communications Technology (ICT). Studies such as Hartmann (2014) highlight the need for governments and companies to promote innovation systems that enable new product, new processes and new service creation continued competitiveness in the global markets. A plethora of studies highlight ICT to play an important role for promoting economic growth and development (Ukwuoma 2019; Andrianaivo and Kpodar 2012; Nasab and Aghaei 2009). Further, through the promotion of financial development as argued by studies as Alshubiri et al. (2019) and Edo et al. (2019) ICT may be argued to promote economic progress including economic diversification. ICT contributes to cost reduction of financial intermediation services, including commercial banks and microfinance institutions that will as a result be able to expand business activity. This is consistent with the argument that ICT diffusion has substantially improved the efficiency of resources allocation, enormously reduced production costs and promoted much greater demand and investment in all economic sectors as argued in the ICT and economic growth literature (Pradhan et al. 2015; Lee et al. 2012; Grimes et al. 2012; Vu 2011; Jorgenson and Stiroh 1999). However, the argument for economic diversification is at variance with the prescription of conventional Ricardian theory emphasizing specialization of countries in one line of exports as they take advantage of their comparative advantage in producing the commodity in order to benefit from international trade with another country (Jones and Weder 2017). On the other hand, Ukwandu (2015) highlights the failure of Ricardian theory to successfully address SSA economic development challenges and hence the need for policies tailored to the circumstances of SSA countries emphasizing increasing returns and adding value to natural resources which are exported. This is more so in light of the abundance of resources in SSA countries, many of which have remained relatively un-tapped.

Various ICT infrastructure may be identified to be linked with the promotion of financial development amongst which are Broadband, mobile cellular subscriptions, internet, secure servers, personal computers, fixed line telephones (World Bank 2022; ITU 2017). Over the years, ICT-based technologies such as mobile payments, transactions, social networks and so on have plunged the financial sector into a higher dimension which is fast leading to the improvement of financial development across nations. According to

World Bank (2022), aiding financial development is the availability of the internet which has been used to promote easier access to financial services, especially through enabling electronic banking. Instances exist where ICT has had significant impact on the financial sector of countries of the world. For example, digital infrastructure such as the internet has enabled the provision of financial services which has become the new way of availing the unbanked population more opportunities of partaking in the formal financial system. Thulani et al. (2014) highlight that the use of mobile money services has increased the access of people in both the rural and urban areas to financial products and services at reasonable costs.

Further World Bank (2016) highlights African countries as having recorded impressive performance as regards mobile phone accounts and mobile phone transactions which contributed to improvement in mobile phone-based financial development of African countries. As at 2014, sub-Saharan Africa's mobile phone-based financial development indicators of mobile phones, senders of remittances via a mobile phone as a percentage of senders and receivers of remittances via a mobile phone as a percentage of remittance recipients, was in multiples of that of other country regions such as South Asia, East Asia and Pacific, Europe and Central Asia, and Middle east.

Therefore, on the basis of the above, it is the case that there exists potential for SSA countries to realize their much sought-after economic diversification through improving financial development, while at the same time harnessing the potentials of ICT for both financial development as well as economic diversification. The prospects of economic diversification in SSA countries, in addition to the abundance of natural resources including labour in the vast majority of the countries lies in higher mobile phone development relative to internet use, but with both internet use and mobile cellular subscriptions as measures of ICT rapidly rising overtime. Further financial development indicators of which the major ones, respectively, are private sector domestic credit to Gross domestic product measuring financial widening, and broad money supply to GDP measuring financial deepening while at varied levels across SSA countries are rising in general as financial reforms aimed at promoting financial development has been taking place in respective SSA countries. This study consequently explores the role of ICT and financial development for economic development in a panel of SSA countries.

Previous studies relating ICT and financial development to economic diversification are limited amongst which are Adeola and Evans (2017) and Iyoboyi and Na-Allah (2014). However, the studies focused on a smaller set of countries relative to the panel of SSA countries that this study intends to examine, and also often utilized one measure of financial development without focusing on other measures of financial development. In addition, studies on ICT and financial development as Edo et al. (2019) and Al-Shubiri et al. (2019) did not examine economic diversification, while Ejemeyovwi and Osabuohien (2018) in examining inclusive growth in West Africa do not find a significant influence of mobile technology. However, studies highlight the contributions of ICT to infrastructure across the sectors of the economy including education, health, industry and so on which have supported the development of the aforementioned sectors towards raising welfare levels in countries (Dutta et al. 2019; Phutela and Dwivedi 2019; Irawan and Koesoema 2015; Tikam 2013). This present research consequently is a novel study as it is the first study to explore the roles of both ICT and financial development

for economic diversification in sub-Saharan Africa, combining the strands of research on ICT and financial development, ICT and economic diversification, and financial development and economic diversification. Hence this study makes a significant contribution to the ICT, financial development and economic diversification literature. Two hypotheses in particular are tested in the study. First, whether ICT significantly boosts economic diversification as economic opportunities result from the utilization of ICT in sub-Saharan Africa countries. Second, whether financial development has a role to play in the achievement of economic diversification in sub-Saharan Africa countries.

