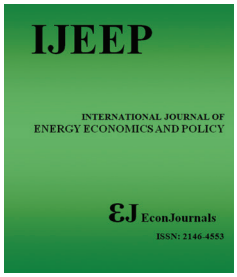

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Access to Electricity, Information and Communications Technology (ICT), and Financial Development: Evidence from West Africa

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ABSTRACT

Poor Access to electricity may hinder West African countries from raising levels of financial development with the aid of Information communication Technology (ICT). Using 16 West African countries, and data over the period of 2000 to 2017, this present study analyses the effect of greater access to electricity on financial development through ICT. ICT was measured using mobile use and internet use, while financial development was measured using private bank credit to GDP ratio and Broad Money Supply to GDP ratio. Panel data fixed effect instrumental variables estimation was used for analysis and the study found that access to electricity significantly boosts mobile use and internet use, while resulting from access to electricity mobile use significantly boosted both measures of financial development but internet use significantly reduced the measures. Further categorizing sample countries into Anglophone and Francophone West Africa countries, access to electricity through ICT boosted both measures of financial development for Francophone countries, while only boosting broad money supply to GDP ratio for Anglophone countries. Thus greater access to electricity through for example provision of electricity infrastructure and regulation of electricity charges to households and firms is important to boost levels of financial development in West Africa.

Keywords: Access to Electricity, Information communication Technology, Financial Development, Mobile Subscription, Internet Use, West Africa
JEL Classifications: O16, O33, E51

1. INTRODUCTION

Access to electricity is central to the processes driving the development of a country (Matthew et al., 2019; Ogundipe et al., 2016). Electricity powers activities, and contributes to the promotion of a conducive environment for economic progress. While powering the development of an economy as a whole, electricity may contribute to the economy through the economy's productive sectors, and consequently, the value of electricity in terms of what it enables to take place may be realised.

Electricity is required for production by industries in countries such as Nigeria where adequate access to electricity will ensure that machines and technologies used for production of physical goods are powered. The financial sector is a further sector of an economy which must of a necessity be productive for the economy to make progress and for which electricity is essential. Consequently the achievement of the process of financial development depends on the availability of electricity amongst a variety of other factors.

Financial development may be defined as the advancement of an economy in terms of measurable indicators capturing the extent to which individuals access financial services. Through financial deepening and financial widening, the progress of a country in achieving financial development is popularly assessed. Financial deepening enables an assessment of the extent to which access

to financial goods and services by individuals has improved consequent upon provision of higher financial goods and services and is measured by Private Sector Domestic Credit to Gross Domestic Product (GDP) Ratio. On the other hand, financial widening measures the extent to which a wide range of financial goods and services with different maturities, risks and returns are distributed amongst private sector participants by financial intermediaries and is measured by Broad Money Supply (referred to as M2 Money Supply) to Gross Domestic Product (GDP) Ratio.

High levels of financial development have been elusive for most Sub-Saharan Africa countries for the past four decades as highlighted by Mlachila et al. (2016). While low levels of financial development are said to characterize developing countries, the economic progress of the countries importantly hinge on financial development as highlighted by Levine (1997). Poverty, unemployment and socio-economic progress in general of developing countries provide a role for financial development which itself may be aided by information and communications technology (ICT) which is in turn powered by electricity. Hence from this viewpoint a link may be established between access to electricity and financial development.

Information and communications technology (ICT) has been argued to be playing a large role in many world economies, with many developing countries featuring ICT adoption rates amongst the highest in the world. For instance, Sadorsky (2012) highlights that in developed countries, between the years 2000 and 2010, mobile cellular subscriptions per 100 inhabitants increased by 107%, while developing countries recorded an increase of 255% surpassing that of the world as a whole of 187% increase. A provision of ICT amongst many other roles is the enablement of financial institutions to provide access to financial services for the benefit of individuals, household and businesses. With regards to individuals and households, access to financial services is especially important for rural dwellers in Sub-Saharan Africa countries that have been excluded. An individual or household, is excluded from financial services provision if they are not permitted to use such services and hence resulting in the entity's inability to engage maximally in social and economic activities which consequently gives rise to increase in hardship and poverty (Burkett and Sheehan, 2009).

Lapukeni (2015) argues access to finance including usage and quality of financial services as central for financial inclusion. Greater access to financial services will promote competition amongst financial service providers, resulting in greater financial development as costs of providing financial services reduce and providers enjoy economies of scale. ICT mediums as mobile phones, internet, ATMs and point of sale and so on will enable individuals' access financial services services any time of the day or night to perform their financial transactions and access other automated bank services. The financial service providers consequent upon ICT are further at an advantage as they will be able to automate their services resulting in cheaper costs of providing services to customers.

The West Africa region of Sub-Saharan Africa features countries which have experienced uneven levels of financial development since the 1980s (World Bank 2019). Private sector domestic credit to GDP Ratio of most West African countries are <10% with only a handful of countries comprising Cape Verde, Cote D'Ivoire, Senegal and Togo having achieved a ratio as high as 20% and above. Togo and Cape verde once again feature as countries with the highest levels of financial development as measured by broad money supply to GDP ratio with average values of 35.8% and 64.8% amongst all the countries in West Africa. Hence improving financial development remains a critical challenge for most West African countries, and this is despite significant financial sector reforms undertaken by sub-Saharan Africa countries in general, many of which underwent structural adjustment programme reforms in the 1990s to re-position their economies.

ICT has the potential to promote financial development through greater financial inclusion (Chithralega and Veralakshmi, 2016). The fundamental benefits of greater financial inclusion include poverty reduction, greater productivity of micro, small and medium enterprises, effectiveness of monetary policy, reduction in income inequality, stability of the financial system and so on giving rise to greater economic growth and development (Lapukeni, 2015). Further as at 2014, Sub-Saharan Africa had the third highest unbanked population in the world (World Bank Group, 2013). Remarkable progress has however been made as regards mobile phone development in African countries, especially mobile phone accounts and mobile phone transactions, as World Bank (2016) highlights.

Mobile money as an application of ICT in the financial sector has further increasingly gained popularity in Africa in general and West Africa in particular as it enabled banks reach the unreached in regard to access to financial services thus transforming the financial sector. It was estimated that as at 2019, 469 million mobile money accounts existed in West Africa, making West Africa the region with the highest number of mobile money accounts in the world (Naghavi, 2019). Despite that the 2017 Global Findex report highlights Nigeria as one of seven countries constituting the 1.7 billion unbanked individuals in the world. This may be attributed to poor ICT development in West Africa in general where apart from mobile phone, all other forms of ICT are at poor levels including internet, Broad band, fixed line telephone and ICT infrastructure (World Bank, 2017). This may be a result of poor access to electricity observed in West Africa.

