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Information and Communications Technology and the Level of Income in Africa

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Abstract:

The use of electronic equipment for storing, analysing, distributing, or communicating information—popularly known as information and communications technology (ICT)—has been identified as a factor that drives income, economic growth, and development. Because of this, several studies have been carried out to ascertain the effects of ICT on economic growth. However, such studies failed to examine whether real per capita income influences the effect of ICT on income level and whether the effect of ICT on income level differs among regions of African countries. This study, therefore, investigated the effect of ICT on income level. Specifically, it examined whether real per capita income influences the effect of ICT on income level and whether the effect of ICT on income level differs among the sub-regions of African countries. Thus, empirical models were estimated using the panel regression analysis with fixed-effect and random-effect

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estimators. The results show that ICT proxied by Fixed Telephone Subscription, Mobile Cellular Subscription, Internet Users, Fixed Broadband Subscriptions affected income level in African countries except for Fixed Telephone Subscription and that real income per capita influenced the effect of mobile cellular subscription and internet usage on income level in Africa sub-regions. Furthermore, the study found that the effect of ICT on the level of income differed among African regions and that the effect was larger in Eastern, Southern and Northern African countries than the Middle and Western African countries. Therefore, authorities concerned should consider investment in ICT as a tool or mechanism for enhancing the level of income.
Keywords: Fixed Telephone Subscription, Mobile Cellular Subscription, Internet Users, Fixed Broadband Subscriptions, ICT.
JEL Codes: O10, O11, O30.

1. Introduction

The use of electronic equipment, such as computers, phones, and the Internet, for storing, analysing, distributing, or communicating information, popularly known as information and communications technology (ICT), has become a vital component of economic activities in the world today. The importance of ICT in economic and social development arises naturally since its inception in the mid-nineties (Hodrab, Maitah & Lubos, 2016). Most firms and consumers now use computers and the Internet for their economic activities to provide themselves with more diversified and customized products as well as improved product quality (Farhadi, Ismail & Fooladi, 2012). ICT reduces the economic impact of physical distances, the costs of access to information, and the cost of establishing new small businesses, thereby making businesses more efficient and more competitive (Can & Terziev, 2016).

Consequently, many developing countries now consider ICT as one of the key tools that drive productivity growth and it has become an integral part of development strategies. ICT orchestrated globalization and offer a unique opportunity for developing countries to free themselves from historical and geographic constraints, allowing trade and economic activities to be conducted as efficiently as it is in the developed world. An evolving and increasingly powerful ICT infrastructure has fundamentally changed the nature of global relationships, sources of competitive advantage, and opportunities for economic and social development. Technologies such as the internet, personal computers, broadband, and wireless telephony have created an interconnected global network of individuals, firms, and governments (Veeramacheneni et al., 2011).

Meanwhile, human welfare via income enhancement is one of the major policy agendas of policymakers across developed and developing economies but it has been uninspiring and unsatisfactory in most developing African countries. The unsatisfactory level of income can be explained partly by inappropriate policies, which can be addressed if policymakers are better informed of the determinants of income level. In order to assist policymakers in this regard, theoretical and empirical studies have sought to shed light on factors determining the level of income, one of which has been considered to be ICT. The impact of ICT on income level has become a theoretical as well as an empirical issue that has lingered on. The role of ICT activities in enhancing income is at the heart of the debate on the impact of investment in ICT on an economy (Veeramacheneni, Ekanayake & Vogel, 2011). The bone of contention is that, by investing in ICT, is it possible for developing countries to raise their income at the level of that of developed countries?

A cursory look at studies in the literature, such as Asongu and Odhiambo (2019), Bahrini and Qaffas (2019), Sezer and Abasiz (2018), and Aghaei and Mahdieh (2017) revealed that the majority of the focused largely on the effect of ICT on income level. However, it would have been more informative if such studies had examined whether the effect of ICT on income level differs among African regions—Eastern Africa, Western Africa, North Africa, Southern Africa, and Middle Africa—and if they had examined whether the level of real per capita income influences the effect of ICT on income level. To the best of the researchers' knowledge, none of these studies examined the pressure real per capita income would exert on the effect of ICT on per capita income level. This forms the motivation for this study.

