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Impact of Information Communication Technology Infrastructure and Energy on Industrial Value-added Growth of Africa

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Abstract

This paper investigates the impact of Information Communication Technology (ICT) infrastructures and energy on the industrial value-added growth of Africa. Most previous studies examine the effect of ICT infrastructure on aggregate economic growth. This study is original in that it investigates the impact of ICT infrastructures and energy on the industry sector value-added growth of Africa. Data are subtracted from World Bank Development Indicators, and International Telecommunication Union (ITU) databases from 2005-2017. We employed a dynamic growth model with a two-step difference GMM estimation method that allows instrumenting the endogenous and not strictly exogenous variables. The regression result shows that fixed telephone, mobile telephone, internet, fixed broadband and energy use are found to be positive determinants of industry value-added growth of Africa. Log-linear specifications with the same estimation method is employed to check the robustness and confirmed that consistent results. The overall policy implication is that investment to improve the penetration of information communication technology and energy use together with use of automation in production, commerce and governance should be a priority for governments, development partners, and other stakeholders.

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Introduction

Africa is a known agricultural region around the world. Over the previous decades, the economy in Africa has grown consistently with global and regional shocks, slowing in 2015 and 2016 but recovering since 2017 (AfDB, 2018; Mbah T. and Ojo V., 2018). Agriculture and other extractive primary goods have been the key drivers of this rise. Different policy orientations aimed at achieving growth and industrialization are applied in the region. However, the region continues to have a low degree of industrial value-added and is primarily regarded as an agrarian zone. Africa's industry sector that comprises manufacturing, construction, mining, water and electricity contributed around 33.5 percent of GDP in 1981; 25.18 percent in 2017, and the manufacturing sub-sector, which is expected to contribute significantly to job creation, higher income, and transformation, contributes only 10.1 percent of GDP, which is similar to the 1970s (WB, 2018; Newman et al., 2016). Technology plays significant role in economic growth. Robert Solow (1956) declared the vital role of technological progress on long run economic growth although he considerers it as exogenous factor. However, economists like Paul M. Romer (1986), Robert E. Lucas (1988) introduced and asserted the new growth theory that takes technology as endogenous technical change to foster economic growth. Information communication technology improves productivity and economic growth through its backward and forward linkages with the other parts of the economy (Van Zon and Muysken, 2005; Pohjola, 2002). Information communication technology creates ample advantages that improve the life standards of society through improvement in input's productivity, transaction cost minimization, facilitation in creation of knowledge, efficient markets and promotion of investment (Giday, 2018). Although far behind the developed world, Africa has given priority to the development of ICT infrastructures. As a result, adoptions of these infrastructures like fixed telephone lines, internet, fixed broadband, and mobile subscriber are increasing. For instance, in 2017, according to International Telecommunication Union, 87.6% of the population in African had access to mobile and the subscription of mobile phones per 100 people for the same period was 74.4 percent. Some studies that examine the impact of ICT infrastructures (telecommunication) on the economic growth of countries confirmed positive and significant results (Ding and Haynes, 2006; Datta and Agarwal, 2004). However, studies that investigate the impact of ICT infrastructure and energy on the industry value-added growth of Africa are scarce. Several studies that we discovered in the literature examine the effect of ICT infrastructure on aggregate economic growth (Lee et al., 2012; Albiman and Sulong, 2016; Chavula, 2013). Therefore, it is important to ask whether information communication infrastructures and energy use are helping to improve the industrial value-added growth of Africa or not. Hence, the research question posed is: Do information communication technology infrastructures have an impact on industrial value-added growth of Africa? What is the effect of energy use on industry value-added growth of Africa? These research questions guides to investigate the impact of information communication infrastructures and energy use on the industry sector value-added growth of Africa, which is very important to put remedial measures that enhance industrial value-added growth in the region. The study is different from other studies in that, first, it investigates the impact of all ICT infrastructures (fixed telephone, mobile telephone, broadband and internet) and energy use on the industry value-added growth of Africa. Previous studies that investigate the impact of ICT on economic growth are mainly focused at aggregate but not industry sector. Second, this study is based on recent data from Africa, and its findings will aid in the development of industrialization-enhancing policies, strategies, and projects for Africa and other emerging nations.. Thirdly, ICT infrastructure and energy variables in this study are considered as endogenous and we provided possible treatment of endogeneity for each information communication infrastructure variables. The rest parts of the paper are organized as follows. Part two provides reviews of the pieces of the literatur. In part three, the methodology that includes the model, estimation methods and the data are presented. Part four reports regression results and discussions. In part five, the conclusion and policy implications are forwarded.

Literature Review

Growth theory

Economists suggested that two growth models to explain growth differences across countries around the world. These are neoclassical growth model and the endogenous growth model. According to Solow (1956) labor, capital and in the long run exogenously determined level of technological changes are the main factors of production and growth. However, different scholars (Romer, 1986; Lucas, 1988) criticized the assumption of exogenously determined technological progress and declared that knowledge can obtained from decision of individuals or firms that seeks profit and other objectives. As a result these scholars introduced a new model known as endogenous growth model. This model considers level of technology as endogenous factor in the production process. Information communication infrastructures and energy consumption as components of technology might be significant endogenous elements in Africa's industrialization. Therefore, we have used endogenous growth framework in our econometrics analysis because of its wide application in diverse growth related studies.

