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The Impact of Information and Communication Technology (ICT) Development on Economic Growth in Africa

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Abstract:-

Purpose - In order to accurately analyze the impact of Information and Communication Technology (ICT) development on economic growth in Africa, 51 African countries were selected from the 5 sub-regions thus; from the East, West, South, Central, and North Africa within 20 years from 2000 to 2019. Design/methodology/approach - The outcome of this paper is measured by estimating pooled ordinary least squares (POLS), random and fixed effects (RE & FE), and system-generalized method of moment models (sys-GMM). The individual internet users, mobile telephone subscription and fixed telephone subscribers are the ICT indicators with foreign direct investment, domestic credit provided by the private sector, and level of international trade serving as control variables. Findings - The findings show that: (1) ICT development has a statistically significant positive relationship with economic growth, (2) that the three ICT indicators are significantly different in their output determination, (3) the findings confirm that the "leapfrogging" hypothesis exists in the African context, (4) it is observed that percentage of people using the internet has the immense capacities to empower Africa to skip traditional developmental stages across all the estimates, (5) and in terms of the regressions for the sub-samples, it shows statistically significant differences in the output elasticity of ICT indicators. Suggestions - Based on the above findings, we suggest that it is necessary to propose policy recommendations to reduce costs caused by the use of communication technology facilities, including the cost of buying a cellular phone, Internet connectivity rates, and subscription rates.

Keywords:- *Africa; Economic Growth; ICT; Impact; Leapfrogging.*

I. INTRODUCTION

Africa's internet economy has been critically analyzed as one of the biggest potential markets in this 21st century, which has the propensity to drive the economic growth of the continent. The technological transformation and other propellers of growth are claimed to be one of the obligatory instruments of economic growth and prosperity for any country. It is therefore believed that to get an advantage from other instigators of growth, effective usage of Information Technology is crucial to keep up with the curve. Needless to say, that, for any African country or sub-region to bypass the traditional stages or processes required for any development and capacity building, ICT must be inculcated in every aspect of our daily dealings on the continent. This is a term known as "technology leapfrogging" (Fong, M.W.L. 2009). Though statistically wise internet users, broad-brand subscription, internet access, and telecommunication infrastructure in this region are low from those of developed countries, and in the last twenty years, mobile communications in this region have been exceptional since 2000. Lately, the digital startups in Africa are driving innovation in fast-growing sectors, including fintech, health tech, media and entertainment, e-commerce, e-mobility, and e-logistics, contributing to Africa's growing Internet gross domestic product (iGDP) which has been a massive driver to the contribution of the continent's economic growth.

ICT has been touted as the bedrock of economic growth; reports by the (United Nations, 2011) and (World Bank 2017) confirms that emerging economies, including China, South Korea, Hong Kong, and Singapore leapfrog the traditional development phase due to the in-depth application of ICT in their production processes. However, for Africa to fully benefit from the usage of ICT, the unskilled population must be equipped with the technical know-how and the cost outlay of ICT infrastructure must be managed to fully harness the opportunities that ICT brings to the continent.

Despite all this, the usage of ICT on the continent about mobile money transfers has recorded many successes, and as a tool, it has saved travel time thereby reducing transaction cost.

The largest Free Trade Agreement signed by the various African countries as a single market can boost and increase the economic growth of the continent. This can only happen when a conducive environment such as a better internet connectivity is created. Expanding the urban population, setting up and growing tech talent tool and a vibrant startup ecosystem must be a commitment that needs to be achieved.

On the other hand, there are therefore several factors that determine economic growth, and by definition, is the rise and combination of the goods and services produced in a country by all firms and enterprises over a certain period. Such economic factors include, social and political, foreign direct investment, financial development, employment rates, investment (both public and private), capital (human and physical), public expenditure, and exchange rates to mention a few, which impact economic growth, the implication of each are in their own distinct way. Hence, there is a mixture of factors that can have a major impact on the country's economic growth. Therefore, the study of economic growth is an ongoing event that is still gaining relevance in contemporary literature. The development and investment in ICT have become the stepping stone for growth in productivity, which has underpinned the foundation for improvement in the standard of living of the people. The use of ICT services has contributed to the positive transformation of lives and livelihoods in the rural African settings evidenced by job-creation, increased income, cost minimization, reduction in uncertainty and risk to mention a few.

An in-depth study has been carried out and documented on the relationship between ICT and economic growth in the literature, particularly for developed, emerging, developing, and exclusive studies on specific African economies due to the data on ICT variables.

Within the context of the "leapfrogging" hypothesis, this study fills that gap, which largely differs from similar works on the ICT-growth nexus by engaging a new dialogue, which is exclusive to evaluate the impact ICT development has on economic growth in Africa. The question to be asked is, will the impact of ICT on economic growth aid Africa to skip some developmental stages? In the quest to answer this important question, the three stated objectives of these studies will be the foundation on which the results of the question will be based on. They are, (1) to examine the impact of ICT development on economic growth in Africa, (2) to show whether the ICT "leapfrogging" hypothesis holds in the African context, and (3) to assess whether ICT development possesses growth-stimulating potentials in Africa, and to the best of our knowledge, this study will be one of its kind to aid the evaluation of that claim. In essence, the outcome of this study will bring about a revival in the area of policy discussions on how the developing ICT sector will generate a greater contribution to the economic growth of the continent and by extension engender a new course of action on how Africa can use ICT opportunities to advance the socio-economic goals of the continent. In 2001, Steinmueller explained that, for the "leapfrogging" hypothesis to hold, the impact of the output elasticity on the three ICT indicators should differ significantly across the five sub-regions: Central Africa, East Africa, North Africa, South Africa, and West Africa. That is, in realistic terms, any of the three ICT indicators that have the largest output determination should be the variable to provide evidence to enable Africa to skip traditional developmental stages in addition to validating the positive growth impact of ICT. The relationship impact that exists between ICT and economic growth will differ significantly in its output growth base on their contributions in the five sub-regions. Therefore, the ICT-growth relationship will be studied in terms of its methodological approach, and hence its empirical style will differ in several aspects: (1) the sample contains 51 African countries, (2) the focus is on the ICT flourishing dispensation, that is, from 2000-2019, and (3) four empirical techniques - pooled ordinary least squares (POLS), random and fixed effects (RE & FE) and system-generalized method of moments (sys-GMM) is applied. The rapid development and investment in ICT usage during these periods deem it a thought-provoking phenomenon to be investigated. Likewise, an augmented Cobb-Douglas production function, which consists of gross fixed capital formation, labor force participation rate, internet users, mobile subscribers, and fixed telephone subscription is employed with the level of international trade, financial development, and foreign direct investment as control variables. All data are rightfully sourced from the World Bank Development Indicators and Internet World Stats.