Thus, the main objective of this study was to examine the effect of ICT on income level in African countries. Specifically, the study investigated whether real per capita income influences the effect of ICT on income level and whether the effect of ICT on income level differs in the sub-regions of African countries. It examined, among others, the effects of the Number of Fixed Telephone Subscriptions per 100 inhabitants (FTS), Mobile Cellular subscriptions per 100 Inhabitants (MCS), Number of Internet Users as a Percentage of Population (IU), and Number of Fixed Broadband Subscriptions per 100 Inhabitants (FBS) on income level in Africa.

This research was carried out with annual data spanning 2008 to 2017 across African countries. This period was considered in this study because data for ICT variables were not available both before 2008 and beyond 2017 at the time of data analysis for the study. The year 2008 coincides with the emergence of ICT development in Africa.

Fifty-four African countries were considered and grouped into five

sub-regions—the Eastern, Western, Northern, Southern, and Middle African countries. The six Eastern African countries are Tanzania, Kenya, Uganda, Rwanda, Burundi, South Sudan Eritrea, Mauritius, Djibouti, Comoros, and Seychelles. The sixteen African Countries belonging to the Western sub-region are Nigeria, Ghana, Cote d'Ivoire, Niger, Mali, Senegal, Guinea, Benin, Liberia, Mauritania, Gambia, Guinea-Bissau, Cabe Verde, Togo, Sierra Leone, and Burkina Faso. The six Northern sub-region consists of Egypt, Algeria, Sudan, Morocco, Tunisia, and Libya. The ten African countries belonging to the Southern sub-region include Mozambique, Malawi, Zambia, Zimbabwe, South Africa, Namibia, Botswana, Lesotho, Eswatini/Swaziland, and Angola. Lastly, the eleven Middle African countries are Rwanda, Burundi, Democratic Republic of Congo, Angola, Cameroon, Chad, Congo, Central African Republic, Gabon, Equatorial Guinea, Sao Tome & Principle.

The rest of this research is organized into three sections. Following this introduction, section two covers data and methodology, while section three contains results and discussion, and then section four is the conclusion.

2. Data and methodology

The theoretical foundation of the growth of GDP per capita (i.e., economic growth) model can be found in the neoclassical growth model, which models economic growth in terms of the Cobb-Douglas production function

$$Y = AK^{a}N^{1-a} \tag{1}$$

Where A = technological progress or total factor productivity, K = Capital stock, N = Labour, and Y = output.
Dividing Equation (1) through by N gives the per capita variables

$$\frac{Y}{N} = A\left(\frac{K}{N}\right)^{\alpha}\left(\frac{N}{N}\right)^{1-\alpha} \tag{2}$$

Taking the logarithm of Equation (2) gives

$$\ln\left(\frac{Y}{N}\right) = lnA + aln\left(\frac{K}{N}\right) + (1-a)ln\left(\frac{N}{N}\right) \tag{3}$$

$$\ln\left(\frac{Y}{N}\right) = lnA + aln\left(\frac{K}{N}\right) + (1-a)\ln 1 \tag{4}$$

$$\ln(y) = lnA + aln(k) \tag{5}$$

Where $y \equiv \frac{Y}{N}$ *and* $k \equiv \frac{K}{N}$

Equation (5) indicates that output per capita is equal to capital per capita plus the total factor productivity. This theoretical structure of the effect of a factor on output or income would be useful in evaluating the results of the analysis of this study.

2.1. Model specification

This section contains three models adapted for this study. It includes (1) Model 1 for the effects of ICT indicators and the control variables on the income level, (2) Model 2, which investigates whether per capita income influences the effect of ICT on income level; and (3) Model 3, investigating whether the effect of ICT on income level differs among sub-regions of Africa.