ICT and Economic growth

Information communication technology (ICT) plays vital role in economic development of nations. Researchers use monetary and proxy to measure the impact of ICT on economic growth. ICT capital is the basic measurement of the monetary values of information communication technology. Personal computers (PCs) and communication technology penetration level (main telephone line, mobile, internet, and broadband subscriptions) are dominant proxy measures of ICT. Several studies indicate the impacts of ICT capital/investment on economic performances are divers. The first group shows that ICT capital/investment exhibits a positive and significant impact on economic performance. For instance, Datta and Agarwal (2004) investigated the role of telecommunication infrastructure on the long-run economic growth of OECD countries. They employed a dynamic fixed effect panel data estimation method and the result support that telecommunication is a positive significant factor for real per capita growth. Many studies asserted the positive impact of ICT on different country's economic growth (Feredico, 2013; Colecchia and Schreyer, 2002; Yilmaz et al., 2001). The reason is that ICT facilitates fast communication tools that reduce costs and information asymmetry which helps to enhances revenues. Moreover, ICT increases productivity through capital deepening in the factor market results in positive output growth at the aggregate and sectoral levels. This kind of ICT effect on the aggregate economy indicates that the industry sector in Africa can also accrue benefits from ICT which increases the share of the industry value added in the gross domestic product of each country. The second group of studies shows the impact of ICT investment varies with income level and development status of countries. Some of the results indicate that the impacts of ICT investments are higher and significant in developed countries than in developing group of counties. Yousefi (2011) examined whether and to what extent information technology (ICT) has helped to improve economic growth in 62 developed and developing countries in the period between 2000 and 2006. The result revealed that ICT impact on economic growth differs significantly across the country categories or groups. That is, ICT plays an important role in the high and upper middle income group of countries economic growth but an insignificant role to contribute to the economic growth of the low middle-income group of countries. Similar to the ICT capital/ monetary measures, the impact of proxy measures (fixed telephone, mobile telephone, internet, and fixed broadband) on economic growth assert diverse empirical evidence. The first component of evidence shows that ICT infrastructure variables have a positive and significant impact on economic growth. Todar et al. (2018) examined the effect of ICT infrastructure on economic growth in European Union countries in the period between 2000 and 2017. The result affirmed that significant and positive impact of ICT infrastructure on the economic growth of EU member countries. In the same manner, Ding and Hynes (2006) in china and Correa (2006) in the United Kingdom investigated the impact of ICT infrastructure development on the economic performance of respective countries and found that ICT infrastructures have a positive and significant effect on the GDP growth of China and UK respectively. Several studies confirmed that ICT infrastructure variables have a positive and significant impact on the economic or GDP growth of respective economies (Batou, 2015; Levendis and Lee, 2013). The recent ICT infrastructure development in Africa may have essential input to stimulate the allover social, economic, and political activities of the region. Particularly the business transaction, marketing, and production of enterprises can benefit from information obtained by fast communication infrastructure availabilities. Hence, Africa which is showing encouraging progress on ICT infrastructures can use the advantages to motivate the whole economy as well as the structural transformation of member countries through the industry sector development. In the case of causality between ICT infrastructure variables and economic growth, several studies confirmed the feedback hypothesis (Francis et al., 1991; Lam and Shiu, 2010). For instance, David (2019) investigated the causal relationship between telecommunications, economic growth, and development employing panel data of 46 African countries from 2000-2015. The estimation result suggested that there is a bidirectional long-run relationship between telecommunication infrastructures, economic growth, and development. So, Africa should promote a comprehensive policy that helps to enhance both ICT infrastructure and economic growth. That means African member countries should focus not only to develop ICT infrastructure but also to enhance economic growth. Such kind of comprehensive development direction can promote the industry value added of African countries. All of the shreds of the evidence above show the impact of ICT infrastructure on aggregate economic growth. However, there are also empirical pieces of evidence that show the impact of ICT infrastructure on productivity and value-added growth of specific industries. The service sector, industry sector, manufacturing, transport, and construction are some among others. Similar to the impact of ICT infrastructures on aggregate economic activity, the effect on sector performance differs. Agheli and Hashemi (2018) examined the effect of ICT on the growth of transport sector value-added using estimation of a panel data model for the selected Middle East countries over the period 2000 -2014. The finding shows that the ICT penetration ratio has a significant positive effect on value added of the transport sector. Similarly, Madden and Savage (1998) investigated the causal relationship between gross fixed investment, telecommunication infrastructure investment, and economic growth for a sample of 27 transitional economies in Central and Eastern Europe (CEE) for the period 1990 to 1995 for the industry and service sector. The result confirmed that evidence of the positive role of ICT infrastructure in manufacturing sector GDP growth but no effect on service sector GDP growth. Since the industrial sector includes manufacturing value added, the empirical evidence found here shows that ICT infrastructure development in Africa may stimulate the industry sector value-added growth, which in turn increases the proportion of industry sector value added in the GDP of the region. Energy in general and electricity, in particular, plays important role in economic development. Industrial developments specifically have more demand and require more energy for the production of goods and services. Many emperical evidence supports that energy consumption/use cause economic growth (Akinlo, 2008 in Sudan and Zimbabwe; Kumar et al., 2015; Odhiambo, 2009; Stern and Enflo, 2013). Therefore, to foster the aggregate economy and achieve industrialization in Africa, electricity/ energy access and then consumption promotion in each country should be a priority area of development, otherwise, industry value added growth, as well as overall economic growth, can be negatively affected by energy stress.

