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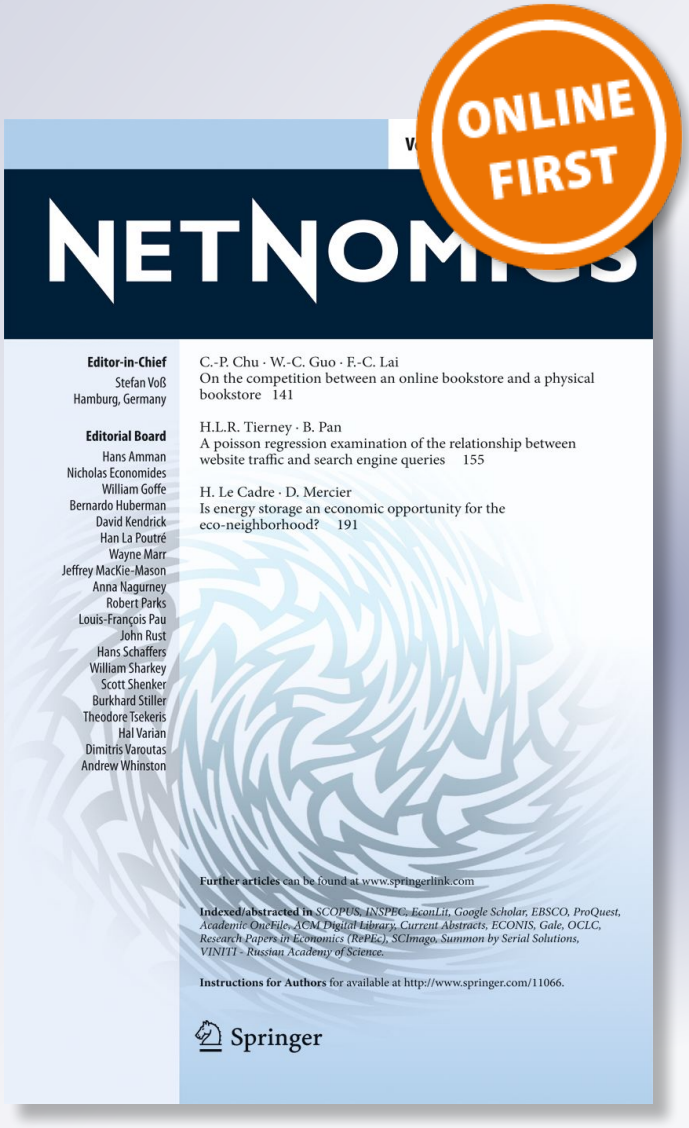

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Evaluation of ICT development and economic growth in Africa

Ngozi Adeleye[1] · **Chiamaka Eboagu**[1]

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Abstract

This paper evaluates the impact of information and communication technology (ICT) on economic growth in Africa based on a sample of 54 countries from 2005 to 2015. The sample is further divided along five sub-regions and the outcomes measured by estimating pooled ordinary least squares, random and fixed effects and system generalised method of moments models. The ICT indicators are individuals using the internet, mobile subscribers and fixed telephone subscribers with trade openness and inflation rate as control variables. Findings, among others, reveal that (1) ICT development has a statistically significant positive relationship with economic growth, (2) the output elasticities of the three ICT indicators are significantly different, (3) the "leapfrogging" hypothesis holds, (4) mobile subscription has the largest output elasticity across all specifications and has the biggest potentials to enable Africa to skip traditional developmental stages, (5) regressions for the sub-samples show statistically significant differences of the output elasticity of ICT indicators. The study recommends that concerted efforts must be directed towards harnessing the inherent benefits of ICT usage which includes reducing the rising cost attributable to the usage of communication technology facilities such as the cost of buying a cellular phone, internet connectivity rates, subscription rates and so on.

Keywords ICT · Economic growth · Leapfrogging · Africa · Pooled OLS · Static models · GMM

✉ Ngozi Adeleye
ngozi.adeleye@covenantuniversity.edu.ng
http://cruncheconometrix.com.ng/

Chiamaka Eboagu
eboaguchiamaka@gmail.com

[1] Department of Economics and Development Studies, Covenant University, Ota, Ogun State, Nigeria

1 Introduction

Several factors determine economic growth which refers to a rise in the output that an economy produces over a period of time. Such factors include, but are not limited to, human capital development, institutional framework, natural resources development, labour productivity, physical capital and information and communication technology (ICT). It is noteworthy that a country's socio-economic development hinges on the rate of growth of its productivity, hence, the study of economic growth is still gaining relevance in the contemporary literature. Needless to say that developmental progress is not feasible without economic growth. Importantly, productivity growth underpins the foundation for improvements in the standard of living, and investment in ICT is a prominent driver of growth. In relation to Africa, the continent became the world's third-fastest growing region after its economy enhanced post-2000 [19] and this growth was largely attributable to the increase in domestic investment in the services sector largely influenced by better ICT usage and efficiencies [1, 2]. Particularly in rural African settings, the usage of ICT services has contributed to the positive transformation of lives and livelihoods evidenced by job-creation, increased income, cost minimisation, reduction in uncertainty and risk, familial bonding to mention a few [2, 3, 22].

ICT, on the other hand, is a general term that includes any communication device or application, encompassing cellular phones, computers, network hardware and software, satellite systems and so on. It comprises the storage, retrieval, conversion and transmission of information in addition to the automation of processes, controls and information production. It is a major factor in shaping the new global economy which produces rapid changes in societies and in recent times it has basically changed communication patterns and business engagements. At country-level, ICT allows countries to sidestep traditional stages or processes required for development and capability building, a situation termed as "technology leapfrogging" [9, 14, 17, 22]. In other words, it is the ability to use ICT to skip traditional paths through "*bypassing some of the processes of accumulation of human capabilities and fixed investment in order to narrow the gaps in productivity and output*" [17]. According to United Nations [20] and World Bank [22] Reports, ICT is the bedrock for economic growth from the experiences of the emerging economies of Asia, such as China, South Korea, Hong Kong, and Singapore who have been able to skip production and developmental stages due to the massive adoption of ICT while Africa, on the other hand, is yet to fully harness the opportunities of ICT for growth perhaps due to the cost outlay of ICT infrastructures and the vast majority of the population who are largely unskilled and unequipped with the necessary technological skills [6, 9]. Though, the continent has recorded successes in the use of ICT for mobile money transfers, and as a tool to save travel time thereby reducing transaction costs [22].