Inserting the relevant explanatory variables in Equation 5 gives rise to the following models:

Model 1:

$$\ln(y)_{it} = \beta_0 + \beta_1 \ln INV_{it} + \beta_2 \mathrm{InICTI}_{it} + \beta_3 \mathrm{InGEXP}_{it} + \beta_4 \mathrm{InEXPT}_{it} + \beta_5 \mathrm{INF}_{it} + \mu_{it}$$

Model 2:

$$\ln(y)_{it} = \beta_0 + \beta_1 \mathrm{In}INV_{it} + \beta_2 \mathrm{InICTI}_{it} + \beta_3 \mathrm{InICTI}_{it} * y + \beta_4 \mathrm{InGEXP}_{it} + \beta_5 \mathrm{InEXPT}_{it} + \beta_6 \mathrm{INF}_{it} + \mu_{it}$$

Model 3:

$$\ln(y)_{it} = \beta_0 + \beta_1 \mathrm{InINV}_{it} + \beta_2 \mathrm{InICTI}_{it} + \beta_3 \mathrm{InICTI}_{it} * \mathrm{E} + \beta_4 \mathrm{InICTI}_{it} * \mathrm{W} + \beta_5 \mathrm{InICTI}_{it} * \mathrm{S} + \beta_6 \mathrm{InICTI}_{it} * \mathrm{N} + \beta_7 \mathrm{InGEXP}_{it} + \beta_8 \mathrm{InEXPT}_{it} + \beta_9 \mathrm{INF}_{it} + \mu_{it}$$

Where y = real per capital income proxied by GDP per capita, ICTI = ICT indicators, alternatively proxied by FTS, IU, FBS, and MCS. While E, W, S, and N are dummy variables representing Eastern, western, Southern and Northern sub-regions, respectively, β_0, β_1, β_2, β_3, β_4, β_5, β_6, and β_7 represent parameters of the models, and subscripts i and t indicate country and year, respectively, μ_{it} is the stochastic error term, and INV = gross fixed capital formation as a percentage of GDP. In all the models, $\frac{\Delta k}{k}$ that represents the growth of capital stock per capita was replaced by the share of gross fixed capital formation in the GDP, denoted by *INV*. This is because the data for $\frac{\Delta k}{k}$ is not available and the only nearest suitable proxy for the growth of capital stock per capita that comes to mind is the share of gross fixed capital

formation in the GDP (*INV*). This study realizes this to be far from being a good approximation, but this is the best that the study can do because there is no growth of capital stock statistics, and it is hoped that the use of INV as a proxy is better than not including any proxy at all.

For estimation purposes, the natural log of the *ICTI*, *GEXP*, and *EXPT* variables, except *INF,* are employed in the models, thereby permitting the estimated slope parameters to be interpreted as elasticities.

To achieve our first objective, Model 1 was specified. Four ICT indicators were included one after another during estimation to give four equations that were estimated from Model 1. The four alternative ICT indicators were included one after another to avoid a high degree of multicollinearity. This is in line with previous studies such as Bahrini and Qaffass (2019) and Toader et al. (2018).

To achieve the second objective of this study—to examine whether per capita income influences the effect of ICT on income level—we specified Model 2 which shows real per capita income as a linear function of ICT indicators and their interactions with real income per capita. The ICT indicators were introduced into the model one after another during estimation, yielding four equation estimates.

To examine whether the effect of ICT on income level differs across the sub-regions of African countries—the third objective—each of the four alternative ICT indicators with regional dummy variables has interacted in Model 3. The dummy variables used were E, W, S and, N, with each taking a value of 1 for its corresponding African sub-region, and 0 otherwise. The reference category for these four dummies is the Middle African countries. Models 3 and 6 show economic growth as linear functions of ICT indicators (ICTI) as well as their interactions with the sub-regional dummies. To avoid serious multicollinearity problems during estimation, the ICT indicators and their interactions with sub-regional dummies are also included one after another.