This present section having introduced the study, the study unfolds over the remaining five sections of the study with relevant literature discussed in the next section and theoretical framework and methodology discussed in Sect. 3. In Sect. 4, results of data analysis and their discussion are done while recommendations resulting from findings, and conclusions drawn from the study are presented in the final section of the study.

2 Literature review

Information and Communications Technology (ICT) is linked to a wide array of economic and social variables as observed from the ICT literature. ICT has been linked to economic growth in the much discussed leap-frogging hypothesis (Adeleye and Eboagu 2019), where ICT is argued to provide developing countries with an advantage in achieving economic development by enabling the countries to by-pass some of the difficult stages of development that developed countries of today passed through. Variety of channels exists through which ICT can influence growth and development and which have informed recent research related to ICT and financial development.

Andrianaivo and Kpodar (2012) assessed the impact of mobile phone penetration and financial inclusion on economic growth for a sample of 44 African countries from 1988 to 2007. The result of the system generalized method of moments (GMM) shows that the development of mobile phones influences economic growth. The interactions between the variables also show that mobile phone penetration and financial inclusion positively and significantly influence growth in Africa. Similarly, Nasab and Aghaei (2009) assessing the effect of ICT on economic growth in 7 OPEC countries covering the period 1990 to 2007 and using both fixed and random effect analysis, as well as generalized method of moments, established that ICT has a positive effect on economic growth in the countries.

Furthermore, Solarin et al. (2019) using quarterly data from Malaysia from 1990 to 2015 examined the effect of information and communication technology, financial development, and economic growth on electricity consumption. The result shows that there exists a long-run relationship between the variables. Also, ICT, financial development, and economic growth influence electricity consumption positively. The causality test also shows the existence of a bidirectional relationship between financial development and electricity consumption, economic growth and electricity consumption, ICT and electricity consumption.

Asongu and Nwachukwu (2019) using the generalized method of moments examined the effect of ICT on financial sector development in 53 African countries for the period of 2004–2011. The result shows that financial activity decline as a result of the relationship between ICT (represented by mobile phone and internet use) and formal financial

development while an increase exists in financial activity as a result of the interaction between ICT and informal financial development. However, the study omits other measures of ICT as fixed line telephones, secure internet servers, fixed broadband and ICT imports.

Further Alshubiri et al. (2019) using internet users and fixed broadband as a proxy for ICT examines the effect of ICT on financial development in six Gulf Cooperation Council (GCC) countries. The study adopted both fixed effect and generalized method of moments in achieving the objectives of the study covering the period 2000–2016. The result shows that both proxies for ICT positively and significantly influence both proxies of financial development (domestic credit to private sector as a percentage of gross domestic product (GDP) and broad money supply/GDP) but in varying proportion. The study also established that trade openness and urbanization affect financial development positively and significantly. However, the study as with that of Asongu and Nwachukwu (2019) use limited ICT measures as they only use broadband and internet while omitting other ICT measures. Similarly, Edo et al. (2019) find in a comparative study of Kenya and Nigeria using Dynamic Ordinary Least Squares and Vector Error Correction Model find that internet adoption is significant for raising the level of financial development. Financial development was measured using private sector domestic credit to Gross Domestic Product (GDP). This study in variance with previous similar studies surveyed used a single ICT indicator.

US Department of Commerce (2000) highlight the emergence of the new economy in US resulting from the embrace of digital technologies owing to the development and diffusion of computer hardware and software, in addition to much cheaper and rapidly increasing electronic connectivity. While diverse opportunities are presented by the new economy for individuals, business, and government to take advantage of, the associated challenges are acknowledged which include employers less readily finding workers with appropriate skills and therefore having to provide further training to current employees, and the need for workers to adapt to new technologies. Further for economists and statistical agencies, improved quality information may be speedily accessed, while they must in turn adapt their frameworks to the fast-changing economy.

Al-Roubaier et al. (2020) emphasize the need for economic diversification by countries on account of price fluctuations in global markets which exposes the countries to vulnerability due to their over-reliance on a limited number of commodities for export, consequently giving rise to a new economy. Digital technologies are argued as aiding the output diversity as well as economic growth of countries as their ability to innovate, create knowledge and share information increases, giving rise to a plethora of opportunities that promote the sustainable development of the countries. Further developing countries will be appropriately placed to diversify output, create opportunities for employment, which for developing countries especially appropriately positions the economy and enhance their global competitiveness as they utilize external knowledge resulting from increased collaboration and information sharing on account of digital networks resulting from digital technologies.

Iyoboyi and Na-Allah (2014) examined the relationship between information and communication technology (ICT) growth and diversification in Nigeria with particular reference to entertainment industry using quarterly data from 2010 to 2013. The result

of the Ordinary Least Squares (OLS) and the Fully Modified Ordinary Least Squares (FMOLS) approach adopted shows that ICT enhances diversification and growth in the entertainment industry. The result also shows that the entertainment industry is a form of diversification in Nigeria's economy. However, the entertainment industry represents one of many industries in a country and the study does not highlight the contribution of ICT to other industries.

Bakwena and Kahaka (2013) in evaluating the progress of Botswana in line with her policy on ICT find ICT quality and access to have substantially improved from 2000 to 2008 based on ICT data from the World Bank and emphasize the centrality of the ICT sector in driving Botswana's economic diversification strategy. Similarly, Leng et al. (2020) in exploring the role of ICT for income diversification in rural households in China find a positive and significant effect of ICT, and further find ICT adoption as more beneficial for the low-income rural households.