Methodology

Economic Model

The empirical model adapted and employed in this study is similar to Levendis and Lee (2013), and Datta & Agrawal (2004), who mainly analyzed the impact of ICT infrastructure on regional growth in Asia, and OCED countries respectively. These authors employed Barro's (1991) type model modified to the panel dynamic effect model following Islam (1995), which is more appropriate to take into account the correlation between the previous and subsequent values of growth, in addition to taking into account separate country effects. The aggregate model is:

$$GDPPGR_{it} = \alpha + \beta_1 GDPPGR_{it-1} + \beta_2 ICTI_{it} + X'_{it}\beta + \mu_i + \varepsilon_{it} ------(1)$$

Where $GDPPGR_{it}$ denotes the growth rate of real per capita GDP of country i in period t. $ICTI_{it}$ is information communication technology infrastructure variables of country i in period t. $X'_{it}\beta$ denotes different control variables that affect GDP per capita growth of country i in the period t. μ_i captures the country fixed effect and ε_{it} is the error term.

The model in equation (1) above is an aggregate growth model that helps to examine the impact of the interest variable and other control variables on the per capita GDP growth of countries. However, this study aims to investigate the impact of ICT infrastructure on industrial sector growth. So, the econometric model adapted and employed here follows the type of Madden and Savage's (1998) extended sectoral growth model. Therefore, equation (1) modifies to capture industry sector growth model but the nature of the model is similar to Levendis and Lee (2013), and Ding and Haynes (2006).

$$IGDPGR_{it} = \alpha_0 + \beta_1 IGDPGR_{it-1} + \beta_2 ICTI_{it} + X'_{i,t}\beta + \mu_i + \varepsilon_{it} ....(2)$$

Where *i* and *t* represent the country and time indexes, μ_i captures the country fixed effect. The error term is represented by ε_{it}.

$IGDPGR_{it}$ represents the growth rate of real per capita industrial sector GDP of a country i in period t, $IGDPGR_{it-1}$ is the lag growth rate of real per capita industrial sector GDP of country i in period t. $ICTI_{it}$ represents information communication technology infrastructure variables. $X'_{i,t}\beta$ captures a list of control that identified in different studies as determinant factors of GDP growth (Ding and Haynse, 2006).

The variables in equation (2) are measured as follows:

IGDPGRit: the growth rate of real per capita industrial sector value added of a country i in period t. Industrial sector comprises value-added in manufacturing, mining, construction, water, electricity, and gas.

IGDPGRit-1 is a one-year lag growth rate of real per capita industrial sector value-added of a country i in period t. it captures that the autoregressive behavior of the variable. The annual growth rate of industrial sector value-added is at least partially dependent on last year's growth.

$ICTI_{it}$ includes four ICT infrastructure variables namely: ***TELE*** represents the number of fixed telephone line subscribers per 100 inhabitants, ***MOB*** represents the number of mobile subscribers per 100 inhabitants. ***INT*** represents the percentage of individuals using the internet. ***FBB*** represents the number of fixed broadband subscribers per 100 inhabitants. ***ICTI*** variables are assumed to have positive relation with industrial sector per value added growth.

ENRG: represents energy consumption and the higher a country consumes energy the higher is the industrial value added per capita growth because energy is one of the key positive determinants of industrial growth. However, due to lack of reliable data, we take electricity access of country i in period t as a proxy measure of energy consumption. The sign is expected to be positive.

The control variables are:

INF: represents inflation rate measured by PPP (purchasing power parity). Inflation and industrial sector GDP growth are expected to be negatively related.

FDI represents foreign direct investment net inflows as a share of GDP. The relation between FDI and industrial sector per capita valu-added growth is expected to be positive. ***HUM:*** represent human capital, which is measured as the gross secondary school enrollment ratio. It is the share of the number of actual students enrolled at the secondary school by the number of potential students to be enrolled.

TRDO is trade openness measured by the import and export volume of the country. It shows the country's openness to international trade. The expected sign of trade openness in the literature is negative for small size countries and positive for large countries, which is mixed, and in Africa, we expect a positive correlation. Export per GDP (exportgdp) and import per GDP (importgdp) variables are estimated in the equation to see the effect of import and export separately.

***INV*:** The share of fixed capital formation in GDP is a proxy of investment in the economy and its expected sign is positive for industry value added growth of Africa.

GOV represents governance indicators. The governance indicator includes six broad categories. These are voice and accountability, political stability and absence of violence; government effectiveness; regulatory quality; rule of law; and control of corruption. We unified the six indicators using the principal component analysis to obtain a single indicator called governance. The positive and higher governance index implies that favorable conditions for industrial development and vice versa. So, the expected sign of governance for industrial value added growth is positive.

Aside, we included the square of ICT infrastructure variables (ICTISQ variable) in equation (3) below to examine the relationship between each ICTI variable (TELE, MOB, INT, and FBB) and industry value added growth to check whether they have a linear relationship or not.

$$IGDPGR_{it} = \alpha_0 + \beta_1 IGDPGR_{it-1} + \beta_2 ICTI_{it} + X'_{i,t}\beta + ICTISQ + \mu_i + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

If the coefficient of each ICTISQ (TELESQ, MOBSQ, INTSQ, and FBBSQ) is negative and significant, then the result supports the diminishing returns hypothesis, indicating that investment in ICT infrastructure expands its incremental effect on industrial value added deterioration. On the other hand, as per Roller and Waverman (2001), a positive sign for both coefficient can indicate increasing returns, however, if signs are reversed, that is the coefficients of ICTISQ is positive and ICTI is negative, then we have evidence in support of the critical mass theory that states investment in ICT infrastructure would not significantly affect industrial value added growth until a certain level of ICT infrastructure is achieved.