On average between the years 2000 to 2018, most West African countries had less than 40% of their population having access to electricity. Fagas et al (2017) highlight consumption of electricity by ICT devices on account of their expanded use as unsustainable and IEA (2009) highlight that in households and work places, electricity use linked to ICT has risen substantially. Further, electricity use linked to communication networks, personal computers and data centers which together constitute ICT equipment is rising at an annual rate of about 7% per year (Van Heddeghem et al., 2014).

Various studies have examined the impact of ICT measures on economic and financial variables (Adeleye and Eboagu, 2019; Alshubiri et al., 2019; Ejemeyovwi and Osabohien 2018; Ejemeyovwi et al, 2018a; Andrianaivo and Kpodar, 2012). However there is a dearth of such studies in regards to West Africa

as regards financial development in particular. Further there exists a paucity of studies relating to the effect of electricity on ICT in West Africa with low levels of electricity evident across most West African countries.

This present study therefore brings together the strands of literature on the effect of electricity on Information and Communications Technology (ICT) and the subsequent effect of ICT on financial development in the context of West Africa in examining the effect of electricity through ICT in promoting financial development in a panel of sixteen West African countries. To the best of the researcher's knowledge and in the context of West Africa in particular no study exists on a link between electricity, ICT and financial development. Financial development is measured in this study using two measures namely: Private sector domestic credit to GDP ratio and Broad money supply to GDP ratio, while ICT is measured in this study using Mobile subscriptions and internet usage. The study further divides the sample of West African countries into those of Anglophone West Africa, and those of Francophone West Africa as a further novel contribution of this study. The main language spoken by countries resulting from the colonisation of respective countries may be reflected in differences in the adoption and therefore use of ICT mediums by West African countries in this study. This may consequently influence differences in financial development between the two classifications of West African countries and may shed light on findings regarding the central hypothesis of this study pertaining to the entire sample of West African countries under study.

This section having introduced the study, the literature review is discussed in section 2, the data and selected stylised facts are presented in section 3, methodology of the study is discussed in section 4, and results are presented, interpreted and discussed in section 5. Section 6 completes this study wherein recommendations are made and the study is concluded.

2. LITERATURE REVIEW

Information and communications technology may boost financial development while it also depends on electricity to power it. Despite the enablement of the new digital economy in developed countries by electricity, limited literature in developing countries have focused on the link between electricity and ICT consequently informing the study of Armey and Hosman (2015) who find that low income countries experience a significant boost in internet users as a result of the improvements in the distribution of electricity within countries. This is because electricity is made more available to the wider populace. Hence increasing electricity access in developing countries is essential in order that the countries maximise their use of ICT.

Greater access to electricity may be affected by the cost of electricity though, which may be high especially in the context of Sub-Sahara Africa where poverty rates are high amongst a number of developmental challenges. In line with this, Mothobi and Grzybowski (2017) utilising individual level survey data from 11 Sub-Saharan Africa countries in 2011 find that individuals are more likely to own a mobile phone in areas with brighter nighttime light or in households with access to electricity. Access to electricity was measured in the study using the average nighttime light and a household's dummy variable. Hence the paper highlights the value of electricity for ICT usage in Sub-Sahara Africa. However where access to electricity is low especially in emerging economies, solar energy may be an alternative source for achieving Information and communication technology progress. This is especially essential in light of the increase in population and expanding industrialisation taking place in such developing countries and the expected increase in demand for electricity in residential, commercial and industrial sectors as highlighted by Uhomoibhi and Paul (2012).

There has however not been explicit attention given to the channel through which electricity consumption may play a role in promoting ICT in the aforementioned literature arguing electricity to influence ICT, of which Armey and Hosman (2015) is one of few as they suggest improved infrastructure is important in promoting greater internet use in low income countries. Poor infrastructure is one of the developmental challenges of developing countries especially low income countries, and this is consistent with the argument of Penard et al., (2012) that the economy plays a role in determining mobile adoption in Africa and the finding of significant role of GDP per capita amongst other factors playing a role in determining mobile penetration in Africa. Further, Aker and Mbiti (2010), highlight network coverage as the first modern technology of any kind in many regions across developing countries, while Odusanya and Adetutu (2020) highlight the potential for omitted variable bias in studies that fail to control for the effect of network infrastructure in the study of broadband adoption across developing countries.

Studies focused on determinants of ICT have often excluded electricity as a factor that could play a role in determining ICT with the exception of studies as Forenbacher et al (2019) who find electricity grid and generator a positive and significant determinant of mobile phone ownership in Nigeria. For instance, Ghebregiorgis and Mehreteab (2019) find in Eritrea that gender and income are important determinants of mobile phone usage, excluding electricity from their analysis. Also Asongu (2013) using cross-sectional data for 2011 for 49 sub-Saharan Africa countries, and Asongu et al (2018) in an extension of the earlier study by Asongu (2013) and utilising panel data on a sample of 49 Sub-Sahara African countries from 2000 – 2012, find various factors that may be categorised into six policy categories (namely, macroeconomics, business, market-related, knowledge economy, external flows and Human development), to affect mobile phone penetration, again excluding the role of electricity. Odusanya and Adetutu (2020) also in Nigeria failed to control for the role of electricity in ICT adoption. These studies thus give rise to the potential for bias in estimation results on account of omission of electricity in determination of mobile phone penetration or ownership. Besides electricity will be used to charge mobile phones and other ICT gadgets and is an important variable that should feature in models determining ICT variables.

Electricity consumption however may be driven by a boost in ICT use in contrast to the limited literature arguing demand for electricity on account of ICT. Such findings appear more popular

in the literature For instance, Afzal and Gow (2016) investigating the case of the next 11 (N-11) emerging economies find information and communications technology as measured using internet connections, mobile phones and the import percentage of ICT goods of total imports to positively and significantly influence electricity consumption. Similarly, Sadorsky (2012) finds ICT in the form of internet connections, mobile phones to boost electricity consumption for a sample of emerging economies based on computed short run and long run elasticities of ICT. Further for a global panel of 67 countries, Saidi et al (2015 find for a panel of high, middle and low income panel of countries, a consistent positive and significant effect of ICT measured using internet connection and mobile phone on electricity consumption.

The sector-specific effect of ICT investment on electricity consumption is highlighted by Cho et al. (2007) based on evidence from South Korea. This study takes into account that the demand for electricity may be uneven and vary from one sector to another. To that effect, the study argues that, whereas ICT investment in certain manufacturing sectors enables energy efficiency as consumption of electricity declines, electricity consumption rises with ICT investment in the service sector and most manufacturing sectors. Meanwhile, Laitner (2003) opines concerning US energy that technical changes are probable to continue amid growing substitution of knowledge for material resources which will give rise to marginal decline in energy.