Gan et al. (2016) highlight the central role played by ICT in the marketing and distribution reach of community-based tourism in Malaysia. However, despite the potentials of the internet as an ICT medium by which community-based tourism in Malaysia may be promoted and hence enabling a global presence of the tourism industry, Language as well as the nature of the community-based tourism are identified as barriers to the use of ICT for the full potentials of tourism to be harnessed, as evidenced by low foreign tourist patronage. Skills training in language is argued as important for community-based tourism in Malaysia to achieve a global presence through leveraging on the potentials of the internet, while marketing, communication relating to bookings, social media and use of smartphone applications with the aid of the internet are further argued as appropriate sales channels in contrast to conventional online booking via search engines on account of the nature of the community-based tourism in Malaysia.

León et al. (2016) provide evidence in line with theoretical argument for the positive association of ICT and diversification strategy that diversified companies have a high use of ICT that plays a role in the extent of international diversification as well relationship of business. The influence of ICT on diverse business processes give rise to greater entry of companies into new lines of business, consequently raising the extent of international diversification. Further small and medium enterprises are observed to have low ICT adoption while they continue to use technological tools as computers, internet, and email. Electronic banking is highlighted as a higher valued technological tool relative to other technologies. Similarly, Hartman (2016) argues the need for Turkey to emphasize innovation and economic diversification for various reasons including sustained economic and technological catch-up and improved two-way understanding and improved cooperation with the European Union.

Financial development may contribute to an economy through enabling economic diversification and this is as highlighted by Adeola and Evans (2017) who using fully modified least square approach examined the effect of financial development and financial inclusion (measured by financial usage and access) on economic diversification of Nigeria from 1981 to 2014. The Shannon index of economic diversification was used for the study and the result of the study showed that although financial inclusion and financial development positively affect economic diversification only financial inclusion has a significant impact on economic diversification. Also, the study examined the effects of some other variables

like GDP per capita, capital formation on economic diversification, but ICT variables are not included in the analysis, which is a gap this study intends to fill. However, this study represents one of limited studies linking financial development to economic diversification especially in Africa. Similarly, Akoto and Adjasi (2020) find greater financial development to boost export diversification in a sample of 41 sub-Saharan Africa countries using data for the period 1995–2013. Further Nieminen (2020) focusing on a diverse data set on firm-level exports of 60 countries find export diversification to improve resulting from firms' greater access to domestic financial services. This is on account that the numbers of small exporters increase as credit market conditions previously hindering access to credit improves.

3 Methodology

This study is founded on economic development theory, in which economic diversification is viewed as driven by simultaneous changes in production, consumption and trade patterns (Petit and Barghouti 1992; Barghouti et al. 1990; Schuh and Barghóuti 1988). The aforementioned changes are in turn a result of various factors including variations in demand and supply conditions, technology change and structural transformation. Through the faster growth of sectors with high income elasticity of demand in addition to forces of unbalanced growth, economic diversification may be driven. Hence in the context of sub-Saharan Africa (SSA) and based on the arguments of this study, both ICT and financial development, working together drive the process of economic diversification.

Equation (1) is the general model specification for this study adapted from Andrianaivo and Kpodar (2012):

$$\text{ECODIV} = f(\text{ICT},\ \text{FINDEV},\ \text{FININC},\ \text{RLAW},\ \text{GEXP},\ \text{TROPEN},\ \text{PSE},\ \text{L},\ \text{K},\ \text{INF}), \tag{1}$$

where ECODIV refers to economic diversification, ICT is Information and Communications Technology, FINDEV is financial development, FININC is financial inclusion, RLAW refers to rule of law, GEXP is government expenditure, TROPEN is trade openness, PSE is primary school enrollment, L is labour, K is capital, and INF is inflation.

Economic diversification measure in this study is the Herfindahl–Hirschman index which is computed for this study. The index measures the concentration of the sectors in the total output of a country and while having a range between zero and one, values closer to one reflect lower diversification and vice versa. ICT indicators in this study are fixed broadband subscriptions (FIXEDBB), Fixed Telephone Subscriptions (FIXEDTSP), ICT good imports (ICTGIMPOT), Internet users (INTUSE), Mobile use (MOBUSE), and secure internet servers (SINTERNET) and rise in the indicators reflect higher levels of ICT development and vice versa. Financial development indicator used was private sector domestic credit to GDP ratio while financial inclusion indicator used was commercial bank branches per 100,000 people. Hence Eq. (2) results:

$$\begin{aligned}\text{HHI} = f(&\text{FIXEDBB},\ \text{FIXEDTSP},\ \text{ICTGIMPOT},\ \text{INTUSE},\\ &\text{MOBUSE},\ \text{SINTERNET},\ \text{FINDEV},\ \text{FININC},\ \text{RLAW},\\ &\text{GEXP},\ \text{TROPEN},\ \text{PSE},\ \text{L},\ \text{K},\ \text{INF}).\end{aligned} \tag{2}$$