Alternatively, we examine the effect of ICT infrastructure variables on industrial sector value added per capita using the model specification similar to Albiman and Sulong (2016) to understand the robustness of our growth model results, as of the following specification.

$$\ln IGDPPC_{it} = \alpha_0 + \beta_1 \ln IGDPPC_{it-1} + \beta_2 \ln ICTI_{it} + \beta_3 \ln ENRG_{it} + \beta_4 INF_{it} + \beta_5 \ln FDI_{it} + \beta_6 \ln HUM_{it} + \beta_7 \ln TRDO_{it} + \beta_8 \ln INV_{it} + \beta_9 GOV_{it} + \mu_i + \varepsilon_{it} \ldots\ldots\ldots\ldots(4)$$

Where: **lnIGDPPC** represents the log of industry value added per capita (in constant 2010 US dollar value) determined by industry value added (in Constant 2010 US dollar) of country i in period t divided by the total population of county i in period t.

lnIGDPPC$_{it-1}$ represents the lag value of industry value added per capita of country i in period t.

lnICTI represents ICT infrastructure variables per head which include: **TELE** - fixed telephone lines per head, calculated by total telephone lines divided by the total population of country i in period t. **MOB** - mobile telephone per head, calculated as total subscribers divided by the total population of country i in period t**. INT**-internet users per head, calculated as total internet users divided by the total population of country i in period t**. FBB** - fixed broadband subscribers per head, which is total fixed broadband subscription divided by the total population of county i in period t. The remaining variables are similar to the definition in equation (2).

Estimation Methods

ICT infrastructure variables are crucial for almost all economic activities; however, investment in ICT infrastructures also depends on countries' GDP and industrialization development too. Hence, we assume that at least some of the interest variables are endogenous. In order to address the reverse causality issue, this study employed the two-step difference GMM estimator of Arellano and Bover's (1995)/Blundell and Bond (1998) methods. The difference GMM estimator of Arellano and Bover (1995)/ Blundell and Bond (1998) is recommended to instrument both potentially endogenous and not strictly exogenous independent variables. This study assumes that the ICT infrastructure variables are potentially endogenous, which means that higher industrial sector value-added growth can be the result of higher ICT infrastructure investment and, higher ICT infrastructure investment can be the outcome of high industrial value-added growth. In the Arellano and Bover (1995) /Blundell and Bond (1998) difference GMM estimator endogenous independent variables are treated by applying the first difference transformation of the growth model of equation (2) into equation (5) and equation (4) into equation (6) of the following form.

$$\Delta IGDPGR_{it} = \beta_1 \Delta IGDPGR_{it-1} + \beta_2 \Delta ICTI_{it} + \Delta X'_{it}\beta + \Delta\varepsilon_{it} \text{..............................}(5)$$

$$\ln\Delta IGDPPC_{it} = \beta_1 \ln\Delta IGDPPC_{it-1} + \beta_2 \ln\Delta ICTI_{it} + \beta_3 \ln\Delta ENRG_{it} + \beta_4 \Delta INF_{it} + \beta_5 \ln\Delta FDI_{it} + \beta_6 \ln\Delta HUM_{it} + \beta_7 \ln\Delta TRDO_{it} + \beta_8 \ln\Delta INV_{it} + \beta_9 \Delta GOV_{it} + \Delta\varepsilon_{it} \text{.............................}(6)$$

The final growth model and the alternative log-linear specification to estimate the results have included time dummies to prevent the cross individual correlations, policy, and other shocks as indicated below in equation (7) and equation (8) respectively.

$$\Delta IGDPGR_{it} = \beta_1 \Delta IGDPGR_{it-1} + \beta_2 \Delta ICTI_{it} + \Delta X'_{it}\beta + D_t + \Delta\varepsilon_{it} \text{.............................}(7)$$

$$\ln\Delta IGDPPC_{it} = \beta_1 \ln\Delta IGDPPC_{it-1} + \beta_2 \ln\Delta ICTI_{it} + \beta_3 \ln\Delta ENRG_{it} + \beta_4 \Delta INF_{it} + \beta_5 \ln\Delta FDI_{it} + \beta_6 \ln\Delta HUM_{it} + \beta_7 \ln\Delta TRDO_{it} + \beta_8 \ln\Delta INV_{it} + \beta_9 \Delta GOV_{it} + D_t + \Delta\varepsilon_{it} \text{................................}(8)$$

For understanding purpose let ICTI represents all endogenous variables of the independent variable in equation (2) and equation (4). The first differencing eliminates any fixed effect (μ_i) as shown in the above equation (5) and equation (6). However, it is still $ICTI_{it}$ in the $\Delta ICTI_{it} = ICTI_{it} - ICTI_{it-1}$ correlated with the ε_{it} in $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-1}$. As explained in David Roodman (2009) lagged difference of variables can be used as instruments for equations in levels and lagged levels of variables are similarly can be employed as instruments for equations in the first difference. According to Arellano and Bover (1995)/ Blundell and Bond (1998) two-step difference GMM estimator instruments levels with differences. Therefore, an endogenous variable $ICTI_{it}$ can be instrumented by the transformed two lagged ICTI variable if ε_{it} does not serially correlate of order 1. That is $\Delta ICTI_{it-2}$ can be used as an instrument if ε_{it} is not serially correlated of order 1 as far as $\Delta ICTI_{it-2} = ICTI_{it-2} - ICTI_{it-3}$ does not correlate with $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-1}$ (Lee, et al, 2012).