It is further the case that ICT constitute one of a number of household appliances, demanding electricity as argued by Pothitou, Hanna, and Chalvatzis (2017) and hence the need for policies which give consideration to the adaptation of drivers of ICT for the conservation of electricity in households especially in developing countries where costs of access to electricity are high, as opposed to raising energy efficiency of ICT devices which are not likely to be successful. Further, the use of ICT, specifically mobile phone and internet, is found to cause electricity consumption in OECD countries by Salahuddin and Alam (2015), highlighting that OECD countries have yet to achieve energy efficiency gains from ICT expansion. On the other hand, higher levels of energy and electricity production and consumption in nations are associated with landline telephones as highlighted by Longo and York (2015), and which may suggest that electricity consumption is dependent on ICT device.

The environmental implications of ICT usage is brought to the fore by a number of studies. For instance, Moyer and Hughes (2012) argue a 50-year time horizon for the decline in carbon emissions as a result of the use of ICT devices based on International Futures (IFs) integrated assessment system. However, in promoting an environment free of carbon emissions despite ICT expansion, global carbon pricing may be necessary. Höjer and Wangel (2015) in line with the arguments of Moyer and Hughes (2012) discuss the role of ICT in future cities, where it is interlinked with issues of transportation, mobility, and energy use in many ways while ICT as an aid for the integration of renewable energy sources into the power grid is discussed by Sonnenschein et al (2014). In addition, design issues related to how households can better manage energy in a smart grid context is brought to the fore by Katzeff and Wangel (2014). Huber and Hilty (2014) further highlight how individuals may be swayed to alter behaviours in aid of the promotion of sustainable consumption of electricity. Maranghino et al (2014) on the other hand illustrate how organisation internal cap-and-trade schemes for CO2 emissions permits and other scarce resources may be given support by an information system.

Amongst the variables that ICT may affect in an economy in affecting the progress of a country is Financial development. Hence inability of developing countries to promote development of ICT may hinder the potential of their financial sectors to contribute significantly to the economy. However limited studies exist providing evidence of the extent of ICT development on financial development. This is more so as sub-Saharan Africa countries while having made significant progress in mobile phone development according to World Bank (2019a) score low on other measures of ICT as internet usage and fixed telephones. Alshubiri et al. (2019) find financial development as measured by Domestic Credit to private sector as a percentage of Gross Domestic Product (GDP) and Broad Money Supply as a percentage of Gross Domestic Product to be positively and significantly influenced by fixed broadband and internet use. In addition examining Nigeria and Kenya, Edo et al. (2019) find internet adoption positive and significant for financial development. On the other hand, financial inclusion more frequently related to ICT in the literature than financial development has been argued as a channel through which greater access to financial services may be achieved especially in developing countries by studies as Chatterjee (2020), Chithralega and Veralakshmi, (2016), and Lapukeni (2015).

Financial inclusion may however be related to financial development as greater financial inclusion promotes greater market competition among market participants resulting in greater access to credit as interest rates fall and the financial service providers also enjoy lower costs per person of providing financial services. Lapukeni (2015) finds that Mobile telephone subscriptions have been growing at a faster rate than financial inclusion in Africa, which presents an opportunity for ICT development to boost financial inclusion through mobile financial services. However provision of social activities as education and health by government as well as household budgets for essentials as food will have to make way for greater investment in ICT by government and households. Chatterjee (2020) however based on evidence from developing countries suggests that financial inclusion in developing countries may not experience the required boost through ICT.

On the basis of the aforementioned association between financial development and ICT and the connection between electricity and ICT, a link may be argued between electricity and financial development for which most studies find financial development to affect electricity consumption (Saidi et al., 2015; Sekantsi and Timuno, 2017). Financial development can impact energy consumption in the economy by reducing financial risk and credit costs, promoting transparency between borrowers and creditors, providing access to more financial capital, investment flows and advanced technologies (Sadorsky, 2012; Komal and Abbas, 2015; Ouyang and Li, 2018). Thus studies as Komal and Abbas (2015), Saidi et al. (2015), Odusanya and Adetutu (2016) and Sekantsi and

Timuno (2017) argue financial development to boost electricity consumption. The results may hold over both the long run and short run time horizons as found by Al-mulali and Lee (2013) in the case of Gulf cooperation council countries. Electricity consumption may however be adversely affected by financial development in some developing countries especially in Africa that are unable to meet the demand for electricity on account of serious electricity deficiency as highlighted by Sekantsi and Motlokoa (2015) and Shahbaz and Lean (2012). This is further evidenced by the popular use of mobile-money services in less electricity deprived areas or households in emerging countries as highlighted by Mothobi and Grzybowski (2017). Hence to that effect causality findings between electricity consumption and financial development may be valid with popular findings of causality running from electricity consumption to financial development found by a number of studies (Ozturk and Acaravci 2013; Solarin et al., 2019).

Through financial development therefore an argument could be made for economic growth and development to result. Evidence in support is provided by Asongu and Odhimabo (2017) who argue mobile banking to promote inclusive development in developing countries through improved quality growth, reduced income inequality and reduced poverty, however the findings contrast with those of Ejemeyovwi and Osabuohien (2018) who find insignificant effect of mobile phone development on inclusive growth in West Africa. Economic growth on the other hand, depends on electricity (Churchill and Ivanovski, 2020; Nathaniel and Bekun, 2020; Ali et al., 2020; Zhang et al., 2017; Sarwar et al., 2017; Shahbaz et al., 2017; and based on the popular leap frogging hypothesis where in ICT enables a faster development for less developed countries as the countries are able to by-pass some difficult stages in the development process, a number of studies have found ICT development to boost economic growth (Myovella et al., 2020; Adeleye and Eboagu, 2019; Pradhan et al., 2018; Niebel, 2018). Therefore consistent with the leap-frogging hypothesis could be the link of electricity to financial development through electricity powering ICT devices.

3. DATA

West African countries constituting the sample of countries for this study comprised all countries classified by the United Nations as West African countries with the exception of the British overseas territory of St. Helena, Ascension and Tristan da Cunha, for which data is unavailable. This gave rise to sixteen countries examined in this study. Further the scope of this study of 2000 to 2017 is informed by the year 2000 being the period when most Sub-Saharan Africa countries (including West African countries) had attained significant levels of ICT development.

An overview of access to electricity, and selected ICT and financial development indicators across West African countries are presented in Table 1. The figures are the means of all indicators in respective countries.

Table 1 highlights significant heterogeneity in electricity, ICT and financial development indicators across sample West African countries. Further amongst sample countries, Cape Verde is observed from Table 1 to have the highest mean values for all indicators except mobile use. This highlights the high level of ICT development, financial development and access to electricity in the country amongst West African countries. Even in regards to Mobile use where it is not the highest Cape Verde ranks the third highest in West Africa, suggesting a high level of development as regards mobile use.