Explicitly expressing Eq. (2) above and log-transforming large variables to ensure standardized regression estimates, Eq. (3) results:

$$\begin{aligned} \mathrm{HHI}_{it} = {} & \beta_0 + \beta_1 \mathrm{FIXEDBB}_{it} + \beta_2 \mathrm{FIXEDTSP}_{it} + \beta_3 \mathrm{ICTGIMPOT}_{it} \\ & + \beta_4 \mathrm{INTUSE}_{it} + \beta_5 \mathrm{MOBUSE}_{it} + \beta_6 \mathrm{SINTERNET}_{it} \\ & + \beta_7 \mathrm{FINDEV}_{it} + \beta_8 \mathrm{FININC}_{it} + \beta_9 \mathrm{RLAW}_{it} \\ & + \beta_{10} \mathrm{LogGEXP}_{it} + \beta_{11} \mathrm{TROPEN}_{it} + \beta_{12} \mathrm{PSE}_{it} \\ & + \beta_{13} \mathrm{LogL}_{it} + \beta_{14} Log\mathrm{K}_{it} + \beta_{15} \mathrm{INF}_{it} + \varepsilon_{it}, \end{aligned} \tag{3}$$

where HHI represents Herfindahl–Hirschman index, FIXEDBB is fixed broadband subscriptions (per 100 subscribers), FIXEDTSP is fixed telephone subscriptions (per 100 subscribers), ICTGIMPOT is ICT good imports (% of total good imports), INTUSE is Internet users (per 100 subscribers), MOBUSE is mobile subscriptions (per 100 subscribers), SINTERNET = secure internet servers, FINDEV is financial development (in percentage), FININC is financial inclusion (commercial bank branches per 100,000 individuals), RLAW is rule of law (ranges between −2.5 and 2.5), GEXP is government expenditure (in billions of US Dollars), TROPEN is trade openness (in percent), PSE is primary school enrollment (in percentage), L is labour (in million), K is capital (in billions of US dollars), INF is inflation (in percentage). ε is the stochastic error term, i represents country, t refers to the time period (2000–2019), β_0 is the constant, $\beta_1 - \beta_{14}$ are the marginal effects of independent variables. Log denotes the logarithm operand.

From Eq. (3), with the exception of rule of law which was sourced from the World Bank World Governance Indicators (WGI), all variables were sourced from the World Bank World Development Indicators (WDI). The model was estimated using Pooled Ordinary Least Squares regression, fixed effects estimation and two-step Generalized Method of Moments (GMM) estimation. The time frame covered by the data is between the year 2000 and 2019 as from 2000 there has been significant ICT penetration in regard to most ICT indicators in SSA countries. Further, 37 of the 48 countries in the SSA country region constitute the sample of countries examined in this present study and give rise to a balanced data panel following interpolation of missing ICT data for the sample countries where necessary, especially for the years 2018 and 2019. The selected countries are Botswana, Benin, Angola, Cabo Verde, Burkina Faso, Cameroon, Burundi, Comoros, Congo Republic, Cote d'Ivoire, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe. The selection of these countries is primarily premised on the extent of data availability.

4 Results and discussion

Table 1 presents the results of descriptive analysis of data used for this study. The mean values of all indicators are low reflecting the low level of development in general of SSA countries. Fixed telephone subscriptions per 100 (FIXEDTSP), mobile subscriptions per 100 (MOBUSE) and number of secure internet servers per 1 million people (SINTERNET) have minimum values of 0.000 indicating that no fixed telephone subscriptions per 100, no mobile subscriptions per 100 and no secure internet servers per 1 million people were recorded in sample countries.

Table 1 Descriptive statistics of variables.

	HHI[e]	FIXEDBB[a]	FIXEDTSP[a]	ICTGIMPOT[a]	INTUSE[a]	MOBUSE[a]	SINTERNET[d]	FINDEV[a]
Mean	0.374	0.487	2.804	3.935	10.038	49.102	145.712	22.502
Median	0.366	0.062	0.950	3.536	4.500	40.604	3.943	14.804
Maximum	0.636	21.639	34.273	12.774	62.000	163.875	14,353.11	160.125
Minimum	0.261	0.0001	0.000	0.595	0.015	0.000	0.000	0.403
Std. dev	0.063	1.889	5.331	2.079	12.814	42.521	1158.825	25.909
Skewness	1.152	7.998	3.776	1.273	1.872	0.647	10.102	3.199
Kurtosis	5.013	74.799	18.512	4.979	6.136	2.468	107.700	13.992
Obs	740	740	740	740	740	740	740	740
	FININC	**RLAW[e]**	**GEXP[b]**	**TROPEN[a]**	**L[c]**	**K[b]**	**INF[a]**	
Mean	4.917	− 0.579	4.11	68.784	7.92	6.73	6.927	
Median	3.252	− 0.598	1.42	60.332	4.97	2.15	5.041	
Maximum	35.051	1.077	82.71	175.798	59.87	85.75	98.224	
Minimum	0.136	− 1.852	0.0387	19.101	0.128	0.0242	− 60.496	
Std. dev	5.382	0.598	10.51	31.531	10.64	13.63	8.878	
Skewness	2.996	0.435	5.20	0.976	2.70	3.55	2.365	
Kurtosis	13.927	2.868	32.20	3.492	10.92	15.89	27.122	
Obs	740	740	740	740	740	740	740	