If however, ε_{it} is serially correlated of order 1, $\Delta ICTI_{it-2}$ (two lagged variables) does no longer a valid instrument and therefore, the appropriate instruments have to be restricted to the third lagged or greater lagged values ($\Delta ICTI_{it-s}$ for s ≥3). In this paper, the author assumes that the ICT infrastructure variables are potentially endogenous and accordingly valid instruments are consulted based on Arellano and Bond (1991) test of autocorrelation. Therefore, we employ two-step difference GMM estimation techniques to investigate the impact of our interest variables on the industry value added growth of Africa.

Data

This study examines the impact of ICT infrastructure and energy condumption on industrial sector value-added growth using a panel dataset of 49 African countries in the period between 2005 and 2017. The World Bank's development indicator (2018) is the main source of our data. The explanatory variables are constructed using different sources. ICT infrastructure variables such as fixed telephone, mobile telephone, internet, and fixed broadband data are collected from ITU (2019). The institutional variable (governance) data are taken from the World Bank Governance indicator WB (2018). We regrouped the WB (2018) six sub-categories of institutional variables into one indicator called governance (GOV) using principal component analysis. Some variables that are missed in some years from the World Bank development indicator and International telecommunication union are filled by data obtained from AfDB (2018) and each countries statistical yearbooks and datasets. For missing data that could not found in any sources, linear interpolation has employed to fill the data capable to estimate the impacts as done by Jin and Cho (2015). The descriptive statics of the study is presented in Table 1. The data shows that the average growth rate of industry value added for the study period is 3.87 percent.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
IGDPGR	637	3.873	8.631	-39.406	47.279
TELE	637	3.589	5.931	0	32.669
MOB	637	59.646	39.577	.538	173.497
INT	637	13.08	14.424	.204	64.191
FBB	637	.833	2.3	0	19.454
ENRG	637	44.841	29.216	.044	100
HUM	637	48.307	22.303	6.636	115.633
FDI	637	5.039	9.372	-7.329	103.337
INV	637	23.115	8.864	2	74.608
INF	636	6.929	7.494	-8.975	95.409
exportgdp	637	.337	.213	.014	1.61
importgdp	637	.439	.209	.064	1.451
GOV	637	0	1	-1.921	2.946

Sources: WB (2018) and ITU (2019)

Estimation Results and Discussions

Theoretically and empirically ICT infrastructures are considered as stimulates of economic growth. Modern sectors such as industry are more demanding new technologies to facilitate fast economic activities. Energy and ICT infrastructures worldwide are considered as general-purpose technologies (GPT) (Rehiel Mathias, 2018), which imply that very crucial to allover economic changes. We assumed that ICT infrastructures and energy have accelerating power to the industrial value-added growth of Africa. Table 2 shows the two-step difference GMM estimation results of the ICT infrastructure and energy together with our control variables. The growth model indicated in equation (7) is employed to estimate the results using the two-step difference GMM estimator technique. In the regression result of table 2, of all five models (1-5), the Arellano-Bond test for AR (1) suggests that we reject the null hypothesis of no first-order autocorrelation in the first difference residuals, and the Arellano-Bond test for AR (2) of the null hypothesis that says no second-order autocorrelation is accepted, and confirming that endogenous variables can be instrumented by their third lagged and deeper values. As a result, ICT infrastructure variables are instrumented with their third and deeper lag. Moreover, we employed the Hansen J-test of over-identification with the null hypothesis "the model is correctly specified and consistent of identification restrictions". As Lee (2012) cited (Baum, 2001) large p-values are not rejecting the null hypothesis, and thus, we conclude that there is no enough evidence to reject the model specification or the identification restrictions. That is Hansen test restrictions are tested and the results of all models are satisfactorily passed. Moreover, the overall model test which shows the calculated F for each model is greater than the table value of F implying that statistically significant. Therefore, we instrumented the endogeneity by using three and above-lagged values of the dynamic and our interest variables.

Table 2 Two-Step Difference GMM Regression Results

IGDPGR	(1)	(2)	(3)	(4)	(5)
IGDPGR L1.	-0.2771** (0.106)	-0.2902*** (0.104)	-0.2696** (0.114)	-0.2834** (0.111)	-0.2659** (0.113)
TELE	1.8025** (0.786)	2.6561 (3.976)	0.7585 (1.152)	1.3808 (0.919)	2.2160* (1.224)
MOB	0.2707** (0.109)	0.3069** (0.138)	0.6179** (0.299)	0.2245 (0.234)	0.2945* (0.161)
INT	0.6593*** (0.241)	0.6172*** (0.229)	0.4300 (0.376)	-0.0618 (0.823)	0.3993 (0.379)
FBB	1.9830** (0.966)	2.3356* (1.332)	2.8413* (1.447)	1.5080 (1.214)	6.5855 (9.490)
ENRG	1.2195** (0.584)	1.4059** (0.671)	0.9839* (0.509)	1.3594** (0.551)	1.2782* (0.671)
HUM	0.2194* (0.124)	0.2337 (0.148)	0.0776 (0.168)	0.1768 (0.157)	0.1510 (0.239)
FDI	0.0510 (0.039)	0.0653 (0.054)	0.0291 (0.041)	0.0231 (0.043)	0.0596 (0.056)
INV	0.1204 (0.109)	0.1101 (0.118)	0.1355 (0.115)	0.1909 (0.139)	0.0790 (0.138)
INF	-0.1506* (0.086)	-0.1460* (0.086)	-0.1055 (0.086)	-0.1247 (0.079)	-0.1445 (0.113)
exportpgdp	16.7440** (7.374)	17.4371** (8.019)	12.0806 (8.217)	15.6767** (6.866)	15.8094 (16.051)
importpgdp	2.7210 (9.513)	0.1799 (10.540)	-1.5480 (9.861)	0.5292 (10.214)	-4.2342 (11.741)
GOV	-6.3990** (2.805)	-7.2735* (3.823)	-5.2053* (2.620)	-5.7391* (2.909)	-5.5314* (3.239)
TELESQ		-0.0248 (0.073)			
MOBSQ			-0.0019 (0.002)		
INTSQ				0.0085 (0.009)	
FBBSQ					-0.1389 (0.299)
Year dummy	yes	yes	yes	yes	yes
N. obs	538	538	538	538	538
N. group	49	49	49	49	49
N. Instr	44	42	43	42	44
F-test	4.49	5.89	3.19	5.34	4.57
AR (1)	0.034	0.034	0.036	0.040	0.050
AR (2)	0.148	0.127	0.096	0.134	0.340
Hansen test	0.891	0.930	0.959	0.963	0.950