2.2. Definition and measurement of variables

The definitions of the variables employed and their measurement are described below. The data for the variables were obtained from World Bank's World Development Indicators (2019).

2.2.1. ICT indicators

ICT indicators (ICTI)—measured by the number of internet users, fixed telephone subscriptions, mobile-cellular subscriptions, and fixed

broadband subscriptions—are assumed to impact economic growth positively. An increase in the level of each ICT indicator is posited to lead to an increase in technological progress, which in turn leads to economic growth. This is because technological progress would improve the efficiency of production and distribution of goods and services. This postulation is in line with Farhadi, Ismail, and Fooladi (2012), Sezer and Abasiz (2018), Bahrini and Qaffas (2019), and Eboagu and Adeleye (2019). The ICT indicators are operationalized as (1) number of fixed telephone subscriptions per 100 inhabitants, (2) mobile cellular subscriptions per 100 inhabitants, (3) number of internet users as a percentage of the population, and (4) number of fixed broadband subscriptions per 100 inhabitants.

- The number of fixed telephone subscriptions per 100 inhabitants (FTS) refers to the sum of 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 (World Bank, 2019).
- Mobile cellular subscription per 100 inhabitants (MCS) According to World Bank (2019), mobile cellular telephone subscriptions are subscriptions to a public mobile telephone service that provides access to the PSTN, using cellular technology. It includes the number of postpaid subscriptions and the number of active prepaid accounts that have been used during the last three months. The indicator applies to all mobile cellular subscriptions that offer voice communications. It excludes subscriptions via data cards or USB modems, subscriptions to public mobile data services, private trunked mobile radio, telepoint, radio paging and telemetry services.
- The number of internet users as a percentage of the population (IU) represents individuals who have used the Internet (from any location) in the last 3 months (World Bank, 2019). The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV, etc. It is measured as a percentage of the population.
- The number of fixed broadband subscriptions per 100 inhabitants (FBS) refers to fixed subscriptions to high-speed access to the public internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s (World Bank, 2019). This includes cable modem, DSL, fibre-to-the-home/building, other fixed (wired)-broadband subscriptions, satellite broadband, and terrestrial fixed wireless broadband. This total is measured irrespective of the method of payment. It excludes subscriptions that have access to data communications (including the Internet) via mobile-cellular

networks. It includes fixed WiMAX and any other fixed wireless technologies. It also includes both residential subscriptions and subscriptions for organizations.

2.2.2. Gross fixed capital formation (INV)

Gross fixed capital formation, as described by World Bank (2019), includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. According to the System of National Accounts (SNA) (1993), net acquisitions of valuables are also considered capital formation. The variable was measured as a ratio of GDP, in nominal terms and local currency.

2.2.3. Real per-capita income (y)

This refers to gross domestic product divided by midyear population. The data were the same as the ones used in computing per capita output growth in (3) above, except that the data used for the latter were measured at levels.

2.2.4. General government final consumption expenditure (GEXP)

This variable represents all government current expenditures for purchases of goods and services, including compensation of employees (World Bank, 2019). It also includes most expenditures on national defence and security but excludes government military expenditures that are a part of government capital formation. The variable was measured as a ratio of GDP, in nominal terms and local currency. General government final consumption expenditure was postulated to have a negative effect on productivity growth. Spending on public goods and services, as anecdotal evidence suggests, may be wasteful due to bribery and corruption or the varieties of taxes imposed by the government on citizens may be higher, thereby affecting productivity adversely. The inclusion of this variable is in line with the findings in some of such studies as Asongu and Odhiambo (2019) and Bahrini and Qaffas (2019).