[a] Figures in percentage

[b] Figures in billions of US dollars

[c] Figures in million

[d] Figures per 1 million

[e] In decimal figures

Maximum values of Herfindahl–Hirschman index (HHI) of 0.636 reflect the low level of diversification of SSA countries. However maximum values for mobile subscriptions per 100 (MOBUSE), secure internet servers per 1 million people (SINTERNET), financial development measured by private sector domestic credit to GDP ratio (FINDEV) and trade openness in percentage (TROPEN) of 163.88, 14,353.11, 160.13, 175.80, respectively, reflect that some of sample SSA countries recorded impressive levels of the respective indicators over the period of focus of this study. Rule of law on the other hand, with a maximum value of 1.077 and a minimum of − 1.852 reflects the poor quality of institutions prevalent in SSA countries.

From the measures of dispersion (standard deviation, skewness and kurtosis), standard deviation values show the spread of the data in each variable about their mean values. In Table 1, the standard deviation values are generally low as it ranges between 0.063 (for economic diversification; HHI) and 42.521 (for mobile subscriptions per 100; MOBUSE), except that of the number of secure internet servers per 1 million people (SINTERNET), which is 1158.825. Also, the skewness results revealed that most of the variables are positively skewed, while only three (capital (K), labour (L) and primary school enrolments (PSE)) are negatively skewed. In the case of kurtosis, all the series in the variables exhibited kurtosis values greater than + 1, implying that the data distributions are picked.

The result of estimating the effects of selected ICT variables [mobile subscriptions per 100 (MOBUSE), the number of secure Internet servers per 1 million people (SINTERNET), internet users per 100 (INTUSE), fixed broadband per 100 (FIXEDBB), fixed telephone subscriptions per 100 (FIXEDTSP), and ICT goods imports percentage of total

goods imports (ICTGIMPOT)], and finance variables [financial development (FINDEV) and financial inclusion (FININC)] on economic diversification (HHI) based on the specified empirical models for this study as in Eq. (3), are presented and discussed. Other explanatory variables engaged in the estimated model of the study are the control variables.

Four empirical models are estimated using three estimation techniques; Pooled Ordinary Least Square (Pooled OLS), Fixed Effect Model (FEM) and Two-Step System Generalized Method of Moments (2-Step System GMM) in testing the hypotheses of the study. The essence of adopting more than one technique is the need for robustness check of the results. GMM is chosen as the main technique of estimation in this study because it is argued that it takes care of endogeneity issue of explanatory variables, it has large sample properties and it can be specified without including full data generating process (Hansen 1982, 2010). The results of the estimation are reported in Table 2, and 1, 5 and 10% levels of significance, respectively, are reckoned with while the list of GMM instruments utilized for 2-Step GMM estimations are described in Appendix.

From Table 2, models 1 and 2 are the results of performing pooled OLS and fixed effect model (FEM) estimations, respectively, while models 3 and 4 are the results of performing two-step system GMM estimations. The results of estimations as in model 1 revealed that all the explanatory variables significantly explained the diversification of the economies in SSA with *F*-statistic of 41.848 (Pr. = 0.000 < 0.01). The adjusted *R*-square of model 1 showed that about 42% of variations in economic diversification is explained by the model. Similarly, model 2 estimation results showed that all the explanatory variables significantly explained the diversification of the economies with *F*-statistic of 55.124 (Pr. = 0.000 < 0.01). The adjusted *R*-square of model 2 showed that about 79% of variations in economic diversification is explained by the model. Prior to the choice of FEM, Hausman test on the choice of either random or fixed effect model was carried out with the null hypothesis that there is no misspecification in the random effect model. The Hausman test result rejected the null hypothesis (Pr. = 0.000 < 0.01), we then accept the alternative hypothesis that there is misspecification in the random effect model. This implies adopting the fixed effect model (FEM) over the random effect.

Models 3 and 4 are simply reporting the effects of financial development and financial inclusion, respectively, on economic diversification in models with ICT variables among other control variables. In the respective models as shown in Table 2, the AR(1) and AR(2) represent the Arellano and Bond (1991) tests for first and second order serial correlation, respectively. The null hypothesis tested in both is 'no serial correlation'. The results revealed that for both models 3 and 4, the null hypothesis of no first order [AR(1) = 3.32 and 3.38 for models 3 and 4, respectively] serial correlation is rejected, while the null hypothesis is accepted for the second order [AR(2) = 1.04 and 1.05 for models 3 and 4, respectively] serial correlation at the 5% level of significance. These results revealed that the system GMM estimates are consistent (Baltagi 2005). Also, the instruments rank in both models is 51 each, which satisfy the condition that the rank of instruments in each model should be greater than the number of coefficients estimated (Roodman 2006).

The findings from Hansen test (HT) of over-identified restrictions (*p*-values for models 3 and 4 are 0.797 and 0.828, respectively) showed that the instruments are valid, as

Table 2 Analysis of the effect of ICT and finance on economic diversification.