The country with the lowest access to electricity is Niger (12.20%), while the least ICT developed country as regards mobile phone use is Togo (1.18%) and as regards internet usage is Niger (1.40%). Sierra Leone ranks the lowest as regards financial development measured by private sector domestic credit to GDP Ratio (4.96%), while Liberia ranks lowest for financial development measured by broad money supply to GDP Ratio (15.42%).

In general except for Cape Verde, means of financial development indicators are very low for virtually all countries, while internet usage is also extremely low for most West African countries. This suggest the need for a rise in both ICT and financial development which may both be dependent on the increased access to electricity which is generally low on average in Sub-Saharan Africa (SSA) countries in general.

With reference to the trends of access to electricity, ICT indicators and financial development indicators as presented in Figures 1-4 the proportion of the population with access to electricity on average is observed to have been on the rise from 2008 onwards, but prior to that it had been on the decline as observed from Figure 1.

Figures 2 and 3 provides the trend of mobile use (i.e, mobile subscriptions) and internet usage. Both trends have been rising from 2000 when both were at their lowest points till 2017 when both trends attained their respective peaks. However the trend of mobile subscriptions is higher than that of internet usage.

Figures 4 and 5 show the trends of the means of the two financial development indicators in this study, Private sector domestic credit to GDP ratio and Broad money supply to GDP ratio. Both trends show a decline in their respective idnicators from 2000 to 2002 and thereafter the trends are observed to be on the rise reaching their highest points in 2019 after years of a continuous ascendancy.

4. METHODOLOGY

This study is built on the leap frogging hypothesis which argues ICT to give developing countries an advantage in their quest for development as they by-pass hurdles which developed countries were not fortunate to by-pass on their road to development. Thus aided by electricity ICT can play its role in leap-frogging the economies of West Africa to economic development by promoting a developed financial sector. In light of the effect of electricity on financial development through ICT, a two-stage (otherwise referred to as instrumental variable) model is specified for this study. In the first stage of the model electricity in addition to other control variables determine ICT in respect of each of mobile phone use and internet usage, while in the second stage predicted ICT in respect both mobile phone use and internet

Table 1: Distribution of Mean of ICT and Financial Development Variables by West Africa Country

Country	Access to electricity (% of Population)	Mean of Mobile Use (Per 100 Individuals)	Mean of Internet usage (% of Population)	Mean of Private Sector Domestic Credit to GDP Ratio (In Percentage)	Mean of Broad Money Supply to GDP ratio (In Percentage)
Benin	30.63	46.19	4.34	12.49	30.97
Burkina Faso	13.39	34.16	4.26	18.58	27.91
Cape Verde	78.37	57.61	22.14	51.31	82.39
Cote D'Ivoire	57.14	59.97	11.75	18.08	29.21
Gambia	41.02	52.98	7.59	8.47	28.92
Ghana	61.77	58.46	10.49	14.15	28.34
Guinea	25.47	38.09	3.42	5.65	19.59
Guinea Bissau	41.64	34.24	2.29	6.18	27.95
Liberia	36.50	35.13	4.22	8.07	15.42
Mali	24.76	51.57	3.26	18.05	24.12
Mauritania	33.47	73.97	5.90	23.71	28.45
Niger	12.20	18.09	1.40	10.32	17.33
Nigeria	50.52	41.14	12.26	11.82	19.19
Senegal	50.84	51.58	11.05	19.91	26.14
Sierra Leone	37.44	35.20	2.84	4.96	19.05
Togo	32.07	1.18	3.27	23.10	34.96

Source: Author's computations using data from World Bank (2019)

Figure 1: Trend of Mean of Access to Electricity of West Africa

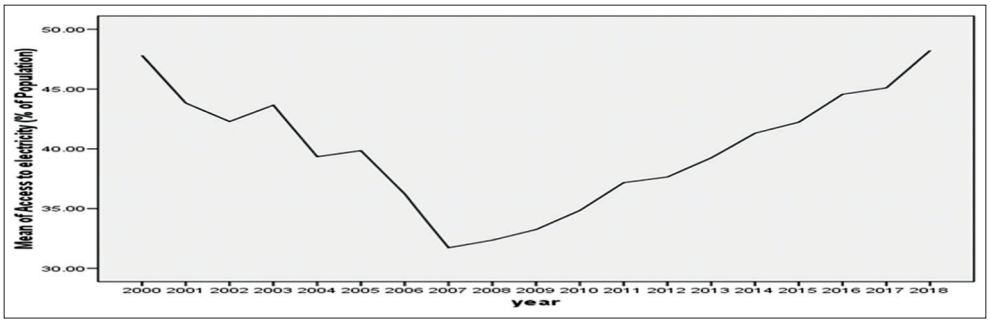


Figure 2: Trend of Mobile use of West Africa

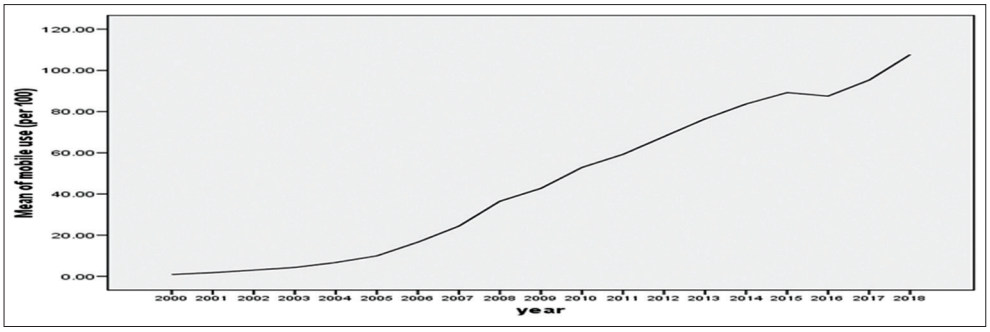


Figure 3: Trend of Mean of Internet Usage of West Africa

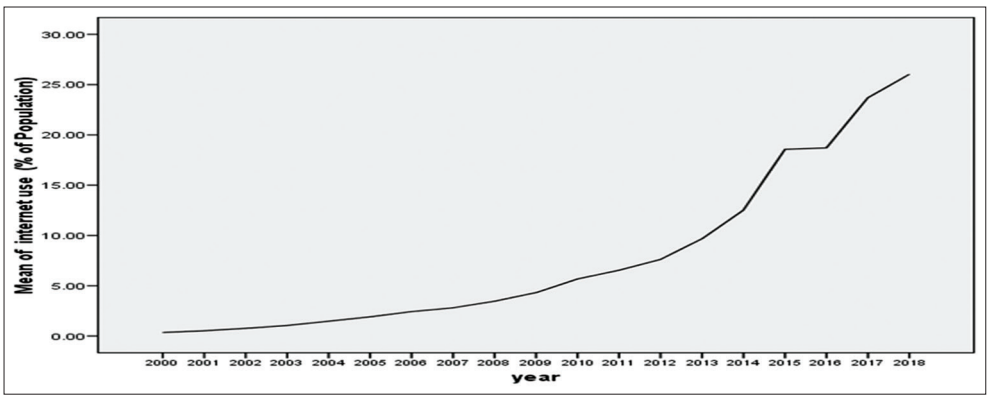


Figure 4: Trend of Mean Private Sector Domestic Credit to GDP Rato of West Africa