The ICT-economic growth relationship has been extensively documented in the literature, particularly for developed and emerging economies [4, 14, 21] with sparse exclusive studies on Africa [3, 5] owing largely due to a lack of data on ICT variables. Hence, this study fills that gap and differs from similar works on the ICT-growth nexus by engaging a new discourse which is to exclusively examine the impact of ICT

development on economic growth in Africa within the context of the "leapfrogging" hypothesis. That is, can Africa use ICT to skip some developmental stages through its impact on economic growth? To the best of our knowledge, this study is the first to evaluate the ICT-growth relationship for Africa within the "leapfrogging" hypothesis framework. The study has three objectives: (1) to show whether the "leapfrogging" hypothesis holds, (2) to analyse the impact of ICT on the economies of African countries in a bid to draw out its significance and (3) to assess if it possesses growth-stimulating potentials. The outcome of this study will motivate policy discussions on developing the ICT sector for greater contributions to economic growth and by extension engender a new dialogue on how Africa can use ICT opportunities to advance the socio-economic goals of the continent best. As defined by Steinmueller (2001), for the 'leapfrogging' hypothesis to hold, the output elasticities of ICT effect for the three indicators should differ significantly across the five sub-regions: Central Africa, East Africa, North Africa, South Africa and West Africa.[1] That is, the output elasticities that are largest among the three ICT indicators should provide evidence on which indicator enables Africa to skip traditional developmental stages in addition to substantiating the positive growth effect of ICT.

To analyse the ICT-growth relationship, we show whether the contributions of ICT to output growth significantly differ among Africa's five sub-regions. Our empirical approach modifies the methodology outlined in Niebel [14] and differs in several aspects: (1) the sample contains all of Africa's 54 countries, (2) the focus is on the ICT boom era, that is, 2005-2015, and (3) four empirical techniques - pooled ordinary least squares (POLS), random effects (RE), fixed effects (FE) and system generalised method of moments (sys-GMM) are applied. The rapid increase in ICT adoption and usage during these periods deem it an interesting phenomenon to be investigated. Furthermore, an augmented Cobb-Douglas production function which consists of gross fixed capital formation, labour force participation rate, internet users, mobile subscribers and fixed telephone subscribers is employed with trade openness and inflation rate as control variables. All data is sourced from the World Bank [23].

The rest of the study is structured as follows: Section 2 reviews relevant empirical literature and details stylized 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 concludes.

2 Literature review and review of ICT usage in Africa

A large number of macro-level studies on the relationship between ICT development and economic growth have been carried out with opposing results which is often attributable to the scope of study and the econometric methodologies adopted.

[1] Niebel [14] in his article "*ICT and Economic Growth - Comparing Developing, Emerging and Developed Countries"* posited that a 'leapfrogging' effect will imply that the output elasticities of ICT in developing and emerging countries should be larger than those in developed countries.

Some studies analyse ICT in relation to economic growth, inclusive growth, financial intermediation, human capital development, and knowledge economy to mention a few. For instance, Niebel [14] using various panel data regressions across a sample of 59 developed, emerging and developing countries from 1995 to 2010 confirms that the contributory effects of ICT-capital on output growth is higher in developed economies. In the same vein, Dedrick, Kraemer, and Shih [7] from a sample of 45 upper-income developing and developed countries for the period 1994 to 2007 show that output elasticities of ICT stock is slightly larger in developed than in the upper-income developing countries. Likewise, Papaioannou and Dimelis [15] find that the effect of ICT capital stock on labour productivity growth is stronger in developed than in developing countries from a sample of 22 developed and 20 developing countries for the period 1993 to 2001. Similarly, the study by Jorgenson and Vu [11] with particular reference to Asia, provides evidence on the contribution of ICT to growth in developing, emerging and developed countries and likewise Vu [21] shows that among a panel of 107 developing, emerging and developed countries, ICT is a strong predictor of economic growth.

On studies related to Africa, Batuo [3] using a sample of 44 African countries from 1990 to 2010, finds that ICT investment is subject to increasing returns, demonstrating that an increase in telecommunications investment produces further growth. Adopting both system GMM and OLS estimation techniques, the results further suggest that real per capita GDP rises between 0.5% and 0.8%, following an increase in teledensity by 10 people per 100 inhabitants providing evidence on the positive contribution of telecommunications to Africa's regional economic growth. Similarly, Chavula [5] from a sample of 49 African countries (1990 to 2007) uses an endogenous growth model to provide evidence on the significant impact of telephone main lines and mobile telephony on living standards while Internet usage does not show a significant influence on productivity. Also, Asongu and Le Roux [1] with a sample of 49 sub-Saharan African (SSA) countries from 2002 to 2012, show that policies designed to boost ICT (mobile phone, internet, telephone) penetration will increase inclusive development in the post-2015 sustainable development agenda. Likewise, Kuada [12] shows that the knowledge economy is central to economic and human developments. However, Ejemeyovwi and Osabuohien [8] from a panel of 15 West African countries from 2004 to 2014 show that mobile subscription has a statistically insignificant effect on inclusive growth which somewhat refutes the positive and significant role of ICT on growth.

Using three ICT indicators – mobile subscribers, individuals using the internet and fixed telephone subscribers, a review of some African countries reveals that on mobile subscription, Nigeria has consistently maintained the lead as having the highest number of mobile cellular subscribers with 18.59 million subscribers as at 2005 to 151 million in 2015, representing a growth of 711%. Closely following is Egypt with a surge in the number of mobile phone subscribers from 13.63 million in 2005 to 99.7 million in 2013 representing an increase of 631%. Ranked third is South Africa with a growing mobile subscription base from 33.96 million in 2005 to 87.99 million

in 2015 representing an increase of 159.13%. As at 2015, the countries with less than 1 million mobile subscribers are: Sao Tome and Principe with 132,000; Seychelles has 148,244; Djibouti, 314,350; Comoros with 424,786; Eritrea, 475,000; Equatorial Guinea, 533,336; Cabo Verde, 602, 779 and Swaziland with 941,000.

On the number of individuals using the internet (% of population), statistics reveal that Seychelles recorded the highest with 58.12% in 2015, followed by Morocco which has consistently maintained an increasing percentage across 2012 to 2015 covering 55.4% to 57.08% while South Africa ranks third with 51.91%. As at 2015, the countries with the lowest percentage of individuals using the internet are Eritrea (1.08%); Somalia (1.76%); Niger (2.22%); Sierra Leone (2.5%); Chad (2.7%); Guinea-Bissau (3.54%); Congo, Dem. Rep. (3.79%); Madagascar (4.17%); Central African Republic (4.56%); Guinea (4.7%) and Burundi (4.86%). Statistics on the number of fixed telephone subscriptions show that Egypt consistently has maintained the lead from 2005 to 2015. The country's number of subscribers grew from 10.32 million in 2005 to 11.85 million in 2008 which later dropped to about 6.24 million in 2015. South Africa follows closely with 4.8 million subscribers in 2005 but experienced a later decrease to about 4.131 million in 2015.