2.2.5. Export of goods and services (EXPT)

This represents the value of all goods and other services provided to

the rest of the world. According to the data source, they include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments. Data are measured as a ratio of GDP, with both being nominal terms and in local currency before expressing one as a ratio of the other. An increase in export of goods and services (EXPT) was hypothesized to lead to an increase in net export through an increase in local production, low consumption of foreign goods by citizens and low excise duties. By this, an increase in net export would lead to an increase in aggregate expenditure, productivity growth, and economic growth. In their respective studies, Pham and Martin (2007) and Hesse (2008) have confirmed that export has a non-linear positive effect on economic growth in their estimation.

2.2.6. Inflation rate (INF)

Price stability, which is usually measured by inflation rate (INF), is important for economic agents to make accurate resource allocation decisions. Some previous studies, such as Bahrini and Qaffas (2019), Asongu and Odhiambo (2019) and, Eboagu and Adeleye (2019) have empirically confirmed that the inflation rate has a negative effect on economic growth. The inflation rate is, therefore, expected to have a negative effect on productivity growth.

2.2.7. Regional dummies (E, W, S, N, and E)

The varying impacts of ICT on economic growth and income level among the African sub-regions are measured by the regional dummy variables E, W, S and, N, which take a value of 1 for its corresponding African sub-region, and 0 otherwise. The reference category or sub-region for the four dummies is Middle African countries. The five-way classification is adopted from the International Monetary Fund (IMF) classification of African countries.

2.2.8. Estimation techniques

Three-panel methods of estimations were considered in this study: pooled-OLS, fixed effect (FE), and random-effect (RE) methods. The pooled OLS method of estimation, also called the common constant method, assumes that there are no differences between the estimated cross-sections (African

countries). In other words, the model estimates a common constant for all the cross-sections (African countries), and, the unobservable individual effect is assumed to be zero in pooled OLS estimator (Asteriou & Hall, 2007).

The FE estimator, known as the least-square dummy variables (LSDV) estimator, allows for the estimation of different constants for each group and includes a dummy variable for each group. It captures all effects that are specific to a particular individual and which do not vary over time. It is possible to the fixed-effect model by including a set of time dummies as well. This is known as the two-way fixed effect model and has the advantage of capturing any effects that vary over time but are common across the whole panel (Asteriou & Hall, 2007). The fixed effect is an appropriate specification when focusing on a specific set of *N* units, say countries. However, it suffers from a large loss of degrees of freedom when many dummies are included and the inclusion of too many dummies aggravates the problem of multicollinearity among the regressors. Furthermore, it cannot be used to estimate the effect of any time-invariant variable like sex, race, religion, and other categorical variables (Baltagi, 2005). The overall significance of the dummies is tested by F-test statistics.

The RE method is an alternative method of estimating a model. The major difference between the fixed effects and the random effects method is that the former treats the constant for each group as fixed while the latter treats the constant as random parameters (Asteriou & Hall, 2007).

In order to choose among these three estimators, we carried out four decision rules tests: poolability test, Hausman test, Breusch-Pagan Lagrange multiplier (LM) test. The poolability test is a test used to know whether the constant of a function is treated as homogeneous or heterogeneous. The test assists in knowing the appropriate estimators to use, whether pooled regression that follows the OLS approach or FE estimator. Before assessing the validity of the fixed effects method, we need to apply tests to check whether fixed effects (i.e., different constants for the various units) should indeed be included in the model. To do this, the standard F-test can be used to check fixed effects against the simple common constant OLS method. The null hypothesis is that all the constants are the same (homogeneity) and the alternative hypothesis is that all the constants differ (heterogeneity). If the p-value of the F-test is less than 0.05 level of significance (or any other chosen level of significance, say 0.01), then we reject the null hypothesis (Asteriou & Hall, 2007).

Hausman test is a test used to select the better model between FE and RE because both have their demerits and merits. In general, the difference between the two-panel data models is that the FE model assumes that each

country differs in its intercept term, whereas the RE model assumes that each country differs in its error term. Usually, when the panel is balanced, one might expect that the FE model will work best. In other cases, whereby the sample contains limited observations of the existing cross-sectional units, the random-effects model might be more appropriate (Asteriou & Hall, 2007).