The subsequent sections of the study are arranged in this order: Section 2 will talk about the empirical relevant literature review of ICT impact on Africa and details formalized facts on the trend of ICT among African countries, Section 3 outlines the empirical approach and data, Section 4 discusses the results while Section 5 gives the summary of findings, conclusion, and recommendations.

II. EMPIRICAL LITERATURE REVIEW OF ICT IMPACT ON AFRICA

A major number of macro-level studies have been conducted on the relationship between ICT development and economic growth within the bracket of these four major worldwide economies; developed, emerging, developing, and underdeveloped states. Base on the scope of study and the econometric methodologies adopted, the evidence from these four major economies might be showing opposing results.

In developed countries, some studies have shown in the World Development Journal, as stated by Thoman Niebel, that ICT plays a significant role in developing 59 major states from 1995 to 2010, based on their empirical evidence. According to them, the observed excess of returns from the ICT investment enhanced the positive link between ICT and economic development. That is why, the developed region excessively used the advanced technology in their operating activities of a state compared to emerging and developing nations (Niebel, 2018). In the same line of studies, in 2020, Kashif Iqbal with others drives the same research on the Belt and Road (BRI) based on emerging states, especially China by stating that from 2000-2017, a positive migration and economic development has been seen in fifty-nine BRI states due to the continuous development of ICT projects within the region (Iqbal, Peng, & Hafeez, 2020). All these states focused on empirical research, and as a result, most scholars have proposed that developing proper legislation and policies to upgrade the ICT diffusion, R & D

investment, and economic growth initiatives in upcoming years will be the way forward.

In studies related to Africa-Specific Countries, Jeremiah Ejemeyovwi, (2018) with others majorly examines how such technology-based human development can upgrade the economic status of the under-developed states. In their empirical research analysis, they concluded that the investment in the ICT projects did not generate a statistically significant relationship with the African's development because of the existence of various factors that result in the attribution of relatively low telecommunication's investment accompanied by the high cost of technological acquisition in their hash policy environment (Ejemeyovwi, Osabuohien, & Osabohien, 2018). In the following year, Girmay Giday Haftu also empirically analyzed the influence of the internet and mobile phone on Sub-Sahara Africa's per capita income from 2006-2015. These scholars used panel data of 40 underdeveloped states in which the robust two-step system GMM outcomes depicted that the growth in mobile phone penetration directly contributed to the GDP per capita of this region. As a 10% increase in mobile phone, penetration causes a 1.2% change in the GDP per capita of the underdeveloped African state, so the improvement of such ICT skills reduces the poverty level by raising the per capita income of its population (Haftu, 2019). Recently, similar outcomes were generated by Simplice Asongu and Nicholas Odhiambo by considering how ICT modulates the impact of foreign direct investments (FDI) on the economic growth of 25 Sub-Saharan African states period of 1980-2014. Their empirical evidence is based on a generalized method of moments and concluded that ICT directly modulates the FDI to positively boost the net effect on the overall economic growth dynamics (that is real GDP, GDP, and GDP per capita) of this region (Asongu & Odhiambo, 2020).

From the Internet World Stats, the penetration rate of internet users in Africa stands at 39.3% translating into an internet growth rate of 11.5% whiles the rest of the world shows 62.5% showing a growth rate of 88.5% from December 2000 to September 2020. Considering the five sub-regions of Africa and their respective Internet penetration rate (% of the population), the statistics show that Kenya which is at the East part of Africa has the highest penetration rate of 87.2%, followed by Mauritius with 67.0% located at the Southern part of Africa, next is Morocco located at the Northern part of Africa with an internet penetration rate of 64.3%, Cabo Verbe, located at the West part of Africa also has a rate of 63.3% and finally Gabon at the Central part of Africa has a penetration rate of 58.8%. All these respective countries have the highest internet penetration rate at their various sub-regions of Africa as of the end of September 2020. On the number of individuals using the internet from the last day of December 2000 to the last day of September 2020, statistics reveal that Kenya had a record of 200,000 people using the internet as of December 2000 but by the close of September 2020, the figure stood at more than 46 million people, the next country, South Africa recorded 2.4 million as at December 2000 and had more than 32 million people using the internet as at September 2020. Subsequently, Egypt had recorded 450,000 people using the internet as of December 2000 and had catapulted its number to more than 49 million people. Nigeria which has the highest population in Africa had 200,000 people using the internet as at the end of December 2000 but had increased it to more than 126,000 million showing an increase of about 15% more of its population added to the bracket of the internet users and lastly Ethiopia which had a record of 10,000 people using the internet but as of September 2020, had increased its number to more than 20 million. (Internet World Stats). In a nutshell, the facts and figures from the Internet World Stats show that there has been a massive increase in the use of the internet on the continent which will eventually boost the economic growth of the continent as a result of using mobile phones in addition to multiple subscriptions to different service providers or networks.

III. DATA AND MODEL

The objective of this current study is to determine the impact of ICT infrastructure development on African countries' economic growth. The aspect of ICT infrastructure investment has been studied by taking different dimensions of it. These include internet usage, mobile subscription, and fixed telephone subscribers. The impact of all these dimensions is to be studied on the economic growth of African countries. For this purpose, the secondary panel data were collected from these countries for 20 years. The particular countries from which these data were collected include the five sub-regions of Africa (51 countries), thus Central Africa, East Africa, North Africa, South Africa and West Africa. To ensure that the reliability of the collected data and the accuracy of the results remain intact, the researcher has collected data from reliable databases such as the World Bank Development Indicators, Global Economy, Google-IFC report, and Internet World Stats.