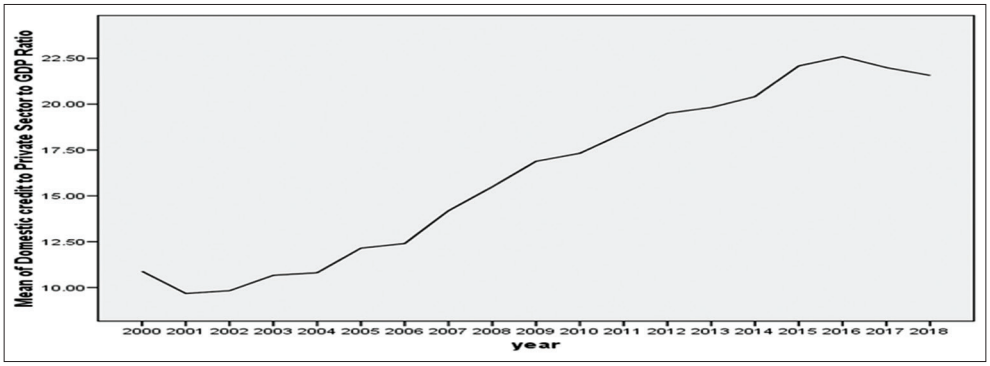
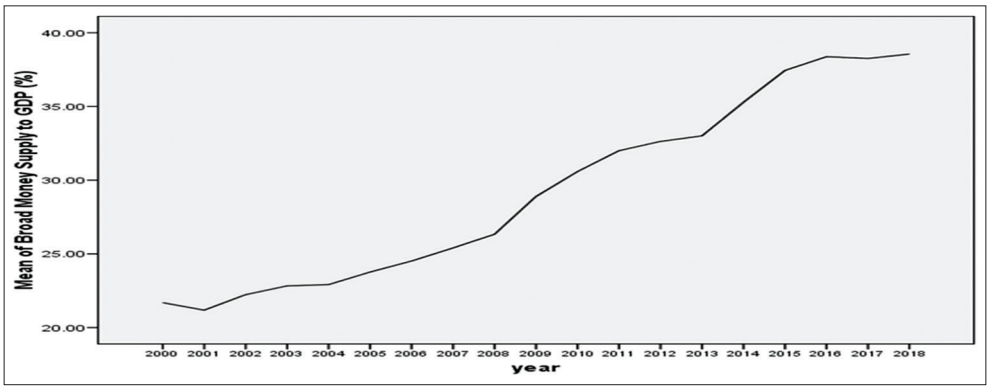


Figure 5: Trend of Mean Broad Money Supply to GDP of West Africa



usage determines financial development. It is the case that the second stage model of this study is an adaptation of the model of Andrianaivo and Kpodar (2012). Equations (1) and (2) are the two stage model specification for this study. The models are specified as fixed effects estimations on account of the appeal of fixed effects panel data estimation able to allow control for time invariant country specific heterogeneity across sample countries in the panel data:

$$ICT_{it} = \alpha_0 + \alpha_1 AELECT_{it} + \alpha_2 GDPPC_{it} + \alpha_3 AELECT * GDPPC_{it} + \nu_i + \varepsilon_{i,t} \quad (1)$$

$$FINDEV_{it} = \alpha_0 + \alpha_1 ICT_{it} + \alpha_2 GDPPC_{it} + \alpha_3 ICT * GDPPC_{it} + \alpha_4 RLAW_{it} + \nu_i + \varepsilon_{i,t} \quad (2)$$

Where ICT= Information and Communications Technology, AELECT = Access to Electricity, GDPPC = GDP per capita, RLAW= Rule of Law, ν_i = country fixed effects, ε = stochastic error term.

All variables in the above model with the exception of Rule of Law are sourced from the World Bank World Development Indicators (World Bank, 2019). Rule of Law on the other hand is sourced from World Bank World Governance Indicators (World Bank, 2019a) and features in the above specified model as an institutional variable on account of its importance in promoting financial development through enabling protection of creditor rights and by so doing will support efforts for the achievement of high levels of financial development.

In this present study ICT is measured by mobile phone use (MOBUSE) (using mobile cellular subscriptions per 100 individuals as proxy) and internet usage (INTUSE) (using proportion of individuals using the internet as proxy), while financial development is measured by Private sector domestic credit to GDP ratio and Broad money supply to GDP ratio. Note that ICT in the second stage model is the predicted value of ICT from the first stage of the regression. Substituting the respective measures of ICT and financial development into the above equations (1) and (2) the following two pairs of models result for this study.

4.1. Determining Private Sector Domestic Credit to GDP ratio

$$MOBUSE_{it} = \delta_0 + \delta_1 AELECT_{it} + \delta_2 GDPPC_{it} + \delta_3 AELECT * GDPPC_{it} + \nu_i + \varepsilon_{i,t} \quad (3)$$

$$INTUSE_{it} = \theta_0 + \theta_1 AELECT_{it} + \theta_2 GDPPC_{it} + \theta_3 AELECT * GDPPC_{it} + \nu_i + \varepsilon_{i,t} \quad (4)$$

$$PSDCRGDP_{it} = \gamma_0 + \gamma_1 MOBUSE_{it} + \gamma_2 INTUSE_{it} + \gamma_3 GDPPC_{it} + \gamma_4 MOBUSE * GDPPC_{it} + \gamma_5 INTUSE * GDPPC_{it} + \gamma_6 RLAW_{it} + \nu_i + \varepsilon_{i,t} \quad (5)$$

Where MOBUSE = Mobile Phone Use, INTUSE = Internet usage, PSDCRGDP = Private sector domestic credit to GDP ratio, AELECT = Access to Electricity, GDPPC = GDP per capita,

RLAW= Rule of Law, v_i = country fixed effects, ε = stochastic error term, i =1-16, t = 2000 - 2017.