Dependent variable: HHI				
Method used	**Panel least squares**		**2-Step system GMM**	
	Pooled OLS	**Fixed effect**		
Independent variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
C	0.213*** (0.000)	1.053*** (0.000)	0.0219** (0.021)	0.0203*** (0.004)
FIXEDBB	0.000117 (0.938)	0.00103 (0.361)	0.000201 (0.255)	0.000160 (0.361)
FIXEDTSP	0.00272*** (0.000)	0.00197 (0.271)	0.000388*** (0.003)	0.000311** (0.045)
ICTGIMPOT	0.00268** (0.017)	− 0.000540 (0.548)	0.000495** (0.024)	0.000488*** (0.009)
INTUSE	0.000648** (0.014)	0.000189 (0.367)	− 0.0000447 (0.158)	− 0.0000674* (0.060)
MOBUSE	− 0.000325*** (0.000)	0.000175** (0.0249)	− 0.00000798 (0.398)	0.00000288 (0.779)
SINTERNET	0.0000016 (0.342)	− 0.000000427 (0.698)	0.000000169 (0.126)	0.000000133 (0.380)
FINDEV	0.000247** (0.049)	0.000737*** (0.001)	− 0.00000218 (0.945)	–
FININC	0.0000589 (0.920)	− 0.00676*** (0.000)	–	0.0000188 (0.793)
RLAW	− 0.039751*** (0.000)	− 0.0263*** (0.000)	− 0.00162 (0.129)	− 0.00108 (0.333)
LogGEXP	0.018894*** (0.000)	0.0152*** (0.000)	0.00339*** (0.001)	0.00326*** (0.001)
TROPEN	0.000543*** (0.000)	− 0.0000459 (0.624)	0.0000314 (0.101)	0.0000172 (0.421)
PSE	0.000320*** (0.000)	0.0000952 (0.456)	0.0000556*** (0.009)	0.0000399** (0.045)
LogL	− 0.0228*** (0.000)	− 0.0533*** (0.0004)	− 0.00306*** (0.000)	− 0.00309*** (0.000)
LogK	0.0000579 (0.987)	− 0.010016** (0.0141)	− 0.000589 (0.484)	− 0.000511 (0.492)
INF	− 0.000269 (0.185)	− 0.000173 (0.266)	− 0.0000818** (0.039)	− 0.0000876** (0.031)
HHI(− 1)	–	–	0.877*** (0.000)	0.892*** (0.000)
R-squared	0.4644	0.8030	AR(1) = − 3.32 (0.001)	AR(1) = − 3.38 (0.001)
Adj. *R*-squared	0.4533	0.7888	AR(2) = 1.04(0.298)	AR(2) = 1.05(0.295)
F-statistic	41.848*** (0.000)	55.124*** (0.000)	WT = 133,368.84*** (0.000)	WT = 465,030.24*** (0.000)
Durbin–Wat. stat	0.212	0.559	Instr. rank = 51	Instr. rank = 51
Hausman test	–	46.39(0.000)***	HT = 12.05 (0.797)	HT = 11.52 (0.828)

***,**,*Indicates significance at 1%, 5% and 10%. Probability value in parenthesis. HT means Hansen Test of over-identified restrictions. WT represents Wald Chi-square test of model significance

this is a necessary condition for GMM estimates. The Wald Chi-square statistic of model significance revealed that the explanatory variables in models 3 and 4 significantly [Pr. (WT) = 0.000 in both models] explained the variation in economic diversification at 1 percent level of significance.

Further in models 3 and 4, considering the effects of the ICT variables on the economic diversification measure, Herfindahl–Hirschman Index (HHI), fixed broadband per 100

(FIXEDBB) consistently exhibited positive impact on Herfindahl–Hirschman Index (HHI), but the impacts are not statistically significant at 1, 5 or 10% levels of significance. Note however that the positive effect of fixed broadband on Herfindahl–Hirschman Index (HHI) is consistent with respect to models 1 and 2 also. Similarly, the number of secure internet servers per 1 million people (SINTERNET) positively impacted Herfindahl–Hirschman Index and thus contributed to reduced economic diversification in SSA as revealed in models 3 and 4, but the impacts are not statistically significant. The fixed telephone subscriptions per 100 (FIXEDTSP) has positive and statistically significant (p-values = 0.003 and 0.045) effects on Herfindahl–Hirschman Index as shown in models 3 and 4 and hence is significant in less diversifying the domestic economy (a similar significant positive effect of fixed telephone subscriptions on Herfindahl–Hirschman Index is observed in model 1 also). A unit increase in fixed telephone subscriptions per 100 will raise Herfindahl–Hirschman Index with respect to models 3 and 4, slightly (coefficient ranges between 0.000311 and 0.000388) and hence results in a less diversified economy and vice versa. In similar manner, ICT goods imports percentage of total goods imports (ICTGIMPOT) has positive and statistically significant (p-values = 0.024 and 0.009) effect on Herfindahl–Hirschman Index (HHI) as found in models 3 and 4. A unit increase in ICT goods imports percentage of total goods imports will slightly (coefficient ranges between 0.000488 and 0.00495) raise Herfindahl–Hirschman Index and hence consequently result in a less diversified economy in sample countries. Internet users per 100 (INTUSE) has negative and statistically insignificant effect on Herfindahl–Hirschman Index in model 3 indicating lack of importance in its positive contribution to economic diversification. However, in model 4, internet users per 100 (INTUSE) is statistically significant (p-value = 0.060) in positively contributing to economic diversification in SSA as it results in a decline in the Herfindahl–Hirschman Index (HHI). In the case of mobile subscriptions per 100 (MOBUSE), the impact on economic diversification is inconsistent across models 3 and 4 (negative in model 3, but positive in model 4) and statistically insignificant.