3.1. Model Specifications

The key variables in these studies are categorized into dependent, independent, and control variables. The dependent variable is the GDP per capita (GDPPC) which is for measuring the country's economic growth. The independent variables which are for information and communication technology (ICT) include Internet usage (INTUSAGE), Mobile Telephone Subscriptions (MOBILE), and fixed telephone subscribers (FIXED TELE). The other independent variables are gross fixed capital formation (GFCF); and labor participation (LABOR). The study also includes control variables for robustness, such as financial development (FD); foreign direct investments (FDI), and trade (TRADE).

3.2. Summary statistics and correlation matrix analysis.

Table 1. below shows the relative summary statistics of these indicators for the full sample across the five sub-regions. The highest average gross domestic product per capita (GDPPC) for the full sample is US$2081.10. Likewise, the average gross fixed capital formation (% of GDP) shows at US$19.25. Also, the domestic credit provided by the private sector (DCPS) has an average of

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US$17.4. The labor participation rate (LABOR) stands at US$68.3 while foreign direct investment (FDI) depicts an average rate of US$4.6. The average of trade, which represents the level of international trade (% of GDP) records at US$54.6. On the ICT variables, Mobile Telephone Subscriptions (MOBILE) and fixed telephone subscribers (FIXED TELE) have an average figure of US$45.9 and US$2.9 respectively, whiles the internet records the average number of users at US$8.25.

Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDPPC	1000	2081.1310	3027.4470	0.0000	22942.580
GFCF	1000	19.2500	10.4600	0.0000	59.7230
DCPS	1000	17.4070	15.1750	0.0000	84.0520
LABOR	1000	68.2870	44.1950	0.0000	347.9970
FDI	1000	4.5760	8.2880	-11.6350	103.3370
TRADE	1000	54.5650	30.1250	0.0000	244.8880
MOBILE	1000	45.8610	43.4300	0.0000	198.1520
INTERNET	1000	8.2540	12.4020	0.0000	74.3760
FIXED TELE	1000	2.9070	4.7030	0.0000	30.3780

Source: Author's compilation

Acronyms: GDPPC: Gross Domestic Product per Capital; GFCF: Gross Fixed Capital Formation; and DCPS: Domestic Credit provided by Private Sector.

3.3 The theoretical framework and model Specification

The most commonly used model to analyze the impact of ICT investments on output growth is Solow's neoclassical model, where the technological factor, or total factor productivity, is a parameter of great importance. It includes all other factors of production that cannot be explained by capital and labor alone. Hence, technology is often determined by innovations, externalities, human capital, and investment decisions. There are reasons to believe in a positive relationship between the Solow residual and ICT indicators, making the neoclassical model suitable to use in this context. Also, to evaluate the development and its impact of ICT using the full and sub-samples, the study adopts a Cobb-Douglas production function, represented as

$$Y_{it} = A_{it}L_{it}^{\beta 1} + L_{it}^{\beta 2} + e^{uit}, \quad i = 1, 2, \dots\dots\dots\dots, N; \quad t = 1, 2, \dots\dots., T \quad \dots. \textbf{(1)}$$

Yit is output stock, A is the technological parameter affecting K and L; K and L are the stocks of capital and labor, respectively. This empirical approach modifies the methodology outlined by Solow, R.M. (1956). A vector of ICT variables, Z, a row vector of control variables, X, and regional dummy variables (to capture variations across the five sub-regions) is included to achieve this study's objectives. Without applying a constant return to scale by using a natural logarithm, the model can be transformed as follows:

$$lnY_{it} = \beta_0 + \beta_1 lnL_{it} + \beta_2 lnK_{it} + \beta_3 lnZ'_{it} + \beta_4 lnX'_{it} + \delta_i + \gamma_t + \mu_{it} \quad \dots. \textbf{(2)}$$

Where lnYit is the natural logarithm of GDPPC; lnKit, the natural logarithm of gross fixed capital formation (% of GDP); lnLit, the natural logarithm of labor participation, Zit is the vector of natural logarithms of ICT variables (internet usage, mobile subscription and fixed telephone subscribers);

Xit is the vector of control variables (Foreign direct investment, trade and financial development) in natural logarithms; δi represents year dummies (which controls for common stocks, such as the global financial crises of 2007-2009), γt indicates regional dummies; and uit is the general error term.

Furthermore, if the study variables are categorized, and dependent variables are for measuring the country's economic growth. These include GDP per capita (GDPPC). The independent variable, information, and communication technology (ICT) variables include Internet usage (INTUSAGE), mobile telephone subscriptions (MOBILE), and fixed telephone subscribers (FIXED TELE). The other independent variables are gross fixed capital formation (GFCF); and labor participation (LABOR). The study also includes control variables such as financial development (FD); foreign direct investments (FDI), and trade (TRADE). Based on all these variables, the following regression models for the two dependent variables can be developed;

$$GDPPC_{it} = \beta + \beta_1 LABOR_{it} + \beta_2 GFCF_{it} + \beta_3 MOBILE_{it} + \beta_4 FIXED_{it} + \beta_5 INTUSAGE_{it} + \beta_6 FD_{it} + \beta_7 FDI_{it} + \beta_8 TRADE_i + \delta_i + \gamma_t + \varepsilon_{it} \quad \dots\dots\dots\dots \textbf{(3)}$$

In the equation above, GDPPCit denotes economic growth, LABORit represents labor participation in Africa, GFCFit indicates non-ICT capital available in the continent, MOBILEit denote a mobile telephone penetration, FIXEDit represent fixed telephone subscriptions, INTUSAGEit measure the percentage of people using the Internet in Africa, FDit indicates the level of financial development, FDIit represent the net inflow of foreign direct investment in the region, and TRADEit represent the level of international trade. The error term is shown by εit. δi and γi represents

year and regional dummies respectively. i the country of data collection while t represents the time of data collection.