Note from equations (3), (4) and (5) that while, δ_0, θ_0, and γ_0, are constants of the respective models, $\delta_1 \ldots \delta_3$ and $\theta_1 \ldots \theta_3$ are the marginal effects of access to electricity and other explanatory variables determining Mobile phone Use and internet usage respectively. The parameters, $\gamma_0 \ldots \gamma_6$, are the marginal effects of predicted mobile phone use and predicted internet usage and other explanatory variables determining private sector domestic credit to GDP ratio. The interaction of Access to Electricity and GDPPC measure the effect of access to electricity on mobile phone use and internet usage as sample countries improve in their level of economic development. Similarly, the interaction between each of mobile phone use and internet usage and GDP per capita (GDPPC), measure the effect of mobile use and internet usage respectively on Private sector domestic credit to GDP ratio as sample countries improve in their economic development.

4.2. Determining Broad Money Supply to GDP ratio

The determination of Broad Money supply to GDP ratio, the second stage estimation of the model is performed using the same predicted values of ICT variables obtained in equations (3) and (4) while only the second stage regression for determining Broad money supply is different to that used in determining private sector domestic credit in equation (5)

$$\begin{aligned} MOBUSE_{it} &= \delta_0 + \delta_1 AELECT_{it} + \delta_2 GDPPC_{it} \\ &+ \delta_3 AELECT * GDPPC_{it} + \nu_i + \varepsilon_{i,t} \end{aligned} \quad (6)$$

$$\begin{aligned} INTUSE_{it} &= \theta_0 + \theta_1 AELECT_{it} + \theta_2 GDPPC_{it} \\ &+ \theta_3 AELECT * GDPPC_{it} + \nu_i + \varepsilon_{i,t} \end{aligned} \quad (7)$$

$$\begin{aligned} BRMSGDP_{it} &= \varphi_0 + \varphi_1 MOBUSE_{it} + \varphi_2 INTUSE_{it} \\ &+ \varphi_3 GDPPC_{it} + \varphi_4 MOBUSE * GDPPC_{it} \\ &+ \varphi_5 INTUSE * GDPPC_{it} + \varphi_6 RLAW_{it} + \nu_i + \varepsilon_{i,t} \end{aligned} \quad (8)$$

Where MOBUSE= Mobile Phone Use, INTUSE= Internet usage, BRMSGDP = Broad Money Supply to GDP ratio, AELECT = Access to Electricity, GDPPC = GDP per capita, RLAW= Rule of Law, v_i = country fixed effects, ε = stochastic error term, i =1-16, t = 2000 - 2017.

Note from equations (6), (7) and (8) that while, δ_0, θ_0, and φ_0 are constants of the respective models, $\delta_1 \ldots \delta_3$ and $\theta_1 \ldots \theta_3$ are the marginal effects of access to electricity and other explanatory variables determining Mobile phone use and internet usage respectively as in equations (3) and (4). The parameters, $\varphi_0 \ldots \varphi_6$, are the marginal effects of predicted mobile phone use and predicted internet usage and other explanatory variables determining Broad money supply to GDP ratio. The interaction of Access to Electricity and GDPPC measure the effect of access to electricity on mobile phone use and internet usage as sample countries improve in their economic development. Similarly, the interaction between mobile phone use and GDPPC and internet usage and GDPPC measure the effect of both mobile phone use and internet usage on Broad money supply to GDP ratio as sample countries improve in their economic development.

5. RESULTS

Table 2 provides the descriptive statistics for data used in this study. All missing data have been excluded from the sample resulting in a total of 273 observations. Some countries are more represented in the sample of countries than others on account of missing data and this gives rise to an unbalanced panel data of countries used for this study.

From the above table, all the means of the variables are quite low with the exception of GDP per capita. Rule of Law of sample countries is also quite poor in quality on average given the mean figure of −0.66. Note that rule of law is an index and as sourced from ICRG ranges between −2.5 and 2.5. The closer a country's Rule of Law index is to 2.5, the better is the quality of the respective country's rule of law.

The standard deviations of all variables are sizeable, reflecting considerable variation in all variables across sample countries employed for this study.

Following panel data fixed effects regression in performing analysis and undertaking the first-stage and second stages of the fixed effects instrumental variable two-stage regression in line with the model specification of the study, the results are presented and discussed based on the results from each stage.

5.1. Panel Data Fixed Effects Instrumental Variables First Stage Regression for Determination of ICT in West Africa

Each of Internet usage and Mobile phone use are determined in the first stage regression for the complete sample of West African countries using electricity and some control variables as presented in Table 3.

Table 3 shows that all variables are statistically significant in determining ICT with respect to both mobile phone use and internet usage. This highlights the importance of all the variables in determining ICT in general and each of mobile phone use and internet usage respectively in particular. Access to electricity (AELECT) is positive in respect of both Mobile phone use with a significant coefficient of 3.43 and Internet usage with a coefficient of 0.47. Thus access to electricity positively and significantly boosts both mobile phone use and internet usage and therefore ICT in sample West African countries. This is in line with findings by Forenbacher et al. (2019) who find electricity grid and generator a positive and significant determinant of mobile phone ownership in Nigeria. Further as West African countries fall within the low income bracket, the findings of this study as regard internet usage are supported by findings by Armey and Hosman (2015) that Low income countries experience a significant boost in internet users as a result of the improvements in the distribution of electricity within countries. In the context of SSA where countries are lacking in quality infrastructure which includes that of electricity, it may be argued that access to electricity is of essential importance relative to whether electricity is consumed or not. However access to electricity from the findings of this study has a larger effect on mobile use than internet usage given the relatively larger size of

Table 2: Descriptive Statistics of Dependent and Independent Variables

Descriptive Statistics	Access to Electricity (% of Population)	Mobile Use (per 100)	Internet usage (% of Population)	Rule of Law	GDP Per Capita In USD	Private Sector Domestic Credit to GDP ratio (%)	Broad Money Supply to GDP ratio (%)
Mean	35.80	45.46	7.46	-0.63	953.36	16.71	29.62
Std. Dev.	20.81	39.40	10.78	0.52	753.41	12.11	16.64
Minimum	1.24	0.018	0.036	-1.59	158.71	2.34	8.16
Maximum	91.42	138.81	57.16	0.653	3740.39	65.74	104.63
Observations	256	256	256	256	256	256	256

Source: Author's computations using data from World Bank (2019; 2019a)

Table 3: Panel data fixed effects regression results determining ICT

Equation	(1)	(2)
Dependent variables	MOBUSE	INTUSE
CONSTANT	−104.25***	−10.91***
	(7.20)	(2.37)
AELECT	3.43***	0.47***
	(0.21)	(0.07)
GDPPC	0.042***	−0.013**
	(0.0092)	(0.003)
AELECT*GDPPC	−0.00028***	0.00030***
	(0.00013)	(0.000042)
R-Squared	0.7617	0.6154
F-Stat	252.46***	126.41***
No. of Observations	256	256
No. of countries	16	16

***, **, * indicate significance at 1%, 5% and 10% levels of significance. Source: Author's Computation (2020)

the coefficient of access to electricity with respect to mobile use (3.43) relative to the same coefficient for internet usage (0.47).