The countries[2] with the least number of fixed telephone subscribers are Central African Republic (1,881); Sao Tome and Principe (7,000); Liberia (9,000); Equatorial Guinea (11,334); Malawi (14,462); Comoros (14,599); Rwanda (16,983); Congo, Rep. (17,000); Sierra Leone (17,000); Chad (17,029) and Gabon (18,758). Lastly, using regional delineation, Southern Africa has the highest average internet users and fixed telephone users at 11.07 and 639,786.1, respectively, while North Africa records the highest average mobile subscribers at 23.6 million. Overall, relative to other ICT indicators, statistics show that mobile cellular subscriptions have increased substantially. This is due to the convenience of using mobile phones in addition to multiple subscriptions to different service providers or networks.

3 Data and model

The study uses data on 54 African countries from 2005 to 2015 with all variables sourced from World Bank [22, 23] World Development Indicators (WDI). The main reason for limiting the sample period is because pre-2005, most African countries show considerable missing values for the ICT variables. Hence, there is the need to restrict the period to allow more countries in order to make the sample size more representative of the continent. In addition, since the aim of this empirical study is to compare the contribution of ICT to economic growth in Africa, it is essential to divide

[2]From World Bank WDI [22, 23] data, figures for 2015 are not available for Congo, Dem. Rep., Guinea, Guinea-Bissau and South Sudan. These figures in () are statistics obtained from the data used in the study which reflects fixed telephone subscriptions per 100 people.

the full sample into five sub-samples across regional delineations[3] – Central Africa, East Africa, North Africa, Southern Africa and West Africa – to show variations across the five sub-regions.

3.1 The indicators

In line with similar studies, the main variables are gross domestic product (*GDP*) which is the measure of economic growth; gross fixed capital formation (*GFCF*); labour participation rate (*LABOUR*); individuals using the internet (% of population) (*INTERNET*), mobile cellular subscription (*MOBILE*) and fixed telephone subscription (*TEL*). For robustness, two control variables, trade openness (*TRADE*) and inflation (*INFL*) are included. The economic growth variable has been extensively explained in the introduction, hence other indicators are explained in brief.

Gross fixed capital formation is the net increase in physical assets within the measurement period. It does not account for the consumption (depreciation) of fixed capital, and also does not include land purchases. This indicator is included because it captures absorptive capacity to produce, which in turn affects economic growth [18]. It is expected that a positive relationship exists between gross fixed capital formation and economic growth.

Labour force participation rate is the proportion of the population aged 15 and older that is economically active. That is, all able-bodied individuals who supply labour for the production of goods and services during a specified period. This variable is used because labour is a key production factor in developing countries due to the high cost of acquiring capital. It is therefore important that necessary technical skills and education are acquired to enhance labour productivity in the course of attaining a high level of growth. Thus, the significance of the variable in this model is to capture the existence to which labour input affects economic growth and a positive coefficient is expected.

Internet users are individuals that use the internet from any location. It refers to the world-wide public computer network that offers access to several communication services including the world wide web which carries email, news, entertainment and data files. The internet can be accessed via computers, internet-enabled mobile phones, digital television, and game machines.

Mobile cellular subscription refers to the number of subscriptions to a public mobile-telephone service that provides access to the public switched telephone network

[3]The list of countries and their respective regions are shown in Appendix Table 8.

(PSTN) using cellular technology. The indicator applies to all mobile-cellular subscriptions that offer voice communication excluding subscriptions via data cards or USB modems, public mobile data services, private trunked mobile radio, radio paging and telemetry services.

Telephone line subscription captures the active number of analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones. It is hypothesized that an efficient use of ICT variables will have considerable boost on economic growth.

For the control variables, t*rade openness* shows the extent of integration among countries within the continent and with the rest of the world and it is expected that increased trade will have positive impact on growth. Lastly, *inflation*, a rising price level is expected to have a non-linear relationship with economic growth. This is because at the initial stage, inflation is expected to stimulate (drag) economic growth after which it becomes a drag (inhibitor) on growth upon attaining certain thresholds. Hence, the expected sign of the coefficient is indeterminate.

3.2 Summary statistics and correlation analysis

The relative statistics of these indicators are shown in Table 1 for the full sample and across the five sub-regions. The average gross domestic product (GDP) for the full sample is US$34.9 billion with Nigeria having the highest at US$547 billion in 2014 and Sao Tome and Principe shows the lowest in 2011 with US$126 million. Likewise across regional classification, average GDP ranges between US$13.7 billion (East Africa) and US$93.9 billion (North Africa). Average gross fixed capital formation (% of GDP) which is highest in North Africa at 26.65 and lowest in West Africa at 20.67 shows the relative absorptive capacity of both regions. The largest average labour participation rate occurs in Central Africa with 72.45% followed by East Africa at 71.94%. The highest average trade openness (% of GDP) occurs in Southern Africa with 89.874 and the lowest is recorded for Central Africa with 73.84.

Also, the average inflation rate is lowest in West Africa at 5.74% while the highest is in East Africa at 199.15% (with contributions from Zimbabwe at 24,411.33%, 1,096.68% and 302.12% for periods 2007, 2006, and 2005, respectively). On the ICT variables, per 100 people, Southern Africa has the highest average number of internet users and fixed telephone users at 11.07 and 639,786.1, respectively, while North Africa records the highest average number of mobile subscribers at 23.6 million. A close scrutiny of the data shows that relative to others, Egypt has the highest number of fixed telephone users ranging between 11.8 million (2008) and 6.235 million (2015) while Nigeria has the highest number of mobile telephone users ranging between 113 million (2012) to 151 million (2015). The correlation matrix with the natural logarithms of the variables in Table 2 shows that gross fixed capital formation and all the ICT indicators have a positive and statistically significant association

Table 1 Summary statistics

Variables	Full sample		Central Africa		East Africa	
	Mean	SD	Mean	SD	Mean	SD
GDP	3.49E+10	7.52E+10	2.19E+10	2.84E+10	1.37E+10	1.39E+10
GFCF	22.26532	8.904629	22.37035	9.994872	21.76518	8.42603
LABOUR	67.34951	12.85585	72.45199	10.73972	71.94571	12.18461
TRADE	79.272	38.104	73.584	32.804	78.816	44.069
INFLATION	53.12296	1030.434	8.324217	8.864306	199.1539	2101.628
INTERNET	10.16592	12.3186	6.31319	7.085187	9.508218	12.29396
MOBILE	1.03E+07	1.88E+07	4269375	7057565	7137922	9593327
TEL	541844.1	1480251	193723.5	306248.6	106074	132000.7

For example: 3.49E+10 = 34,900,000,000.00; GDP: Gross domestic product; GFCF: Gross fixed capital formation; TEL: Fixed telephone subscription

Source: Authors' Computations

Table 1 (continued)