The research uses a panel of 51 countries (N) over 20 years. The survey is classified into five sub-regional outlines Central Africa, East Africa, North Africa, South Africa, and West Africa. To systematically determine the value of ICT for economic development, the research adopts the use of static and dynamic models. The econometric research is conducted on the complete sample and the sub-sample of the areas. The adoption of these techniques serves as robustness for each other to observe the accuracy of the effect of ICT variables on development. Static models are pooled ordinary least squares (POLS) that do not enable heterogeneity across panels and fixed effects (FE) models here consider panel heterogeneity, although dynamic models are generalized moment process systems (sys-GMM).

The research uses system-generalized methods of the moment (sys-GMM) to measure the ICT component's economic effect on the economy. It also uses the Fixed Effects (FE) model, which considers the panel's variability and the POLS as the baseline model for the whole study.

IV. RESULTS AND DISCUSSIONS

4.1. Pooled OLS estimation results

The results for the full sample estimation through the POLS are represented in table 2. The first two columns are showing the results of the main regression where gross domestic product per capita is the dependent variable and the ICT indicators have been included as independent variables. Whereas the factors like FDI, DCPS, FDIGDP act as control variables. The results in the first two columns show that there is the presence of a positive and significant association between the ICT variables and economic growth as depicted by GDPPC. The coefficients for MOBILE, FIXED TELE, and INTERNET are 0.3749%, 0.2924%, and 0.4155% respectively and the models estimated for robustness depict similar estimations as well in the third and fourth columns. These results are in with the findings of (Adeleye and Eboagu 2019; Amiri and Woodside 2017) who found a positive relationship impact of ICT variables and economic growth. However, the findings of this study contrast with the results of (Baharini and Quaffas 2019), who suggest a negative impact of the ICT variables on economic growth. Several valuable findings emerge from the results that is, the output of the coefficient for INTERNET is the largest indicating that an increase in Internet usage and subscription will have a stimulating effect on the economic growth of the continent compared to other ICT factors. In addition, our findings are in accordance with most previous empirical studies that showed a significant positive effect of the internet on economic growth in developing countries (Andrianaivo and Kpodar 2011; Sassi and Goaied 2013; Wamboye et al. 2015; Pradhan et al. 2018; etc.). The leapfrogging hypothesis is also found to be true among the three indicators. INTERNET is most probably the cause for the development and growth to occur in Africa. The positive effects of the estimates or coefficients of ICT indicators are harmonious with previous expectations as the presence of ICT presents a framework for the delivery of various services in the form of fintech, health tech, media and entertainment, e-commerce, e-mobility, and e-logistics. Moreover, the presence of technology improves the proficiency, productivity, and abilities of the labor force and further communication among firms and industries.

The gross fixed capital formation (GFCF) which is among the factors of production is found to have a positive and significant association for ICT regressions and is significant at the 1 percent level, respectively. The positive and significant association authenticates the role that capital formation plays in economic growth. This finding follows findings from similar studies from (Adeleye and Eboagu 2019) that show the positive and statistically significant relationship between economic growth and ICT variables. The capital input in this scenario is an important consideration for driving the economic growth in Africa. The impact of Labor is also found to be significant and positive, which is also according to the prior expectation that labor productivity is an essential factor for the stimulation of economic growth. The DCPS, however, has a negative association with economic growth showing that an increase in credit lend to the domestic sector will impede the growth of the continent because of the mismanagement of the facility.

Table 1. Pooled OLS estimation results (Dep. Variable GDPPC, log)

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	Main Regression		Robustness Check	
	[1]	[2]	[3]	[4]
GFCF, log	0.2968***	0.2940***	0.2968***	0.2940***
	(4.9036)	(5.0002)	(5.1370)	(5.0774)
Labour, log	0.3104***	0.0718	0.3104***	0.0718
	(5.4703)	(0.7567)	(5.4135)	(0.7860)
DCPS, log	-0.2728***	-0.2547***	-0.2728***	-0.2547***
	(-7.6820)	(-7.1414)	(-6.4492)	(-6.7532)
FDIGDP, log	0.0005		0.0005	
	(0.0296)		(0.0276)	
Internet, log	0.4155***		0.4155***	
	(13.8362)		(12.0444)	
Fixed Tele., log	0.2924***	0.3939***	0.2924***	0.3939***
	(11.8979)	(18.4797)	(10.7004)	(16.6317)
Trade, log		0.2081*		0.2081*
		(2.1916)		(2.0778)
Mobile, log		0.3749***		0.3749***
		(12.7453)		(10.2086)
East Africa	-0.5510***	-0.5393***	-0.5510***	-0.5393***
	(-7.9512)	(-8.3514)	(-6.7310)	(-6.9993)
South Africa	-0.4095***	-0.4827***	-0.4095***	-0.4827***
	(-4.2931)	(-5.2772)	(-3.8150)	(-4.7789)
West Africa	-0.2826***	-0.3964***	-0.2826**	-0.3964***
	(-3.4161)	(-4.9311)	(-2.7742)	(-4.0866)
Central Africa	-0.6174***	-07148***	-0.6174***	-0.7148***
	(-9.2718)	(-11.4598)	(-7.7173)	(-8.9502)
Constant	5.9507***	5.7573***	5.9507***	5.7573***
	(20.7738)	(21.7424)	(20.1919)	(20.5477)
Year Dummies	YES	YES	YES	YES
R-Squared	0.7459	0.7276	0.7459	0.7276
F Statistic	69.5399	70.4479	73.2846	75.4926
No. of Obs.	717.0000	795.0000	717.0000	795.0000

Source: Author's Compilations

Acronyms: EA: East Africa, SA: South Africa; WA: West Africa; CA: Central Africa; and NA: North Africa. The ***, **, * are statistically significant at 1%, 5%, and 10% levels respectively, t-statistics (in parentheses) are based on white heteroscedasticity-consistent std. errors

The control variable TRADE is statistically significant and shows an asymmetric relationship with the economic growth at the 10 percent level.