Note: Standard errors in parentheses;
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$;

IGDPGR is the dependent variable that represents industry GDP per capita growth of Africa. N.obs represents number of observations included in the regression. N.group represents number of African countries included in the estimation. N.Instr represents number of instruments employed in the GMM estimation that shows less than the number of groups in all of the models. Model 1 in Table 2 is the two-step difference GMM estimation result of growth model equation (7) that included all interest and control variables with years as dummy to consider any shocks in the sample periods. The result confirmed that L.IGDPGR (lagged industry value added growth) is significant at a 5 percent significance level with the expected negative sign, which asserted that our dynamic model choice to evaluate the impact of our interest variables on industry value added growth of Africa is properly specified. The two-step difference GMM regression results in model 1 indicate that fixed telephone (TELE), mobile telephone (MOB), and fixed broadband (FBB) are positive and significant at a 5 percent significant level, while internet (INT) is significant at 1 percent significance level. The implication is that fixed telephone, mobile telephone, internet, and fixed broadband are all important factors that improve industrialization in Africa. The coefficient of fixed telephone implies that keeping all other things constant, an increase a 1 fixed telephone subscriber per 100 inhabitants (a 1 percent fixed telephone increase) results in a 1.802 percentage point increase in growth of industry value added of Africa. The positive contribution of fixed telephone to economic growth is similar to earlier study findings (Sridhar and Sridhar, 2007; Qiang and Rossotto 2009; Waverman et al, 2005). Likewise, the Internet is a significant determinant of African industry value added growth at a 1 percent significance level, which confirms 1 percent internet user increase in Africa results in a 0.659 percentage point increase in industry value added growth of Africa. The coefficient of the fixed telephone is greater than the internet, which shows that the impact of fixed telephone in the industrial value-added growth of Africa is still more than the internet that contradicts with the findings Qiang & Rossotto (2009). However, this doesn't show that the internet is less important than the fixed telephone but it is because internet usage is not widely developed across the region.

The Internet needs different skills to capture its benefits but in many parts of Africa, people are less skilled, uneducated, they cannot easily know the internet languages, and the internet is more costly. Comparatively, the use of fixed telephone requires less skill, once it is established people can easily communicate with their languages directly. So, to enhance the effect of the internet on the industrialization of Africa governments in the region have to establish systems that help people to use the internet for economic and social activities in smooth and easy ways. The ICT infrastructure variables such as mobile telephone (MOB) and fixed broadband (FBB) are also positive and significant determinants of industry value added growth in Africa. The coefficients of the mobile telephone (MOB) and fixed broadband (FBB) are statistically significant at a 5 percent significance level. The relation implies that more investment in mobile telephone and fixed broad development in Africa brings about improvements in industry value added share of the gross domestic product (GDP) of the continent. The coefficients of mobile telephone indicate that keeping all other things constant an increase of 1 mobile subscriber per 100 people (a 1 percent mobile penetration) results in an increase of 0.271 percentage point in industry value added growth of Africa. In Africa, as part of technological change, mobile plays vital role to stimulate industrialization in the region. For instance, mobile communication closes the gap of modern transportation problem where travel in poor transport facilities take many hours to get market information for manufactured goods and inputs. Mobile enables suppliers and consumers to reach a wider market with affordable and minimum mobile costs. Mobile service uses devices that help people easily access information from everywhere as far as the owner/users are in the mobile networks area. However, mobile penetration has shown growth recently, its impact on industrial value added needs to improve. Marketing and communication with mobile have to be developed. Automation of production types of machinery that use mobile connections to manage production, maintenance, and technology transfer systems have to be put in place. Besides, construction, marketing, and mining activities also have to use mobile services optimally to enhance value additions. However, the growth effect of the mobile telephone is less than that of fixed broadband and internet, where the result is in line with the findings of Qiang & Rossotto (2009) and less than the growth effect of the fixed telephone that contradicts with Chavula (2013) for overall economic growth but not for industry sector value added growth.