Variables	North Africa		Southern Africa		West Africa	
	Mean	SD	Mean	SD	Mean	SD
GDP	9.39E+10	7.79E+10	4.40E+10	1.03E+11	2.96E+10	8.97E+10
GFCF	26.6503	9.419201	22.37391	7.238429	20.6741	8.794349
LABOUR	48.14523	3.186839	68.50589	13.10669	68.87922	8.456939
TRADE	76.119	28.08	89.874	23.82	78.098	44.105
INFLATION	7.170792	7.217981	7.585632	4.53417	5.745547	6.846131
INTERNET	21.06728	15.54834	11.70773	12.8682	7.173768	9.668342
MOBILE	2.36E+07	2.38E+07	9156587	1.85E+07	1.13E+07	2.39E+07
TEL	2485757	3039276	639786.1	1419525	167437.7	269320.5

For example: 9.39E+10 = 93,900,000,000.00; GDP: Gross domestic product; GFCF: Gross fixed capital formation; TEL: Fixed telephone subscription

Source: Authors' Computations

Table 2 Correlation matrix (with natural logarithm)

Variables	GDP	GFCF	LAB	TR	INFL	INT	MOB	TEL
GDP	1.00							
GFCF	0.1247***	1.00						
LABOUR	−0.2637***	−0.11	1.00					
TRADE	−0.1637***	0.2540***	−0.1796***	1.00				
INFLATION	−0.02	−0.1549***	0.06	0.02	1.00			
INTERNET	0.3222***	0.2572***	−0.4230***	0.1916***	−0.02	1.00		
MOBILE	0.8559***	0.09	−0.1410***	−0.2574***	−0.02	0.3235***	1.00	
TEL	0.7658***	0.08	−0.3301***	−0.1586***	0.03	0.3806***	0.6816***	1.00

GDP: Gross domestic product; GFCF: Gross fixed capital formation; LAB: Labour; TR: Trade; INF: Inflation; INT: Internet usage; MOB: Mobile subscription; TEL: Fixed telephone subscription
Source: Authors' Computations

with economic growth while labour and trade openness have a negative and statistically significant association. However, a strong and positive correlation is detected between mobile subscribers and fixed telephone subscribers (0.682).

3.3 The model

A common model used in investigating the effects of ICT investments on output growth is the neoclassical model by Solow [16] where the technological factor, or total factor productivity,[4] is a parameter of great importance. It includes all other factors of production that cannot be explained by capital and labour alone. Since growth is influenced by technology, which often is determined by factors such as new 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. In addition, to evaluate the impact of ICT using the full and sub-samples, the study adopts a Cobb-Douglas production function, represented as:

$$Y_{it} = A_{it} L_{it}^{\alpha_1} K_{it}^{\alpha_2} e^{u_{it}}, \quad i = 1, 2, \ldots, N; \quad t = 1, 2, \ldots, T \tag{1}$$

where Y is output stock, A is the technological parameter affecting the productivity of K and L; K and L are the stocks of capital and labour, respectively. This empirical

[4] Also known as Solow residual.

approach modifies the methodology outlined by Niebel [14]. To achieve the study objectives, a column vector of ICT variables, Z', a row vector of control variables, X' and regional dummy variables (to capture variations across the five sub-regions) are included. Without imposing constant returns to scale and using natural logarithm transformation, the model becomes:

$$\ln Y_{it} = \alpha_0 + \alpha_1 \ln L_{it} + \alpha_2 \ln K_{it} + \alpha_3 \mathbf{Z}'_{it} + \alpha_4 \mathbf{X}'_{it} + \gamma_i + \varphi_t + u_{it} \quad (2)$$

With $\ln Y_{it}$ being the natural logarithm of GDP; $\ln K_{it}$, the natural logarithm of gross fixed capital formation (% of GDP); $\ln L_{it}$, the natural logarithm of labour participation, $\mathbf{Z}'_{it}$ is the vector of natural logarithms of ICT variables (internet usage, mobile subscription and fixed telephone subscribers); $\mathbf{X}'_{it}$ is the vector of control variables (trade openness and inflation rate) in natural logarithms; φ_t represents year dummies (which controls for common shocks such as the global financial crises of 2007-2009), γ_i indicates regional dummies; and u_{it} is the general error term.

Furthermore, the following estimation approaches are adopted: (1) the sample is split along five sub-regional delineations: Central Africa, East Africa, North Africa, South Africa and West Africa to allow for the comparison of findings across the continent. (2) To systematically draw the significance of ICT on economic growth, the study adopts the use of static and dynamic models. These estimation methods are used by similar studies [8, 14] and given that the study uses a short panel of 54 countries (N) across 11 years (T), hence, $N>T$. Similarly, the adoption of these techniques serve as robustness for one another in order to observe the consistency of the impact of ICT variables on economic growth. The static models are the pooled ordinary least squares (*POLS*) which do not allow for heterogeneities across the panels and the fixed effects (*FE*) model[5] which recognises panel heterogeneities while the dynamic model is the systems generalised method of moments (*sys-GMM*). The *sys-GMM* estimator is designed for short panel analysis and has the following assumptions about the data-generating process which includes the fact that the process may be dynamic, with current realisations of the dependent variable influenced by past ones in addition to the fact that the regressors are not strictly exogenous and may be correlated with past and possibly current realisations of the error term. Econometric analysis is carried out on the full sample as well as for the sub-sample of regions. The *POLS* which is the baseline model is used to estimate the full and sub-samples, while the *FE* and *sys-GMM* approaches are used only on the full sample as they are not feasible for sub-sample regressions due to the small number of obser-

[5]The Hausman test supports the use of an FE model in 3 out of 4 panel regressions. Hence, random effects (RE) estimator is used for one of the panel regressions.

vations.[6] The *sys-GMM* specification includes the lagged GDP as a regressor. (3) To avoid collinearity problems given the degree of substitutability between mobile subscription and fixed telephone (correlation index is 0.6816), both are not included together in the same model.