The year dummies were controlled and the goodness of fit of the models shows that the proportion of variation in the dependent variable explained by the regresses varies from 72%-75%. Across all four models, the values of the F-statistic show that the regresses are jointly significant and contribute to explaining the economic growth.

The results for the full sub-sample for the internet and telephone regression through the POLS estimator are exhibited in table 3, while those for the mobile and fixed telephone are depicted in table 4. The findings of these estimations show that the coefficient for the internet is highest in Central Africa (0.4186%) followed by East Africa (0.2810%). In accordance with the leapfrogging hypothesis, it can be inferred that Internet subscriptions can be provided for facilitating the development in Central Africa with comparison to the other regions of the continent. The fixed telephone elasticities are positive for the regions as well, showing the coefficient is highest in South Africa (0.5223), followed by Central Africa (0.3659), East Africa (0.3343%), North Africa (0.3253%), and the lowest in West Africa (0.0626%), showing the adoption in South Africa will contribute to the facilitation of the development. The coefficients are statistically significant at 1 percent for CA, SA, EA, and NA and are significant at 10 percent for WA. These results show that internet usage and subscriptions will result in the stimulation of growth in the continent compared to the usage of mobiles. The results are statistically significant for other factors as well and impose asymmetric effects on the economic growth of the continent.

Table 2. Sub-regions' pooled OLS results (Dep. Variable: GDPPC, log)

Variables	CA	EA	NA	SA	WA
GFCF, log	0.0471	-0.2190*	-0.3815*	0.8574***	0.1181
	(0.2181)	(-2.0876)	(-2.5329)	(6.8907)	(1.6989)
LABOUR, log	0.2762	0.5483***	0.6226	-0.3384	-0.1182
	(0.5179)	(4.9382)	(1.8876)	(-1.3010)	(-0.9584)
DCPS, log	-0.4967***	-0.0738	-0.3304***	0.0382	0.1430**
	(-3.6938)	(-1.2199)	(-4.1452)	(0.5188)	(2.9206)
FDIGDP, log	-0.1087	0.0859***	-0.1233*	0.0470	-0.0083
	(-1.8453)	(3.8069)	(-2.5572)	(1.3005)	(-0.3141)
TRADE, log	0.5749	-0.3874**	0.2287	-0.1204	-0.0601
	(1.3191)	(-3.0288)	(0.6794)	(-0.4881)	(-0.4722)
INTERNET, log	0.4186***	0.2810***	0.2627***	0.2079***	0.2634***
	(7.1067)	(10.3910)	(8.5629)	(6.5136)	(13.8212)
FIXED TELE, log	0.3659***	0.3343***	0.3253***	0.5223***	0.0626*
	(6.7539)	(12.3451)	(5.3820)	(12.6966)	(2.1108)
Constant	4.8085***	6.4637***	5.5893***	5.8794***	6.4118***
	(5.1421)	(14.8767)	(12.9249)	(9.9241)	(18.8325)
R-Squared	0.7930	0.8624	0.7862	0.8761	0.6883
F Statistic	51.4317	140.5482	53.0672	142.4611	70.9734
No. of Obs.	102	165	109	149	233

Source: Author's Compilations

Acronyms: EA: East Africa, SA: South Africa; WA: West Africa; CA: Central Africa; and NA: North Africa. The ***, **, * are statistically significant at 1%, 5% and 10% levels respectively, t-statistics (in parentheses) are based on white heteroscedasticity-consistent std. errors

The results depicted in Table 4 also show that the mobile telephone subscription and the presence of fixed telephone subscribers produce significant effects on the growth of the five sub-regions of the continent. In the adoption of Mobile, the North African region has the highest elasticity (0.2767%), followed by the central African region (0.2722%), South Africa (0.2190%), East Africa (0.2156%), and has the least effect in West Africa (0.1899), relative to the other sub-regions. Similarly, the output for the fixed telephone elasticities shows that there is a positive and significant association between this ICT factor and the economic growth of African regions. The highest elasticity is present in South Africa (0.5214%), followed by Central Africa (0.4077%), North Africa (0.3876%), and East Africa (0.3681%) and has the least effect in West Africa (0.1211%). These elasticities or the coefficients depict that the impact of the fixed telephone subscriptions is expected to bring about more impactful and developmental changes in the continent.

Table 4. Sub-regions' pooled OLS results (Dep. Variable: GDPPC, log)

	CA	EA	NA	SA	WA
GFCF, log	0.0598	-0.0991	-0.5140***	0.7758***	0.1482
	(0.2560)	(-0.8780)	(-4.2205)	(6.5712)	(1.8769)
LABOR, log	0.1649	0.6023***	0.4136	-0.3124	-0.0825
	(0.2829)	(5.0592)	(1.7840)	(-1.2620)	(-0.5881)
DCPS, log	-0.1932	0.0496	-0.2923***	0.0683	0.1813**
	(-1.4544)	(0.8181)	(-5.0602)	(1.0058)	(3.1053)
FDI, log	-0.1061	0.0991***	-0.1653***	0.0378	-0.0211
	(-1.6488)	(4.1671)	(-4.0314)	(1.0722)	(-0.6763)
TRADE, log	0.7467	-0.5282***	0.2462	-0.1337	-0.2287
	(1.5696)	(-3.9641)	(1.0303)	(-0.5730)	(-1.6014)
MOBILE, log	0.2722***	0.2156***	0.2767***	0.2190***	0.1899***
	(4.7930)	(8.1025)	(11.8174)	(7.2892)	(10.4970)
FIXED TELE, log	0.4077***	0.3681***	0.3876***	0.5214***	0.1211***
	(7.0922)	(12.8949)	(8.0632)	(13.3356)	(3.7452)
Constant	3.5897***	5.7769***	6.2168***	5.6117***	6.4351***
	(3.6919)	(12.7907)	(16.6272)	(10.2259)	(16.4773)
R-Squared	0.7427	0.8380	0.8477	0.8789	0.5906
F Statistic	40.8276	121.9650	85.0550	154.5189	47.6026
No. of obs.	107	173	115	157	239

Source: Author's Compilations

Acronyms: EA: East Africa, SA: South Africa; WA: West Africa; CA: Central Africa; and NA: North Africa. The ***, **, * are statistically significant at 1%, 5% and 10% levels respectively, t-statistics (in parentheses) are based on white heteroscedasticity-consistent std. errors

In summary from the results obtained in tables 3 and 4, the stimulating impact of ICT factors and the leapfrogging effect of the internet, mobile and fixed telephone subscriptions have been demonstrated. In terms of the impact generated by the outputs of the coefficients, the fixed telephone ranks highest followed by internet and mobile as the dominant enhancers of the economic growth in Africa and contribute to the leapfrogging effect present among the ICT indicators.