Further, GDP per capita (GDPPC) is positive for mobile phone use (MOBUSE) but has a negative effect on internet usage (INTUSE), while the interaction of access to electricity with GDP per capita (AELECT*GDPPC) reflects the effect of access to electricity on mobile use and internet usage respectively as the level of economic development of respective sample West African countries improve. In particular mobile phone use significantly declines while internet usage is significantly boosted on account of greater access to electricity as sample countries experience improved economic development. This may indicate the greater affordability of internet as incomes of individuals in sample countries improve. Possibly on account of the high cost of maintenance of mobile phones or mobile phone connectivity issues, individuals may spend huge amounts to keep their mobile phones optimally functional and so demand less of mobile phones for financial transactions as their incomes increase. The effects of the interaction of access to electricity and GDP Per capita on mobile use and internet usage respectively are nonetheless very small, −0.00028 and 0.00030 respectively, with the positive effect on internet usage outweighing marginally the negative effect on mobile use.

5.2. Panel Data Fixed Effects Instrumental Variables Second Stage Regression for Determination of Financial Development in West Africa

Table 4 presents the results of the second stage of the fixed effects instrument variables estimation procedure for determining both financial development variables, namely Private sector domestic credit to GDP ratio and Broad Money Supply to GDP ratio in respect of the complete sample of West African countries in this study. Both regression estimates for determining financial development are similar in terms of the significance of the independent variables.

The results with respect to predicted mobile phone use reveals that mobile use has a positive and significant effect on both financial development variables, Private sector domestic credit to GDP ratio (PSDCRGDP) and Broad Money Supply to GDP ratio (BRMSGDP). The coefficient of mobile phone use (MOBUSE) with respect to its effect on Private sector domestic credit to GDP ratio is 0.42. On the other hand with respect to Broad Money Supply to GDP ratio mobile phone use has a coefficient of 0.49 which is 0.02 units higher than the size of the effect of mobile phone use on private sector domestic credit to GDP ratio. The finding of mobile use to boost both measures of financial development taken together with the earlier finding from first stage regressions that access to electricity significantly boosts ICT, implies greater access to electricity through greater mobile use boosts financial development in West Africa. The findings are further given support by Mothobi and Grzybowski (2017) who provide evidence that in emerging countries, mobile money services are more popular in areas or households where electricity deprivation is lower findings.

The boost in financial development consequent upon mobile phone use is in line with arguments by Lapukeni (2015) that ICT development as a result of greater mobile telephone subscriptions in Africa has the potential to boost financial inclusion through mobile financial services. The finding is in line with the leap frogging hypothesis linking ICT with economic growth and for which evidence is provided by studies as Adeleye and Eboagu (2019), while Andrianaivo and Kpodar (2012) also find mobile phone development to boost economic growth and Das et al. (2018) highlights ICT diffusion to boost economic growth in developing countries on account of the development of the financial sector.

Internet usage (INTUSE), a further measure of ICT is found to have a negative and statistically significant effect on both measures of financial development, namely, Private sector domestic credit to GDP ratio (PSDCRGDP) and Broad Money Supply to GDP ratio (BRMSGDP), with coefficients of −1.59 and −1.43 for each of the ICT variables. Hence greater internet usage results in a decline in financial development in West Africa, where greater access to electricity exists. The negative effect of internet usage on financial development variables contrasts with those of Alshubiri et al. (2019)

who find greater internet usage to boost both Private sector domestic credit to GDP ratio and Broad Money Supply to GDP ratio in a panel of six Gulf cooperative Council countries. Also the findings of this study contrast with those of Edo et al. (2019) who find internet adoption to boost financial development in Nigeria and Kenya. However possibility on account of weak internet infrastructure to support internet use in West African countries especially where multitudes of individuals access the internet simultaneously such a finding for sample West African countries may be explained.

Further while internet usage (INTUSE) and GDP per capita (GDPPC) are negative and statistically significant for both Private sector domestic credit to GDP ratio and Broad Money Supply to GDP ratio, internet usage in the presence of greater economic development boosts both measures of financial development. This reflects the greater affordability of internet and perhaps preference for internet relative to mobile phone use as incomes of individuals in West African countries rise.

Finally, rule of law is positive and statistically significant for financial development as measured by both Private sector domestic credit to GDP ratio and Broad Money Supply to GDP ratio highlighting the importance of better quality institutions for financial development consistent with the arguments of Haini (2019) and Marcelin and Mathur (2014) the improved institutions may promote financial development for instance through curbing systemic risk and hence reducing financing costs.

Table 4: Panel data fixed effects regression results determining financial development

Equation	(1)	(2)
Dependent Variables	PSDCRGDP	BRMSGDP
CONSTANT	21.24***	39.33***
	(2.18)	(3.29)
MOBUSE	0.42***	0.49***
	(0.05)	(0.08)
INTUSE	−1.59***	−1.43***
	(0.29)	(0.43)
GDPPC	−0.016***	−0.022***
	(0.005)	(0.07)
MOBUSE*GDPPC	−0.000018	0.000015
	(0.000026)	(0.000040)
INTUSE*GDPPC	0.00046***	0.00028***
	(0.000055)	(0.000083)
RLAW	5.99***	11.36***
	(1.41)	(2.12)
R-Squared	0.6335	0.5123
F-Stat	67.41***	40.96
No. of Observations	256	256
No. of Countries	16	16

***, **, * indicate significance at 1%, 5% and 10% levels of significance. Source: Author's Computation (2020)

5.3. Panel Data Fixed Effects Instrumental Variable Estimation for West African countries classified into Anglophone and Francophone West Africa

The fixed effects regression results in regard to both Anglophone and Francophone West Africa sample countries are presented in Tables 5-6 consistent with the larger sample of West African countries reveals access to electricity is significant in boosting ICT in respect of both Mobile phone use and internet usage for both Anglophone and Francophone West Africa sub-sample of countries.

Further in respect of the effect of ICT on financial development variables resulting from the influence of access to electricity, results are presented in Table 6.

Concerning Anglophone West Africa countries, mobile phone use (MOBUSE) and Internet usage (INTUSE) are both significant for broad money supply to GDP ratio. The ICT variables respectively possess the same signs as that of the larger sample of West African countries presented in Table 4 above, but are insignificant for Private sector domestic credit to GDP ratio. This implies that ICT is only significant for one measure of financial development in Anglophone West Africa. Similarly for Francophone West African countries both mobile phone use (MOBUSE) and Internet usage (INTUSE) are statistically significant for Private sector domestic credit to GDP ratio but only mobile phone use is significant for Broad Money Supply to GDP ratio. This finding contrasts with the finding as regards Anglophone West Africa.