4 Results and discussions

4.1 Pooled OLS results

The results for the full sample using the *POLS* estimator are shown in Table 3. Columns 1 and 2 are specific to the internet/mobile subscription and internet/fixed telephone subscription regressions with trade openness as the control variable while columns 3 and 4 are the respective robustness checks with inflation as the control variable. Results in columns 1 and 2 which are consistent with findings from similar studies [4, 7, 9, 10, 13] show the positive and statistically significant relationship (at the 1% level) between economic growth and ICT variables. The output elasticities of *INTERNET*, *MOBILE* and *TEL* are 0.22%, 0.86% and 0.68%, respectively and those obtained for the robustness checks are not significantly different with output elasticities of 0.22%, 0.86% and 0.71%. Several key findings are gleaned from the results. (1) The estimated elasticity for *MOBILE* is the largest indicating that an increase in the number of mobile phone subscribers has a greater stimulating impact on the continent's economic growth relative to other ICT indicators. (2) The "leapfrogging" hypothesis holds as findings show that among the three indicators, *MOBILE* is the most likely to *leapfrog* Africa through developmental stages. (3) The positive coefficients of the ICT indicators are consistent with *a priori* expectations because the existence of ICT provide the outline for the delivery of various services ranging from telephony and its variants (such as, video phones, tele-conferencing) to high-speed internet access and very diverse services (SMS, mobile banking, video streaming, etc.) with eventual positive boost on economic growth. In addition, technology improves the capabilities of the labour force and communication between firms. The use of ICT spreads to other industries and contributes to their profits thus affecting their overall growth. Likewise, access to the internet provides a bigger boost to economic growth than access to mobile phones. Broadband internet, wireless and fixed, is becoming a service of general economic interest by enhancing the knowledge, skills, and networks of individuals; raising private sector productivity; and increasing

[6]The number of countries in each sub-region: Central Africa (9), East Africa(14), North Africa (7), Southern Africa (9) and West Africa (15). Since the time span is only 11 years, only the sub-samples of East and West Africa meet the criteria for performing FE/RE and sys-GMM and because this will make a comparative analysis impossible, this approach is dropped. Hence, only the POLS is used for comparative analysis.

Table 3 Pooled OLS results (Dep. Variable: GDP, log)

Variables	Main regressions		Robustness checks	
	[1]	[2]	[3]	[4]
Constant	382.4571***	−114.0710***	389.4573***	−153.0632***
	(13.62)	(−2.71)	(13.27)	(−3.56)
GFCF, log	0.0895*	0.0696	0.1333**	−0.1234
	(1.68)	(0.71)	(2.14)	(−1.15)
LABOUR, log	−0.8446***	−0.8077**	−0.9544***	−0.7238**
	(−4.44)	(−2.46)	(−4.72)	(−2.21)
TRADE, log	0.0657	−0.0537		
	(0.81)	(−0.37)		
INFLATION			0.0000***	−0.0001***
			(2.66)	(−7.02)
INTERNET, log	0.2220***	0.0265	0.2261***	−0.0337
	(6.98)	(0.43)	(6.74)	(−0.60)
MOBILE, log	0.8574***		0.8627***	
	(41.54)		(37.27)	
TEL, log		0.6850***		0.7143***
		(19.14)		(21.88)
Central Africa	1.3919***	1.1928***	1.3437***	1.3740***
	(13.12)	(8.65)	(12.12)	(10.58)
East Africa	0.3255***	0.3834**	0.3265***	0.4743***
	(5.69)	(2.51)	(5.34)	(3.01)
North Africa	0.2503**	−0.0339	0.1827	0.0611
	(2.20)	(−0.19)	(1.64)	(0.36)
Southern Africa	0.6512***	0.0246	0.6561***	0.0456
	(9.79)	(0.23)	(9.96)	(0.41)
Year Dummies	Yes	Yes	Yes	Yes
No. of Obs.	492	479	480	469
R-Squared	0.881	0.682	0.881	0.702
F Statistic	219.508	91.315	234.883	106.324

***, **, *are statistically significant at the 1%, 5% and 10% levels, respectively; t-statistics (in parentheses) are based on White heteroscedasticity-consistent std. errors; CA: Central Africa; EA: East Africa; NA: North Africa; SA: South Africa; WA: West Africa
Source: Authors' Computations

community competitiveness. It also plays an essential role as an enabling technology in increasing investment payoffs in other sectors, transforming research and development, facilitating trade in services and globalisation, and improving public services

to enhance national business environment and competitiveness. Overall, we find that ICT stimulates economic growth.

On the factors of production, the coefficient of *GFCF* is positive and statistically significant for the internet/mobile regressions at the 10% and 5% level, respectively, which aligns with what was expected a priori. This validates the role gross fixed capital formation plays as an engine for economic growth. Capital input in this sense turns out to be a major consideration in driving economic growth in Africa. Therefore, productivity will increase in Africa as a result of an increase in capital investment. Contrarily, across all model specifications, the results obtained on labour participation contradicts theory which posits that labour is a key ingredient for growth. The coefficient is negative and statistically significant (at the 1% and 5% level) which implies that a proportionate decrease in economic growth occurs when *LABOUR* changes by 1%, on average, *ceteris paribus*. For the control variables, *TRADE* has no statistically significant impact on economic growth while *INFLATION* shows a statistically significant asymmetric relationship at the 1% level.

On average, *ceteris paribus*, the coefficients of the regional dummies show that the GDP of Central Africa is 302.25%[7] higher than that of West Africa (the base sub-region) for the internet/mobile regression and by 229.63% for the internet/fixed telephone regression. Likewise, East Africa shows to have a higher GDP relative to West Africa by 38.47% to 47.73% in both regressions. Similar findings are reported from their robustness checks. On the other hand, North Africa shows a higher GDP relative to West Africa only for the internet/mobile regression by 28.44% while Southern Africa indicates a higher GDP of 91.78% for the internet/mobile regression and its respective robustness check. Lastly, having controlled for year dummies, the goodness-of-fit of the four model specifications shows that the proportion of variation in the dependent variable explained by the regressors ranges from 68% to 88%. Across all model specifications, the F-statistics indicate that the regressors are jointly significant in explaining economic growth.

The results for the full sub-sample for internet/mobile regression using the *POLS* estimator are shown in Table 4 while those for internet/fixed telephone regression are shown in Table 5. Findings show that the output elasticity for *MOBILE* is the largest for North Africa (1.12%) followed by that of West Africa (0.82%) with Central Africa having the least (0.57%). Using the "leapfrogging" argument, it can be inferred that mobile subscription can facilitate faster developmental progress in North Africa in comparison to other sub-regions. These outcomes are very similar to those obtained for the robustness checks (see Appendix Table 9). Contrary, the output elasticity for *INTERNET* is negative for North Africa (-0.213) while it is statistically not signif-

[7]The formula used is: $\left[e^{\hat{\beta}} - 1\right] \times 100$, where e is the exponent (i.e., the base or the anti-log) of the natural logarithm and $\hat{\beta}$ is the coefficient. This is always used when the dependent variable is expressed in natural logarithm and the explanatory variable is a dummy (1/0) measure.