The coefficient of fixed broadband implies that keeping other things constant, an increase in a fixed broadband subscriber per 100 people (a 1 percent increase in fixed broadband subscribers) results in an increase of 1.983 percentage point of industry value added growth of Africa countries. The impact of fixed broadband in the industrialization of Africa is encouraging. Though the penetration level of fixed broadband is very small (average penetration in the study period is 0.8 percent, see table 1), its impact on industry value added growth of Africa is actually great. Broadband connection plays a stimulus role in the technological transfer. Industry owners and entrepreneurs can learn new production systems, and fill their gaps through downloading designs, production systems, can also learn skills on videos and online systems. African, as indicated in the descriptive statistics of table 1, reached a 0.8 percent penetration level and most of the member countries are below 1 percent broadband penetration level. African average penetration of fixed broadband has reached 1.5 subscribers per 100 inhabitants in 2017; however, this penetration level is far behind 14 subscribers per 100 inhabitants of the world (ITU, 2019). Therefore, to strengthen the effect of broadband on the industrialization of Africa, more investment to intensify broadband services is an inevitable task of African countries. Besides, citizen skill training to utilize fixed broadband services is also another assignment to universities and other development agencies. The regression result of energy consumption (ENRG) proxy by electricity access of sample African countries is also positive significant at 5 percent significance level, indicating that energy consumption is important factor to improves the industrialization of Africa. Keeping other things constant, a 1 percent increase in energy use increases industry value added growth of Africa by 1.220 percentage points. The positive coefficient of the two-step difference GMM estimation result of energy is compatible with economic theories and other previous empirical results (Wang, et al, 2011 for China; Musibaw et al., 2019 for Sub Shara Africa). African countries reached an average of 44 percent in energy access for the study period (see Table 1), which implies that low levels and hampers energy consumption to promote industrialization. It is a common cause in Africa that many industries produce below their production capacity due to the shortfall of energy supply. Energy affects almost all of the industry sectors. Manufacturing without energy use is a very tiresome and inefficient activity. Mining and construction require energy to achieve the targets in each sector. Therefore, energy plays a decisive role to transform Africa into an industrialized continent. Similarly, export volume per gross domestic product (exportgdp) and human capital development has significant positive effects whereas inflation and governance have a significant negative impact on industrialization. On the other hand, the good governance variables (GOV) and inflation (INF) are found to be negative significant variables at 5 and 10 percent significance level respectively. The negative relationship between governance and industry value added growth particularly in developing continents like Africa is consistent with economic theories that say strict regulations may negatively affect productivity and economic growth (Albiman and Sulong, 2016 as cited Law and Singh, 2014). Similarly, the unpredictable inflation damages the smooth socio-economic interactions through uncontrolled or rampant rent-seeking practice in a few parts of the society. Aside, to see whether ICT infrastructure variables have a decreasing or increasing returns relationship with industry value added growth or not, ICTISQ (information communication technology infrastructure square) variables are included in the model. The two-step difference GMM regression result is presented in Table 2. The information communication variables such as fixed telephone square (TELESQ), mobile telephone square (MOBSQ), internet users square (INTSQ), and fixed broadband square (FBBSQ) are regressed in model 2, model 3, model 4, and model 5 respectively. Model 2 shows the regression result of the two-step difference GMM estimation where TELESQ (fixed telephone square) is included. Except for fixed telephone itself, in model 2 each of the ICT infrastructure variable is found positive and significant determinants of industrialization. Internet (INT) and mobile telephone (MOB) are significant at 1 percent and 5 percent significance level respectively while fixed broadband (FBB) is significant at 10 percent significance level. Similarly, energy variable and export per GDP are positive and significant factors at a 5 percent significance level. However, among the control variables, inflation and governance are negative significant variables at a 10 percent significance level. The implication is that inflation deteriorates the growth of industry value addition of African countries. In model 3 mobile telephone square (MOBSQ) variable is included and the result shows that fixed broadband and energy use are found positive and significant factor at 10 percent significance level, whereas mobile telephone itself is significant at 5 percent significance level. Of the control variables, governance is a negative and a significant factor at a 10 percent significance level on the industry value added growth of Africa. In model 4 internet square (INTSQ) is included and only energy and export per GDP variables are significant at a 5 percent significance level, whereas governance is, as usual, a negative significant factor at a 10 percent significance level. Other ICT infrastructures and control variables are insignificant in this case. In model 5 fixed broadband square is included to see the impact on the industrialization of African countries. The regression result indicates that fixed telephone, mobile telephone and energy coefficients are positive significant at a 10 percent significance level. Governance variable is also negative significant factor industrialization at 10 percent significance level. The remaining factors are found to be insignificant. ICT infrastructure variables appeared as significant determinate in the majority of the models presented in Table 2 although there are cases that the variables are insignificant when ICTISQ variables are included in the model. Therefore, we can conclude that ICT infrastructures are very important factors that upsurge industry sector value-added growth in Africa. Similarly, in all of the five models above, energy is a persistently significant factor that has positive impact on industrial growth of Africa at the required significance level. In the two-step difference GMM estimation, when the ICT infrastructure variable square (TELESQ, MOBSQ, INTSQ and FBBSQ) is positive and these variables without square (TELE, MOB, INT and FBB) are negative implying that evidence of critical mass theory, which says that investment in information communication infrastructure would not significantly affect industrial value-added growth until a certain percent of penetration, which is until 40 percent of ICT infrastructure penetration is achieved (Roller and Waverman, 2001). Since the coefficients of all ICTISQ are insignificant and the signs except INTSQ are reversed we have no enough evidence in support of the critical mass theory.

Robustness check regression results

Our growth model two-step difference GMM estimation result confirmed that all ICT infrastructure variables and energy consumption are determinant factors for the industry value added growth of African countries. Though the magnitude of the growth impact of different variables varies, fixed telephone (TELE), mobile telephone (MOB), Internet (INT) and fixed broadband (FBB) are found positive and significant factors of industry value added growth of Africa. To be more confident on the impact of our variable of interest on industry value added growth of Africa, employing other specifications and check the consistency of the regression results are very important and a normal procedure in scientific researches. As we have indicated in the methodology part of this paper, log liner model specification of equation (8) is estimated using the two-step difference GMM methods and the robustness check regression results are presented in Table 3.