4.2 Random and fixed effect result

The pooled OLS estimators may present some degree of heterogeneity, thus the random and fixed effects models are estimated for augmenting the results. The results of the panel fixed and random effects estimation are presented in table 5 for the full sample. The results of the estimation show that the findings are similar to that of the POLS estimation (Table 2), that's, the internet reveals the consistencies of both INTERNET and FIXED TELE is significant growth contributors. Moreover, the leapfrogging hypothesis, the concept that the areas that have poorly developed economy and technology can transcend themselves forward through the adoption of modern systems holds with the internet, which has the largest coefficient showing that internet subscription has the most potent impact on the economic growth of Africa and that it can cause Africa to skip through various developmental changes.

Table 3. Fixed and random effects results (Dep. Variable: GDPPC, log)

	Main Regression		**Robustness Check**	
	FE	**RE**	**FE**	**RE**
GFCF, log	0.0853**	0.0602*	0.0853	0.0602
	(3.3025)	(2.0891)	(1.6530)	(1.1171)
LABOR, log	-0.4011***	-0.3289***	-0.4011***	-0.3289***
	(-10.8610)	(-8.2916)	(-5.0402)	(-3.9799)
DCPS, log	-0.0838***	-0.0954***	-0.0838	-0.0954
	(-4.0933)	(-4.1488)	(-1.6461)	(-1.7258)
FDI, log	-0.0018	-0.0050	-0.0018	-0.0050
	(-0.2615)	(-0.6419)	(-0.1346)	(-0.3509)
INTERNET, log	0.1360***		0.1360***	
	(10.0818)		(5.2076)	
FIXED TELE, log	0.0161	0.0665***	0.0161	0.0665*
	(1.1309)	(4.4279)	(0.4607)	(2.0668)
MOBILE, log		0.1253***		0.1253***
		(9.4729)		(5.1465)
Constant	8.1758***	7.8829***	8.1758***	7.8829***
	(57.1921)	(45.5602)	(26.9053)	(21.5805)
Year Dummies	YES	YES	YES	YES
R-Squared	0.8415		0.8415	
F Statistic	136.7793		37.5507	
Hausman (*p-value)*	0.0000		0.0000	
No. of obs.	717	751	717	751

Source: Author's Compilations

Acronyms: RE: Random Effects; FE: Fixed Effects. The ***, **, * are statistically significant at 1%, 5% and 10% levels respectively, t-statistics (in parentheses) are based on white heteroscedasticity-consistent std. errors

Additionally, the effects of labor and capital investments (positive) are also consistent with the findings reported in Table 2. However, the DCPS, domestic credit to the private sector, which shows the amount of credit extended to the domestic market for extension and development has a negative effect on the economic growth and is significant on the 1 percent level. The goodness of fit, that's the R-squared value of the models shows that the proportion of variation in the dependent variables explained by the independent and control variables is 84.15 percent and the F-statistic is also showing that the regresses are jointly significant in explaining the change and growth in the economic output of Africa. Moreover, in both the models, the fixed effects are significant as indicated by the Hausman test.

4.3. System GMM results (Dep. Variable: GDPPC, log)

In the next step, to evaluate the robustness of the results, the regresses are estimated through the application

of the systematic GMM approach which controls for the probable heteroscedasticity, endogeneity, and effect of omitted variables. The results of the estimation are depicted in table 6. All three ICT indicators, thus internet, mobile, and fixed telephone are significant whereas the coefficient for internet is negative. The results indicate that the unobserved heterogeneity is now accounted for. The results again indicate the leapfrogging potential for the ICT indicators, stating that they can boost the economic growth of the African economies as they have considerably significant output elasticities. Concerning the goodness of fit of the model, there is evidence that no serial correlation prevalent in the study as the AR2 statistics and the Hansen statistic is showing that the null hypothesis cannot be rejected at the 5 percent level of significance. Therefore, the results of this estimation can be used for drawing inferences about factors involved in the study.

Table 4. System GMM results (Dep. Variable: GDPPC, log)

	Main Regression		**Robustness Check**	
	1	2	3	4
L.GDPPC, log	0.9086***	0.9770***	0.9086***	0.9770***
	(60.7017)	(58.2115)	(14.4247)	(20.5606)
GFCF, log	0.0332*	0.0492***	0.0332	0.0492
	(2.2212)	(3.3741)	(0.9187)	(1.1489)
LABOR, log	-0.0212	0.0152	-0.0212	0.0152
	(-0.6642)	(0.7429)	(-0.3338)	(0.2787)
DCPS, log	-0.1080***	-0.0721***	-0.1080*	-0.0721
	(-6.0978)	(-5.6067)	(-2.0505)	(-1.8713)
FDI, log	0.0119	-0.0368**	0.0119	-0.0368
	(1.4096)	(-2.9923)	(0.4880)	(-0.7766)
INTERNET, log	-0.0450***		-0.0450	
	(-3.7534)		(-1.2752)	
FIXED TELE, log	0.1643***	0.0144	0.1643*	0.0144
	(8.5705)	(0.8878)	(2.0814)	(0.2927)
MOBILE, log	0.0678***			0.0678*
		(6.4530)		(2.1625)
Constant	-38.5202***	34.6199***	-38.5202	34.6199*
	(-6.7293)	(7.2476)	(-1.4573)	(2.1057)
Year	Yes	Yes	Yes	Yes
Instruments/Groups	43/48	43/48	43/49	43/50
AR (2)	0.075	0.064	0.079	0.048
Hansen	0.211	0.205	0.211	0.205
F Statistic	38870.06	211949.6	3783.84	16263.53
No. Obs.	677	677	677	677

Source: Author's Compilations

Acronyms: The null hypothesis of instrument validity cannot be rejected at the 5% significance level for the internet/mobile regression robustness checks. The ***, **, * are statistically significant at 1%, 5% and 10% levels respectively, t-statistics (in parentheses) are based on white heteroscedasticity-consistent std. errors

V. SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1. Summary:

This study seeks to evaluate the relationship that exists between ICT development and economic growth in Africa within the context of the "leapfrogging hypothesis."