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

Variables	CA	EA	NA	SA	WA
Constant	3.7587***	10.6109***	5.5439	30.0188***	22.5166***
	(3.17)	(5.25)	(0.86)	(14.15)	(13.56)
GFCF, log	−0.0357	0.0360	−0.7738***	1.0003***	0.0262
	(−0.18)	(0.33)	(−2.88)	(4.80)	(0.24)
LABOUR, log	1.1366***	0.1325	0.5659	−2.7033***	−2.2897***
	(4.85)	(0.31)	(0.40)	(−8.91)	(−6.60)
TRADE, log	1.5591***	0.2694**	0.3790**	−1.5999***	−0.6259***
	(13.26)	(2.04)	(2.05)	(−4.55)	(−4.99)
INTERNET, log	0.0504	−0.0390	−0.2128*	0.0820	-0.0442
	(0.66)	(-0.89)	(−2.00)	(1.23)	(−0.81)
MOBILE, log	0.5689***	0.6975***	1.1201***	0.5765***	0.8201***
	(15.50)	(21.68)	(10.65)	(9.96)	(18.39)
No. of Obs.	74	109	66	87	156
R-Squared	0.838	0.870	0.840	0.897	0.828
F Statistic	88.173	145.666	45.681	191.775	119.519

***, **, *are statistically significant at the 1%, 5% and 10% levels, respectively; t-statistics (in parentheses) are based on White heteroscedasticity-consistent std. errors; CA: Central Africa; EA: East Africa; NA: North Africa; SA: South Africa; WA: West Africa
Source: Authors' Computations

icant for other sub-regions. For its corresponding robustness checks, the elasticities are negative for East, North and Southern Africa. These findings provide further evidence on the growth-stimulating impact of mobile subscriptions in comparison to internet usage. Other results show the statistically significant asymmetric effects of *GFCF*, *LABOUR* and *TRADE*.

Results in Table 5 also reveal that *TEL* positively impacts growth across the five sub-regions with West Africa having the largest elasticity of 0.792, followed by Southern Africa (0.61) and Central Africa (0.464) as the least contributor. Hence, the *leapfrogging* potential of fixed telephone in West Africa relative to other sub-regions can be inferred. Parallel results are obtained from the robustness checks (see Appendix Table 10). Similarly, the output elasticity for *INTERNET* is positive and statistically significant for Central Africa (0.339), North Africa (0.168) and Southern Africa (0.256) while the robustness checks reveal it is significant in Central Africa (0.217) and North Africa (0.212) only.

In summary, findings from Tables 4 and 5 further provide evidence on the growth-stimulating impact and "leapfrogging" potentials of mobile and fixed telephone subscriptions in comparison to internet usage that exhibits both positive and negative

Table 5 Sub-regions' pooled OLS results (Dep. Variable: GDP, log)

Variables	CA	EA	NA	SA	WA
Constant	11.3137***	1.4636	22.1672***	22.0831***	27.6289***
	(7.67)	(0.35)	(4.40)	(6.79)	(7.00)
GFCF, log	−0.1867	0.7967***	0.2163	0.6383**	−0.5080***
	(−1.38)	(4.70)	(1.31)	(2.30)	(−3.59)
LABOUR, log	0.3947	2.1338***	−0.7514	−0.3190	−2.6826***
	(1.35)	(2.85)	(−0.62)	(−0.98)	(−4.02)
TRADE, log	1.3249***	0.7956***	−0.9407***	−1.6401***	−0.2899
	(8.88)	(2.88)	(−8.47)	(−3.45)	(−1.01)
INTERNET, log	0.3387***	0.0712	0.1681**	0.2561***	0.0855
	(5.07)	(0.59)	(2.62)	(3.48)	(0.92)
TEL, log	0.4635***	0.5782***	0.5984***	0.6104***	0.7923***
	(12.32)	(6.09)	(12.92)	(7.57)	(11.45)
No. of Obs.	71	106	66	87	149
R-Squared	0.865	0.506	0.920	0.859	0.703
F Statistic	45.582	13.372	189.211	146.946	75.239

***, **, *are statistically significant at the 1%, 5% and 10% levels, respectively; t-statistics (in parentheses) are based on White heteroscedasticity-consistent std. errors; CA: Central Africa; EA: East Africa; NA: North Africa; SA: South Africa; WA: West Africa
Source: Authors' Computations

effects across the sub-regions. Also, in terms of size of output elasticities, *MOBILE* ranks highest followed by *TEL* and *INTERNET* as the dominant enhancer of economic growth in Africa in addition to exhibiting the most "leapfrogging" potential among the three ICT indicators.

4.2 Random and fixed effects results

Having controlled for panel heterogeneities, the results for the augmented model using the random effects (*RE*)[8] and fixed effects (*FE*) estimators are displayed in Table 6 for the full sample. The findings which are quite similar to those obtained using the *POLS* estimator on the full sample, reveal the consistencies of both *INTERNET* and *MOBILE* as significant growth enhancers while the effect of *TEL* is though positive but statistically not significant. Furthermore, the "leapfrogging" hypothesis holds with *MOBILE* having the largest output elasticities providing

[8]The probability value of the Hausman statistic (0.979) supports the RE estimator be applied to the internet/mobile subscription main regression with trade as the control variable.

Table 6 Random and fixed effects results (Dep. Variable: GDP, log)

Variables	Main regressions		Robustness checks	
	RE	FE	FE	FE
	[1]	[2]	[3]	[4]
Constant	22.7438***	22.3495***	20.3449***	21.4078***
	(20.90)	(15.22)	(16.74)	(14.18)
GFCF, log	0.1054***	0.2058***	0.0468	0.1288***
	(3.53)	(6.01)	(1.56)	(3.71)
LABOUR, log	−0.6183**	0.1734	−0.2237	0.1863
	(−2.43)	(0.51)	(−0.78)	(0.53)
TRADE, log	−0.3422***	−0.3062***		
	(−7.95)	(−6.11)		
INFLATION			−0.0000	−0.0000
			(−1.08)	(−1.54)
INTERNET, log	0.0726 * **	0.3084 * **	0.0993 * **	0.3106 * **
	(4.06)	(27.54)	(5.39)	(26.79)
MOBILE, log	0.2662 * **		0.2310 * **	
	(15.55)		(13.02)	
TEL, log		0.0292		0.0147
		(1.49)		(0.73)
Year Dummies	Yes	Yes	Yes	Yes
No. of Obs.	492	479	480	469
R-Squared		0.711	0.770	0.690
F Statistic		208.807	286.429	185.478
Hausman (p-value)	0.979	0.084	0.000	0.000

***, **, *are statistically significant at the 1%, 5% and 10% levels, respectively; t-statistics (in parentheses) are based on White heteroscedasticity-consistent std. errors; RE: Random Effects; FE: Fixed Effects
Source: Authors' Computations

evidence that mobile subscription has the highest potential to enable Africa skip traditional developmental stages. In addition, the effects of capital investment (positive) and that of *LABOUR* (negative) are consistent with findings reported in Table 3. The results on *TRADE* which controls for differences in production technologies between countries indicate that openness to trade is a drag on economic growth given its negative and statistically significant coefficients at the 1% level. On the goodness-of-fit, the model specifications show that the proportion of variation in the dependent variable explained by the regressors ranges from 69% to 77% and the F-statistics indicate that the regressors are jointly significant in explaining economic growth.