Thus taking the aforementioned findings on the effect of ICT variables on economic diversification together, evidence suggests that of all ICT variables examined, only Fixed telephone subscriptions per 100 people and ICT good imports are statistically significant for economic diversification although reducing economic diversification. The evidence is consistent across the GMM estimations, and suggests an adverse effect of ICT on economic diversification in SSA with respect to the aforementioned statistically significant variables. However, internet use while found as the only ICT variable to contribute to economic diversification in SSA across the GMM estimations was insignificant suggesting the need for adjustments as regards utilizing internet to promote economic diversification. The findings of this present study contrasts with the popular argument by studies that ICT plays a positive role in economic progress in general (such as Ukwuoma 2019; Edo et al. 2019; Alshubiri et al. 2019; Andrianaivo and Kpodar 2012) in line with the leap-frogging hypothesis of Steinmueller (2001), as well as in economic diversification in particular as argued by Al-Roubaier et al. (2020), Iyoboyi and Na-Allah (2014) and US Department of Commerce (2000). However, with reference to the findings of Asongu and Nwachukwu (2019) who find an adverse effect of ICT on financial activity in a sample of African countries and given arguments in the finance-growth literature of positive

correlation between growth and financial development, it may be argued in the present context that ICT variables—fixed telephone subscriptions per 100 people and ICT good imports adversely affect economic diversification in SSA countries as a result of their adverse effect on financial activity amongst a host of economic variables.

ICT may adversely affect economic diversification in SSA on account of poor connectivity of ICT in general in SSA countries. Poor internet connectivity which may further be reflected by the insignificant effect of internet use in this study may be a result of poor ICT infrastructure either on account of insufficient ICT investment for which the government is primarily responsible for the provision or the poor quality of ICT infrastructure provided. In addition, poor access to electricity which hinders the use ICT infrastructure as highlighted by Owolabi et al. (2021) may be argued as a factor giving rise to the adverse effect of ICT on economic diversification of sub-Saharan Africa countries. Further the inability of individuals to appropriately use ICT infrastructure on account of poor literacy as highlighted by Chatterjee (2020) also explains the finding as regards ICT. Lastly, most firms operating across sectors of SSA countries do not have an online presence and this may also explain the finding from this study of adverse effect of ICT on economic diversification.

Further, the findings on the finance variables based on model 3 revealed that financial development (FINDEV) has negative and statistically insignificant (p-value = 0.945) effect on Herfindahl–Hirschman Index and thus is insignificant in contributing to economic diversification in SSA. In model 4, financial inclusion (FININC) on the other hand, has positive and statistically insignificant (p-value = 0.793) effect on economic diversification. Thus the results of models 3 and 4, show that the financial variables: financial development and financial inclusion, are insignificant in promoting economic diversification in SSA. The findings contrast with that of Adeola and Evans (2017) who find financial inclusion positive and significant in its impact on economic diversification in Nigeria, and may reflect the rather low level of financial development as well as financial inclusion in SSA countries in generally. Greater financial development may engender greater financial inclusion. Note however that Adeola and Evans (2017) performed their study focusing on one country in particular, Nigeria, and their findings may contrast with those of this present study which is a panel data study of SSA countries. However, Nieminen (2020) based on an assessment of firm-level exports data for over 60 countries find access to domestic financial services to boost export diversification. Financial development and financial inclusion are r desirable in SSA and despite series of financial sector reforms undertaken over the past three decades in a substantial number of sub-Saharan Africa (SSA) countries as Nigeria and South Africa, they are failing to play their role despite their significant potential to drive economic diversification initiatives in the countries. This may be on account of the poor state of enabling infrastructure as electricity, the rather large segments of the population especially in rural areas who are excluded from financial service provision, as well as low level of education of the public regarding the potentials of ICT for performing financial transactions and the financial products and services provided by financial institutions as highlighted by Chatterjee (2020).

In other results, rule of law' (RLAW) has negative and statistically insignificant (p-value = 0.129 and 0.333) effect on Herfindahl–Hirschman Index and hence is

insignificant for boosting economic diversification in SSA as shown in models 3 and 4. In same manner, capital (LogK) has negative and statistically insignificant (p-value = 0.484 and 0.492) effect on Herfindahl–Hirschman Index as shown in models 3 and 4. On the other hand, trade openness (TROPEN) has positive but statistically insignificant (p-value = 0.101 and 0.421) effect on Herfindahl–Hirschman Index as shown in models 3 and 4, As regards government expenditure (LogGEXP), it has positive and statistically significant (p-values = 0.001) effect on Herfindahl–Hirschman Index in models 3 and 4 estimated. A 1% increase in government expenditure will slightly (coefficient with respect to both models ranges between approximately 0.00326 and 0.00339) raise Herfindahl–Hirschman Index and hence reduce economic diversification in SSA. While primary school enrolment (PSE) has positive and statistically significant (p-value = 0.009 and 0.045) effect on Herfindahl–Hirschman Index as shown in models 3 and 4. A unit increase in primary school enrolment will slightly (coefficient ranges between 0.0000399 and 0.0000556) raise Herfindahl–Hirschman Index and hence reduce economic diversification.