Many countries across the globe have come to recognize the importance of ICT development and how the investment in such areas has yielded much result with respect to the economic growth of the African continent of which has attracted foreign direct investments including both advanced and evolving economies. Similarly, ICT development has become a priority for policymakers, central governments, and digital regulators. Research on the nexus of the impact of ICT development and its investment on the economic growth has been done extensively in the developed and other emerging markets, despite all these, Africa still lacks enough literature on the interaction impact of ICT development on the economic growth of the region. The study used pooled ordinary least squares (POLS), random and fixed effects (RE & FE) and system-generalized method of moment models (sys-GMM) estimation techniques to investigate the impact of ICT development on economic growth in Africa. The alternative estimator of the random effect and the fixed effect were used to cross-wise the sturdiness of the results of the main estimators. Several valuable findings emerge from the results that are, the output of the coefficient for INTERNET is the largest, indicating that an increase in the Internet usage and

subscription will have a stimulating effect on the economic growth of the continent compared to other ICT factors. In addition, our findings are in accordance with most previous empirical studies that showed a significant positive effect of the internet on economic growth in developing countries (Andrianaivo and Kpodar 2011; Sassi and Goaied 2013; Wamboye et al. 2015; Pradhan et al. 2018; etc.). The leapfrogging hypothesis is also found to be true among the three indicators of which INTERNET is most probably the cause for development and growth to occur in Africa. The findings reported by this paper were in accordance with respect to the three objectives stated as follows: The first objective of the study was to examine the impact of ICT development on economic growth in Africa. The second was to show whether ICT "leapfrogging" hypothesis holds in the African context, and lastly was to assess whether ICT development possesses growth-stimulating potentials in Africa. The results again indicate the leapfrogging potential for the ICT indicators, stating that they can boost the economic growth of the African economies as they have considerably significant output elasticities. Finally, this study seeks to establish the role of ICT development and how its investment impact will boost the economic growth of the African continent.

5.2. Conclusion:

Within the context of the "leapfrogging" hypothesis, this study examines the impact of ICT development on economic growth in Africa. By using exclusive panel data of 51 African countries from 2001-2019, a contribution is made to the ICT-economic growth literature on Africa. Three ICT indicators (internet usage, mobile subscriptions, and fixed telephone subscribers) and dynamic modeling techniques were deployed. A remarkable and compelling report was made which shows a robust finding that ICT has a statistically significant impact on economic growth in Africa. The statistically significant coefficient of ICT variables particularly Internet usage and mobile subscription has maintained consistently positive and statistically significant relations to economic growth across all model specifications which is able to leapfrog Africa of its developmental stages. That's the new trend of discussion and results this study seeks to provide. Among the "leapfrogging" hypothesis and the "leapfrogging potentials of the ICT variables, internet usage holds not only for the continent as a whole but also for the sub-regions. The other variables like gross fixed capital formation, fixed telephone subscription, and mobile subscribers, foreign direct investment, financial development, and credit provided by the private sector also have an important role to play since is also a propeller for growth in the region, while labor force participation in another way has a negative impact on economic growth. The huge number of the unproductive and unskilled labour force in Africa has been a major concern in the continent that needs to be addressed, if not this effect will continue to erode the economic growth of the region. Setting up a human library resource training center to empower the unskilled labor force of the region will be the way forward to build human resource capacity for the future, which can complement the usage of ICT base on the socio-economic and political policy of the various regions having a foreshadow of what the world holds for tomorrow that will boost the economic growth of the region.

The remarks that these studies seek will be boxed in the developmental-enhancing potentials of ICT that must be made as a policy that needs to be implemented by African governments and stakeholders, which is not far-fetched. Notwithstanding, a big percentage of African countries are promoting the use of the internet and mobile subscriptions, which serves as a stepping stone for economic growth but the cost associated with its usage discourages the continuity and does not encourage others to come into the bracket of the modern society for the greater impact of economic growth. That is, to be globally and economically relevant, concerted efforts must be directed toward coupling the internet benefits of ICT usage. To achieve this, there must be a need to reduce the rising costs attributable to the usage of communication technology facilities such as the cost of buying a cellular phone, Internet connectivity rates, subscription rates, and other related costs associated with the usage of ICT.

5.3. Policy Implications and Recommendations:

Several policy implications have emanated from this study. The first policy implication from the findings of this study is that the impact of ICT development has become an important determinant of economic activity for developing economies in Africa, which is linked to objective one of this study. It is therefore recommended that developing country governments in Africa should affect ensuring that ICT and all of its application opportunities are put in place to create a friendly and competitive business environment in the respective countries to attract FDI inflows and digital space for businesses to flourish. Finally, policy measures must be put in place to reduce ICT costs and develop the sector into a more friendly, economic, and productive use of which its impact can be easily seen.

5.4. Limitations of the Study and Suggestions for Future Research:

Despite the efforts put in this study, certain limitations cannot be avoided. First, the scope of the study is narrow specifically to frontier markets in Africa, which may not be sufficient for the general conclusion that the impact of ICT development and its investment effectively promote economic activity. Therefore, widening the scope of the research in the future to cover other continents for comparative analysis will be a source of significant research contribution to the literature. This study has included other determinants of economic growth that provided further insight on the determinants of economic growth among developing countries in Africa. However, we were unable to assess the interaction effect between these other determinants on economic growth in this study. Further research in this regard must fill this research gap.