Table 7 System GMM results (Dep. Variable: GDP, log)

Variables	Main regressions		Robustness checks	
	[1]	[2]	[3]	[4]
GDP_1, log	0.9502***	1.0991***	0.9539***	1.1174***
	(10.62)	(23.92)	(16.53)	(15.08)
GFCF, log	0.0458	0.0470	0.0065	0.0429
	(0.99)	(1.14)	(0.20)	(0.48)
LABOUR, log	−0.3034	−0.3420	−0.1182	−0.3586
	(−1.61)	(−1.63)	(−1.12)	(−0.98)
TRADE, log	0.0681	−0.0001		
	(1.17)	(−0.00)		
INFLATION			−0.0001	−0.0000
			(−1.10)	(−0.20)
INTERNET, log	−0.1633*	−0.1725*	−0.0598	−0.1694
	(−1.71)	(−1.81)	(−1.05)	(−1.17)
MOBILE, log	0.1342*		0.0827*	
	(1.90)		(1.78)	
TEL, log		−0.0493		−0.0693
		(−1.39)		(−1.33)
Year Dummies	Yes	Yes	Yes	Yes
No. of Obs.	430	430	423	423
Instruments/Groups	36/49	36/49	36/48	36/48
Hansen *p*value	0.341	0.329	0.071[a]	0.266
AR(*2*) *p*value	0.744	0.855	0.688	0.723
F Statistic	99382.604	101132.963	424766.671	90963.987

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

4.3 System GMM results

Controlling for possible endogeneity, heteroscedasticity and omitted variables, results from the *sys-GMM* estimator are shown in Table 7. *MOBILE* is the only ICT indicator that exhibits a positive and statistically significant relationship with economic growth in the short-run, on average, *ceteris paribus*. *INTERNET* shows a negative relationship while that of *TEL* is both negative and statistically not significant. An explanation for this result could be that the unobserved heterogeneity

in the data is now controlled. Again, findings highlight the "leapfrogging" potentials of mobile subscription for African economies because it has the largest output elasticities of 0.13% and 0.08%, respectively.

Regarding the model's goodness-of-fit, there is no evidence of second-order serial correlation given the *p*-values of the AR(*2*) statistics, while the null hypothesis of instruments validity cannot be rejected at the 5% significance level given the *p*-values of the Hansen statistics. Hence, the results obtained from these augmented regressions can be used for inferences.

5 Conclusion and policy implications

This study evaluates the relationship between ICT development and economic growth in Africa within the context of the "leapfrogging" hypothesis. Contribution is made to the ICT-economic growth literature on Africa by using an exclusive panel data of 54 African countries from 2005 to 2015, three ICT indicators (internet usage, mobile and fixed telephone subscribers) and static and dynamic modelling techniques. We report some compelling and robust findings which substantiate that ICT has a statistically significant influence on economic growth in Africa. This study engages a new discourse and provides evidence that Africa can use ICT to "leapfrog" developmental stages owing to the positive and statistically significant coefficients of the ICT variables, particularly mobile subscribers which maintained a consistent positive and statistically significant relation to economic growth across all model specifications. In other words, the "leapfrogging" hypothesis and the "leapfrogging" potentials of mobile subscription hold not only for the continent as a whole but also for the sub-regions. Other findings are that gross fixed capital formation is an essential ingredient for growth in the region while labour force participation, for the most, has shown to have a negative impact on growth. The reason for this is due to a large percentage of unskilled labour resulting in the unproductiveness of the labour force thereby decreasing economic growth. Added to this are the incessant socio-economic and political crises which reduce the incentive of labour to work. In addition to initiating policies that will engender manpower training, capacity utilisation which are ICT complementarities are required in order to boost economic growth.

The policy implication of our findings is not far-fetched. African governments and stakeholders must take advantage of the developmental-enhancing potentials of ICT. Nonetheless, a greater percentage of African countries are promoting the use of mobile subscriptions but at a rising cost to the teeming population. With ICT as a "leapfrogging" opportunity, more investments need to be channeled to the sector for greater impacts on economic growth. That is, to be globally and economically relevant, concerted efforts must be directed towards harnessing the inherent benefits of ICT usage. These must include the drive to reduce the rising cost attributable to the usage of communication technology facilities such as the cost of buying a

cellular phone, internet connectivity rates, subscription rates, etc. In conclusion, policy measures must be put in place to reduce ICT cost and develop the sector into a more economically and productive use. For further research, assessing ICT-growth nexus as an inequality-reducing mechanism may be taken up.

Appendix

Table 8 List of countries

S/No.	Country	Region	S/No.	Country	Region
1	Algeria	NA	28	Libya	NA
2	Angola	CA	29	Madagascar	SA
3	Benin	WA	30	Malawi	SA
4	Botswana	SA	31	Mali	WA
5	Burkina Faso	WA	32	Mauritania	NA
6	Burundi	EA	33	Mauritius	SA
7	Cabo Verde	WA	34	Morocco	NA
8	Cameroon	CA	35	Mozambique	SA
9	Central African Republic	CA	36	Namibia	SA
10	Chad	CA	37	Niger	WA
11	Comoros	EA	38	Nigeria	WA
12	Congo, Dem. Rep.	EA	39	Rwanda	EA
13	Congo, Rep.	EA	40	Sao Tome and Principe	CA
14	Cote d'Ivoire	WA	41	Senegal	WA
15	Djibouti	EA	42	Seychelles	EA
16	Egypt, Arab Rep.	NA	43	Sierra Leone	WA
17	Equatorial Guinea	CA	44	Somalia	EA
18	Eritrea	CA	45	South Africa	SA
19	Ethiopia	CA	46	South Sudan	EA
20	Gabon	CA	47	Sudan	NA
21	Gambia, The	WA	48	Swaziland	SA
22	Ghana	WA	49	Tanzania	EA
23	Guinea	WA	50	Togo	WA
24	Guinea-Bissau	WA	51	Tunisia	NA
25	Kenya	EA	52	Uganda	EA
26	Lesotho	SA	53	Zambia	EA
27	Liberia	WA	54	Zimbabwe	EA

CA: Central Africa; EA: East Africa;
NA: North Africa; SA: Southern Africa; WA: West Africa Source: Authors' Compilation