Table 3: Robustness Check two-step difference GMM regression result

Ln IGDPPC	(1)
lnL.IGDPPC	0.8967***
	(0.076)
lnTELE	0.0003
	(0.030)
lnMOB	0.2291**
	(0.099)
lnINT	0.1465***
	(0.034)
lnFBB	0.0024
	(0.019)
lnENRG	0.1838**
	(0.088)
lnHUM	-0.0680
	(0.077)
lnFDI	-0.0046
	(0.011)
lnINV	0.0837*
	(0.047)
lnINF	-0.0126*
	(0.007)
lnexportpgdp	-0.0297
	(0.032)
lnimportpgdp	-0.0588
	(0.050)
GOV	0.0072
	(0.037)
N.obs	424
N.group	49
Year dummies	Yes
Ar(1)	Pr>z=0.009
Ar(2)	Pr>z=0.161
Hansen	Pr>chi2=0.930
F-test	66.930

Note: Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

lnL.IGDPPC represents lagged natural log of industry value added per capita (in constant 2010 US dollar value). **lnTELE** represents the log of fixed telephone lines per head. **lnMOB**, represents the log of mobile telephone subscribers per head. **lnINT** represents the log of internet users per head, **lnFBB** represents the log of fixed broadband subscribers per head, and the other variables representation is similar to the definition provided in the data and methodology part. The Test of Arellano-Bond Ar(1) for two-step difference GMM estimation confirms that there is first order autocorrelation in the first difference of the error term implying that reject the null hypothesis. However the test of Ar(2) confirmed there is no second order autocorrelation that indicates our result is robust to both panel-specific heteroskedasticity and autocorrelation. Hansen over identification test shows insignificant result, which confirms the model is identified correctly. The regression results in Table 3 indicate that our dynamic variable, the log of lagged industry value added per capita is positive and significant at a 1 percent significance level. This result again confirmed that our dynamic model/equation is correctly specified and hence employing GMM estimation method is proper. The sign of the coefficient is positive indicating that the result is not in support of the growth

convergence between African countries that say countries with a low level of initial income tend to grow faster than countries that have higher initial income levels, which have a similar level of human capital, macroeconomic conditions, and institutional setups (Mankiew, 2010).
In the regression result, we found that the coefficient of the mobile telephone and internet are positive and significant at a 5 and 1 percent significance level respectively. This result is consistent with our growth model specification regression result in Table 2; however, fixed broadband and fixed telephone are not significant in our log-linear model specification regression result of table 3. Energy consumption is significant at 5 percent significance level. Similarly, capital formation or investment in the economy and inflation rate are significant at a 10 percent significance level. Inflation is consistently significant in the previous growth model and in the log-linear specification. In the contrast, human capital, governance, and export share per GDP variables become insignificant in our log-linear model regression result, which was significant determinants in our growth model regression. Especially the governance variable (GOV) that incorporates the institution's role is not only insignificant but also the sign of the coefficient also changed from negative to positive here. This type of result shows that the impact of institutional quality or governance on economic growth is sensitive to model specification (Albiman and Sulong, 2016). In general, the overall robustness check regression result confirms that from our interest variables, mobile telephone and internet together with energy use are persisting as positive and significant factors to improve industry value-added growth in Africa. Likewise, the dynamic variable lagged log of industry value added per capita is also persisting significantly. However, fixed telephone and fixed broadband are inconsistent in our robustness check log-linear specification results.

Conclusion and Policy Implication

This study employed data from World Bank and International Telecommunication Union for 49 African countries from 2005- 2017 and investigated the impact of ICT infrastructures and energy on industrial value-added growth of Africa using two-step difference GMM estimation methods. The estimator we employed, the Arellano and Bover (1995)/ Blundell and Bond (1998) GMM estimation method not only considers potentially endogeneity independent variables but also allows to instrument not strictly exogenous variables. We considered all ICT and energy variables as endogenous and provided possible treatment of endogeneity. The result of the study confirmed that ICT infrastructures (fixed telephone, mobile telephone, internet and fixed broadband) have positive and significant impacts on industry value-added growth of Africa. Most of the growth model regression results are consistent with the robustness check results. Except for the difference in the magnitudes, all information communication technology infrastructures are very important factors that determine industry value-added growth in Africa. Similarly, energy use upsurges industry value added growth of Africa significantly. These results contribute for the formulation and implementation of policies on ICT infrastructures and energy use to enhance industry value-added in African, and can be adopted across all developing economies. It also provides a unique contribution to the body of knowledge on the impact of ICT infrastructure and energy use on industry sector value added growth of Africa. The policy implication is that Africa has to increase investment on ICT infrastructures and energy use to improve industrial value-added growth of the region. Each country in the region should give priority on investment in mobile telephone and Internet to actualize benefits from each of the infrastructures. Though the growth specification of the two-step difference GMM estimation result of fixed broadband is positive and significant at a 5 percent significance level, the robustness specification (log-linear) result became insignificant. The insignificant result of the log-linear specification is not an indication that fixed broadband is not important in the industrialization of Africa. Rather, it is an indication that fixed broadband is newly introduced and at low level to actualize its benefits in Africa. Therefore, governments in Africa region have to provide sufficient focus to improve the fixed broadband level and how to use the facilities to industry sector value added growth, which is one of the conditions to improve the life situation of citizens. Last not least, the advantages of ICT infrastructure penetrations should be used for automation of production, commerce, and governance to speed up the struggles towards industrialization. The limitation of this study is that it considers the impact of energy use proxy by electricity access not actual energy consumption on industry value added growth of Africa due to insufficient energy consumption data. Thus, a further study based on actual energy use or consumption data would be appropriate to identify the energy impact on the industrial value-added growth of African countries.

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