Appendix

Table 5. Correlation Matrix

Variables	Economic Growth	Capital	Labour	Trade	Domestic Credit	FDI	Mobile Cellular	Intusage	Telephone	Servers
Economic Growth	1									
Capital	0.1377	1								
Labour	0.4064	0.3465	1							
Trade	0.44	0.1714	0.662	1						
Domestic Credit	0.2296	0.0721	0.1037	0.1295	1					
FDI	0.0444	0.1269	0.2411	0.2598	-0.0171	1				
Mobile Cellular	0.4622	0.2036	0.234	0.2315	0.4229	0.0358	1			
Intusage	0.3861	0.1548	0.1665	0.1635	0.477	0.0108	0.6654	1		
Telephone	0.5733	-0.0309	0.3445	0.3022	0.4943	0.0465	0.3824	0.4394	1	
Servers	0.2593	-0.0998	0.1345	0.1065	0.0596	0.0613	0.1794	0.0543	0.207	1

Source: Author's Compilations

Table 8. List of Countries

Country name	Region	Country name	Region
Algeria	NA	Liberia	WA
Angola	CA	Libya	NA
Benin	WA	Madagascar	SA
Botswana	SA	Malawi	SA
Burkina Faso	WA	Mali	WA
Burundi	EA	Mauritania	NA
Cabo Verde	WA	Mauritius	SA
Cameroon	CA	Morocco	NA
Central African Republic	CA	Mozambique	SA
Chad	CA	Namibia	SA
Comoros	EA	Niger	WA
Congo, Dem, Rep	EA	Nigeria	WA
Congo, Rep	EA	Rwanda	EA
Cote d' I voire	WA	Sao Tome and Principe	CA
Djibouti	EA	Senegal	WA
Egypt, Arab Rep.	NA	Seychelles	EA
Equatorial Guinea	CA	Sierra Leone	WA
Eritrea	CA	South Africa	SA
Ethiopia	CA	Sudan	NA
Gabon	CA		
Gambia, The	WA	Tanzania	EA
Ghana	WA	Togo	WA
Guinea	WA	Tunisia	NA
Guinea-Bissau	WA	Uganda	EA
Kenya	EA	Zambia	EA
Lesotho	SA	Zimbabwe	EA

Source: Author's Compilations.

Acronyms: EA: East Africa; SA: South Africa; WA: West Africa; CA: Central Africa; and NA: North Africa.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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REFERENCES

[1]. Adeleye and Eboagu (2019). Evaluation of ICT development and economic growth in Africa.
[2]. Amiri, S., & Woodside, J. M. (2017). Emerging markets: the impact of ICT on the economy and society. Digital Policy, Regulation, and Governance.
[3]. Andrianaivo, Mihasonirina, and Kangni Kpodar. 2011. ICT, Financial Inclusion, and Growth: Evidence from African Countries, Working Paper No. 11/73, International Monetary Fund, IMF Working Paper
[4]. Asongu, S. A., & Odhiambo, N. M. (2020). Foreign direct investment, information technology, and economic growth dynamics in Sub-Saharan Africa. Telecommunications Policy, 44(1), 101838.
[5]. Bahrini, R., & Qaffas, A. A. (2019). Impact of information and communication technology on economic growth: Evidence from developing countries. Economies, 7(1), 21.
[6]. Ejemeyovwi, J. O., Osabuohien, E. S., & Osabohien, R. (2018). ICT investments, human capital development, and institutions in ECOWAS. International Journal of Economics and Business Research, 15(4), 463-474.
[7]. The e-Conomy Africa 2020 & Google-IFC report from https://www.ifc.org/wps/wcm/connect/publications_ext_content/ifc_external_publication_site/publications_listing_page/google-e-conomy.
[8]. Fong, M.W.L. (2009). Technology leapfrogging for developing countries. Encyclopedia of Information Science and Technology, Second Edition, 7 pages.
[9]. Haftu, G. G. (2019). Information communications technology and economic growth in Sub-Saharan Africa: A panel data approach. Telecommunications Policy, 43(1), 88-99.
[10]. Iqbal, K., Peng, H., & Hafeez, M. (2020). Analyzing the Effect of ICT on Migration and Economic Growth in Belt and Road (BRI) countries. Journal of International Migration and Integration, 21(1), 307-318.
[11]. Internet World Stats (https://www.internetworldstats.com/stats1.htm)
[12]. Niebel, T. (2014). ICT and economic growth - comparing developing, emerging, and developed countries. Paper presented at the IARIW 33rd General Conference, Rotterdam, the Netherlands, August 24-30, 2014.
[13]. Pradhan, R. P., Mallik, G., & Bagchi, T. P. (2018). Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. IIMB Management Review, 30(1), 91-103.
[14]. Sassi, S., & Goaied, M. (2013). Financial development, ICT diffusion, and economic growth: Lessons from MENA region. Telecommunications Policy, 37(4-5), 252-261.
[15]. Solow, R. M. (1956). A contribution to the theory of economic growth. The quarterly journal of economics, 70(1), 65-94.
[16]. Steinmueller, W.E. (2001). ICTs and possibilities for leapfrogging by developing countries. International Labour Review, 140(2), 1–18.
[17]. United Nations (2011). Information economy report 2011: ICTs as an enabler for private sector development. Retrieved from https://www.wto.org/english/tratope/inftece/sympmay12e/ speaker19fredriksson.pdf
[18]. World Bank (2017). Leapfrogging: the key to Africa's development? From constraints to investment opportunities. Retrieve from http://documents.worldbank.org/curated/en/121581505973379739/pdf/
[19]. 119849-WP-PUBLIC-Africa-Leapfrogging-text-with-dividers-9-20-17-web.pdf.
[20]. World Bank (2017). World development indicators. Retrieved from https://data.worldbank.org/ data-catalog/world-development-indicators.