Table 9 Sub-Regions' pooled OLS results (Dep. Variable: GDP, log), robustness

Variables	CA	EA	NA	SA	WA
Constant	15.4963***	15.3818***	8.5736	22.3482***	19.1747***
	(8.06)	(9.55)	(1.42)	(11.94)	(9.60)
GFCF, log	0.5693*	−0.1090	−0.7940***	0.4645**	−0.0680
	(1.92)	(−0.86)	(−3.09)	(2.52)	(−0.70)
LABOUR, log	−0.1591	−0.8215**	0.5398	−2.7822***	−2.1558***
	(−0.36)	(−2.12)	(0.37)	(−6.98)	(−5.09)
INFLATION	0.0106	0.0000	−0.0275***	−0.0080	0.0145*
	(0.46)	(1.23)	(−4.14)	(−0.61)	(1.72)
INTERNET, log	0.1465	−0.0870**	−0.1987**	−0.1204**	−0.0560
	(1.27)	(−2.25)	(−2.07)	(−2.12)	(−0.97)
MOBILE, log	0.4556***	0.7634***	1.0541***	0.7737***	0.8420***
	(5.74)	(26.65)	(12.49)	(19.23)	(18.66)
No. of Obs.	69	102	66	87	156
R-Squared	0.508	0.879	0.853	0.863	0.808
F Statistic	22.022	275.044	48.057	92.170	106.810

***, **, *are statistically significant at the 1%, 5% and 10% levels, respectively; *t*-statistics (in parentheses) are based on White heteroscedasticity-consistent std. errors; CA: Central Africa; EA: East Africa; NA: North Africa; SA: South Africa; WA: West Africa
Source: Authors' Computations

Table 10 Sub-regions' pooled OLS results (Dep. Var: GDP, log), robustness

Variables	CA	EA	NA	SA	WA
Constant	19.8690***	5.8721*	21.5532***	10.9093***	24.7060***
	(11.86)	(1.89)	(3.94)	(10.32)	(8.97)
GFCF, log	0.0985	0.6858***	−0.2044	0.0456	−0.5121***
	(0.49)	(4.01)	(−0.75)	(0.23)	(−3.50)
LABOUR, log	−0.4169	2.1202***	−1.4751	0.3574	−2.4914***
	(−1.18)	(3.01)	(−1.25)	(1.16)	(−4.08)
INFLATION	0.0123	−0.0000**	0.0291***	0.0108	0.0383***
	(0.85)	(−2.16)	(3.73)	(0.62)	(3.92)
INTERNET, log	0.2167**	0.1551	0.2115**	0.1126	0.0672
	(2.40)	(1.30)	(2.47)	(1.53)	(0.84)
TEL, log	0.4476***	0.5024***	0.6301***	0.8560***	0.8537***
	(9.30)	(5.15)	(7.77)	(18.65)	(17.89)

Table 10 (continued)

Variables	CA	EA	NA	SA	WA
No. of Obs.	66	101	66	87	149
R-Squared	0.705	0.483	0.874	0.829	0.729
F Statistic	28.575	40.997	113.097	100.657	90.616

***, **, *are statistically significant at the 1%, 5% and 10% levels, respectively; *t*-statistics (in parentheses) are based on White heteroscedasticity-consistent std. errors; CA: Central Africa; EA: East Africa; NA: North Africa; SA: South Africa; WA: West Africa
Source: Authors' Computations

References

1. Asongu, S.A., & Le Roux, S. (2017). Enhancing ICT for inclusive human development in Sub-Saharan Africa. *Technological Forecasting and Social Change*, *118*, 44–54.
2. Baro, E.E., & Endouware, B.-E.C. (2013). The effects of mobile phones on socio-economic life of the rural dwellers in the niger delta region of Nigeria. *Information Technology for Development*, *19*(3), 249–263. https://doi.org/10.1080/02681102.2012.755895.
3. Batuo, E.M. (2015). Role of telecommunications infrastructure in the regional economic growth of Africa. *The Journal of Developing Areas*, *49*(1), 1–19.
4. Cardona, M., Kretschmer, T., Strobel, T. (2013). ICT and productivity: conclusions from the empirical literature. *Information Economics and Policy*, *25*(3), 109–125.
5. Chavula, H.K. (2013). Telecommunications development and economic growth in Africa. *Information Technology for Development*, *19*(1), 5–23. https://doi.org/10.1080/02681102.2012.694794.
6. Chen, Y., Farinelli, U., Johansson, T.B. (2004). Technological leapfrogging: a strategic pathway to modernization of the Chinese iron and steel industry. *Energy for Sustainable Development*, *3*(2), 18–26.
7. Dedrick, J., Kraemer, K.L., Shih, E. (2013). Information technology and productivity in developed and developing countries. *Journal of Management Information Systems*, *30*(1), 97–122.
8. Ejemeyovwi, J.O., & Osabuohien, E.S. (2018). Investigating the relevance of mobile technology adoption on inclusive growth in west Africa. Contemporary Social Science https://doi.org/10.1080/21582041.2018.1503320.
9. Fong, M.W.L. (2009). Technology leapfrogging for developing countries. Encyclopedia of Information Science and Technology, Second Edition, 7 pages.
10. Hanclova, J., Doucek, P., Fischer, J., Vltavska, K. (2015). Does ICT capital affect economic growth in the EU-15 and EU-12 countries? *Journal of Business Economics and Management*, *16*(2), 387–406. https://doi.org/10.3846/16111699.2012.754375.
11. Jorgenson, D.W., & Vu, K.M. (2011). The rise of developing Asia and the new economic order. *Journal of Policy Modeling*, *33*(5), 698–716.
12. Kuada, J. (2015). *Private enterprise-led economic development in Sub-Saharan Africa*. New York: Palgrave Macmillan.
13. Levendis, J., & Lee, S.H. (2013). On the endogeneity of telecommunications and economic growth: evidence form Asia. *Information Technology for Development*, *19*(1), 62–85. https://doi.org/10.1080/02681102.2012.694793.
14. 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.
15. Papaioannou, S., & Dimelis, S. (2007). Information technology as a factor of economic development: evidence from developed and developing countries. *Economics of Innovation and New Technology*, *16*(3), 179–194.
16. Solow, R.M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, *70*(1), 65–94.

17. Steinmueller, W.E. (2001). ICTs and possibilities for leapfrogging by developing countries. *International Labour Review*, *140*(2), 1–18.
18. Ugwuegbe, S.U., & Uruakpa, P.C. (2013). The impact of capital formation on the growth of nigerian economy. *Research Journal of Finance and Accounting*, *4*(9), 36–42.
19. UNDP (2017). Income inequality trends in Sub-Saharan Africa: divergence, determinants and consequences. retrieved from http://www.africa.undp.org/content/rba/en/home/library/reports/income-inequality-trends-in-sub-saharan-africa--divergence--dete.html.
20. 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.
21. Vu, K.M. (2011). ICT as a source of economic growth in the information age: empirical evidence from the 1996-2005 period. *Telecommunications Policy*, *35*(4), 357–372.
22. World Bank (2017). Leapfrogging: the key to Africa's development? from constraints to investment opportunities. Retrieved from http://documents.worldbank.org/curated/en/121581505973379739/pdf/119849-WP-PUBLIC-Africa-Leapfrogging-text-with-dividers-9-20-17-web.pdf.
23. World Bank (2017). World development indicators. Retrieved from https://data.worldbank.org/data-catalog/world-development-indicators.