Further, labour force (LogL) and inflation rate (INF) have negative and statistically significant effects on Herfindahl–Hirschman Index as revealed by the p-values 0.000 for labour, and 0.039 and 0.031 for inflation in models 3 and 4 reflecting that the variables significantly boost economic diversification in SSA since they result in a decline in the Herfindahl–Hirschman Index (HHI). These findings may imply that high inflation supports economic diversification in SSA possibly via the incentive to producers to produce output on account that they will realize massive revenues for their output from high prices. Labour force on the other hand is also encouraging for economic diversification too especially for countries as Nigeria that have a large labour force on account of their large population. Finally, the lagged values of Herfindahl–Hirschman Index [HHI(−1)] as observed from Models 3 and 4 have positive and high level of statistical significance at 1% level of significance (p-value = 0.000 in both models). A high value of the HHI and hence lower economic diversification in the previous year will also lead to lower level of economic diversification in the current year, but at a rate less than the previous year.

5 Recommendations and conclusion

The findings of this present study imply that ICT and financial development may play an important role in the promotion of economic diversification for SSA countries. However, this will require greater development in relation to ICT in a broad range of infrastructure as internet, broadband, ICT imports, fixed telephone amongst other infrastructure, as well as the financial sector. Further if economic diversification is to become a reality in SSA countries, it will require fast-paced and well-targeted financial sector reforms, while costs of firms operating in various sectors across SSA countries for establishing an online presence need to be reduced. On that basis, a number of recommendations are made. First, individuals in SSA countries should have improved access to ICT infrastructure such as internet, mobile phone, broadband through reduction in cost. Second, firms operating in sectors across SSA countries, many of which are small and medium enterprises, should be supported in the cost of providing an online presence in order that the firms goods and services are easily accessible to individuals with access to ICT infrastructure such as mobile phones and internet. Third, Governments of SSA countries

should ensure adequate provision of quality ICT infrastructure so as to enhance internet connectivity which will encourage the use of ICT for patronizing firms across the various sectors of SSA countries. Fourth, governments of SSA countries should promote greater access to electricity for all so that ICT infrastructure can be used to patronize firms in sectors of SSA countries while the firms are incentivized to be present on online mediums for customers to patronize them. Fifth, greater literacy rates of the population should be promoted in SSA countries so that individuals are aware of how they may utilize ICT infrastructure to patronize firms in sectors of SSA countries, Finally, ongoing financial sector reforms, especially those that will speedily result in greater financial development and inclusion should be intensified in order for the financial sector to make its valued contribution to economic diversification initiatives in SSA countries.

In conclusion, economic diversification has long been argued for SSA countries amongst which are countries as Nigeria which has for long depended on one line of exports as its foreign exchange earner despite the abundance of opportunities for maximally exploiting her other natural resources which are in abundance to the benefit of their citizens. Economic diversification is argued as central to countries especially those abundant in resources, for achieving their sizeable economic potentials. This present study has investigated the effects of ICT and financial development on economic diversification in a panel of SSA countries over the period of 2000 to 2019. The findings revealed that the effect of ICT on economic diversification is sensitive to the measure of ICT employed while some evidence was found regarding ICT adversely affecting economic diversification in SSA which was explained as resulting from challenges associated with poor ICT connectivity arising from poor ICT infrastructure provision as well as poor access to enabling infrastructure as electricity in the countries. On the other hand, both financial development and financial inclusion were found to be insignificant for economic diversification in SSA despite the potential role that both may play in ongoing economic diversification efforts in SSA countries highlighting the need for intensified efforts at promoting greater financial development and inclusion. Our results are robust to alternative model estimations.

Appendix: List of GMM instruments and their description

S/N	List of instruments	Description of instruments
1.	$\Delta SINTERNET$	This is the first difference of the SINTERNET (Secure Internet) Variable
2.	$\Delta FIXEDBB$	This is the first difference of the FIXEDBB (Fixed Broadband) Variable
3.	$\Delta FIXEDTSP$	This is the first difference of the FIXEDTSP (Fixed Telephone Subscriptions) Variable
4.	$\Delta ICTGIMPOT$	This is the first difference of the ICTGIMPOT (ICT Imports) Variable
5.	$\Delta RLAW$	This is the first difference of the RLAW (Rule of Law) Variable

Abbreviations

FEM Fixed effects model
GMM Generalized method of moments
HHI Herfindahl–Hirschman Index
ICT Information and Communications Technology

OLS	Ordinary least squares
SSA	Sub-Saharan Africa
WDI	World Development Indicators
WGI	World Governance Indicators

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Author contributions
OAO: conceptualizing the idea and writing, AOA: data analysis and writing, BA: conceptualizing the idea and writing, AOO handled the literature section, TO was responsible for proofreading and manuscript editing. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and analysed during the current study are available from World Bank [https://databank.worldbank.org/source/world-development-indicators] and [https://databank.worldbank.org/source/worldwide-governance-indicators].

Declarations

Competing interests
The authors declare that they have no competing interests.

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