Therefore on the basis of the findings for Anglophone and francophone west Africa sub-samples of observations and comparing the findings to that of the complete sample of observations for sample West African countries, the finding of positive and significant effect of ICT on Private sector domestic credit to GDP ratio as presented in Table 4 is driven by results

Table 5: Panel data fixed effects regression results determining ICT for West Africa country classifications

West Africa Country Classifications	Anglophone West Africa		Francophone West Africa	
Equation	(1)	(2)	(1)	(2)
Dependent variables	MOBUSE	INTUSE	MOBUSE	INTUSE
Constant	−124.30***	−16.07***	−101.86***	−10.00***
	(14.13)	(5.61)	(7.64)	(2.37)
AELECT	3.78***	0.509***	2.993***	0.55***
	(0.34)	(0.138)	(0.248)	(0.080)
GDPPC	0.0039***	−0.0027	3.484***	0.706***
	(0.014)	(0.0062)	(0.012)	(0.004)
AELECT*GDPPC	−0.00036*	0.00015	−0.00044***	0.00035***
	(0.00024)	(0.00010)	(0.00014)	(0.00004)
R-Squared	0.8747	0.6355	0.7469	0.6288
F-Stat	160.58***	41.26***	179.02***	99.95***
No. of observations	77	79	196	191
No. of countries	5	5	11	11

***, **, * indicate significance at 1%, 5% and 10% levels of significance. Source: Author's Computation (2020)

Table 6: Panel Data Fixed Effects Regression Results Determining Financial Development for West Africa Country Classifications

West Africa Country Classifications	Anglophone West Africa		Francophone West Africa	
Equation	(1)	(2)	(3)	(4)
Dependent Variables	PSDCRGDP	BRMSGDP	PSDCRGDP	BRMSGDP
CONSTANT	13.58***	35.23***	28.77***	29.50***
	(2.17)	(2.40)	(4.245)	(6.11)
MOBUSE	0.03	0.61***	0.40***	0.21**
	(0.08)	(0.12)	(0.07)	(0.10)
INTUSE	0.01	-3.61***	-0.97**	0.36
	(0.46)	(0.72)	(0.31)	(0.44)
GDPPC	-0.003	-0.03***	-0.03***	0.006
	(0.004)	(0.006)	(0.008)	(0.012)
MOBUSE*GDPPC	0.0001*	0.0005***	0.000021	-0.0001***
	(0.00006)	(0.0001)	(0.000023)	(0.00003)
INTUSE*GDPPC	-0.0006**	-0.001**	0.0003***	0.0002**
	(0.0002)	(0.0004)	(0.00007)	(0.0001)
RLAW	6.10**	6.10*	5.25***	11.19***
	(2.20)	(3.44)	(1.49)	(2.13)
R-Squared	0.3547	0.5283	0.7513	0.6786
F-Stat	5.77***	11.76***	83.10	58.06
No. of Observations	74	74	182	182
No. of Countries	5	5	11	11

Standard Errors in Parenthesis. *, **, *** indicate significance at 10%, 5% and 1% levels respectively. ***, **, * indicate significance at 1%, 5% and 10% levels of significance. Source: Author's Computation (2020)

for francophone West Africa sub-sample of observations alone. However in regards to Broad money supply a significant amount of the effect of ICT is driven by results of Anglophone West Africa.

The findings of this study in regards to the entire sample of West African countries and the Anglophone and francophone West African categorisation of countries gives rise to interesting implications. First, while greater ICT may boost financial development in West Africa in general, greater access to electricity is necessary to provide energy for ICT to progress. Second, while mobile use may boost financial development, internet usage adversely affects financial development possibly on account of the cost of internet access due to inadequate investment of government in ICT infrastructure, hence the effect of ICT on financial development may be dependent on the ICT media used. Lastly, within regions of Africa as West Africa, colonial origins of countries may play a role in differences in the effects of ICT on financial development, possibly on account of colonial powers playing a role in the diffusion of ICT to their former colonies as the colonialists continue to collaborate with their former colonies in various respects. This may consequently aid the development of the countries both in regards to ICT development and financial development.

6. RECOMMENDATIONS AND CONCLUSION

This study examined the effect of access to electricity through information and communications technology (ICT) in promoting financial development in a sample of West African countries over the period of 2000 to 2017. Two measures of ICT were used namely: Mobile phone use and internet usage, while Private sector domestic credit to GDP ratio and Broad money supply to GDP ratio were employed as measures of financial development in the study. The study found using Panel data fixed effect instrumental variables estimation that while access to electricity boosted both measures of ICT in the first stage of the regression, mobile phone use boosted both measures of financial development, while internet usage was found to adversely affect both measures of financial development. Thus access to electricity using ICT is significant for affecting financial development of sample West African countries. A further classification of sample countries into Anglophone and Francophone West African countries revealed that access to electricity once more boosted both measures of ICT in the first stage of panel regressions, however both measures of ICT are significant for broad money supply to GDP ratio only in respect of Anglophone West African countries. On the other hand, for Francophone West African countries, both measures of ICT are significant for private sector domestic credit to GDP ratio while only mobile use is significant for broad money supply to GDP ratio. Mobile use is found to boost financial development for both Anglophone and francophone West Africa. This study on the basis of findings has thus contributed to the limited literature on ICT and financial development in the context of West Africa, while contributing also to those existing studies relating electricity to financial development in Sub-Saharan Africa. Substantial support was found for the hypothesis of this study that access to electricity through ICT boosts financial development in West Africa in respect of both the complete sample of West African countries as well as sub-samples of the countries. The findings as regards the entire sample of countries as well as the sub-samples of West African countries are the first in the literature. The policy recommendations arising from the study will further financial development in West Africa in general. Future research should extend the scope of ICT examined in this study in respect of sample countries as well as Sub-Saharan Africa.

Based on the findings of this study, it is recommended that greater access to electricity by firms and households should be provided by Governments of West African countries in order that ICT may boost financial development powered by electricity. Secondly, the governments of West African countries should ensure strong regulation of charging of customers by electricity companies so that the costs of electricity are affordable and greater access to electricity may be promoted. Thirdly cost of mobile phones and internet should be made more affordable to individuals, households and businesses, and this will be aided by greater investment of governments in quality ICT infrastructure that is adequate to meet demand. Consequently the costs of provision of financial services by financial institutions will be reduced. This is especially important for the continued efforts to promote innovations in the financial sector as mobile money which has reached significant proportions in West Africa efforts. Fourthly, financial institutions providing financial services in all West African countries should ensure that their services are increasingly accessible via mobile phone network for ease of accessibility by individuals, especially those in rural areas. Lastly residents of all West African countries should be encouraged to use ICT for financial transactions so as to promote financial development, most especially those residents of Anglophone West African countries.

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