Breusch-Pagan Lagrange multiplier (LM) is a test for the random-effects model based on the OLS residual. It helps to select between a RE regression and a simple pooled OLS regression. The null hypothesis is that variance across entities is zero, that is, there is no significant difference across units. A study rejects the null hypothesis if the p-value of the LM test is less than 0.05 significance level or any other chosen level of significance (Kalita & India, 2013). LM test should be conducted based on the following two conditions: (a) if the Poolability test indicates that simple pooled OLS regression is better than FE regression and (b) if the Hausman test shows that RE is better than FE regression. The Lagrange Multiplier Test is required only if the above two conditions are met (Kalita & India, 2013).

We equally carried out four post-estimation tests—multicollinearity test, autocorrelation test, heteroscedasticity test, and non-normality of the residuals test—in order to test the validity of the regression model, to determine if they actually violate the assumptions underlying the OLS method.

3. Results and discussion

This section provides the descriptive and correlation statistics, the estimates of the panel regression equations and the associated post-estimation test results, and the comparison of the estimates of the effect of different explanatory variables on economic growth and per capita output level.

3.1. Descriptive statistics

Table 1. Selected Descriptive Statistics

Variables	Mean	Min.	Max.	Overall Std.	Between	Within	Skewness	Kurtosis	†Coef. v.
INV	23.28	3.29	58.83	9.26	8.24	4.68	0.70	3.66	0.3978
$\frac{\Delta y}{y}$	1.75	-62.38	121.78	7.88	2.29	7.58	4.97	118.15	4.5029
FTS	3.65	0	32.67	6.02	5.97	0.95	2.75	10.91	1.6493
MCS	69.07	2.36	175.87	38.84	34.22	18.98	0.50	2.49	0.5623
IU	14.8	0.25	64.19	14.91	12.46	8.38	1.34	3.95	1.0074
FBS	1.09	0	19.45	2.56	2.31	1.02	4.09	21.89	2.3486
INF	8.58	-4.29	379.84	21.76	13.99	17.09	12.56	193.01	2.5361
Y	5595	637	40368	6703	6551	1317	2.28	8.80	1.1981
GEXP	15.41	2.05	79.17	6.65	5.76	3.41	2.43	20.24	0.4315
EXPT	33.76	4.43	158.27	21.27	22.82	6.65	2.07	10.05	0.6300

† Coef. v = coefficient of variation.

Source: Authors' computation

Table 1 summarises the descriptive statistics for each of the variables employed in the study. It includes the mean, median, maximum, minimum, standard deviation (overall, within and between), skewness and kurtosis for all the variables.

Table 1 depicts the overall standard deviation for gross fixed capital formation to be about 9.26, indicating variations both over time and across

units and, the standard deviation is 8.24, indicating variations across African countries irrespective of the time period while the within the standard deviation, with the value of 4.68, shows the variations over time. The within standard deviation is lower compared to between that is, the data set for the variable do not really change over time when compared to how it varies across African countries. The mean of gross fixed capital formation is about 23.28 with a coefficient of variation of about 0.40.

3.2. Correlation analysis

Table 2 shows the sample correlations between each pair of variables. The p-values of the correlation coefficients in Table 2 indicate the statistical significance of the correlation between each pair of the variables. A correlation is interpreted to exist in this study if the p-value is not more than 5 per cent (i.e., 5% is the chosen cut-off significance level in the study).

Table 2. Correlation Matrix

Variables	$\frac{\Delta y}{y}$	LINV	FTS	MCS	LIU	LFBS	INF	lny	LGEXP	LEXPT
$\frac{\Delta y}{y}$	1									
LINV	0.200	1								
	(0.000)									
LFTS	0.094	0.212	1							
	(0.038)	(0.000)								
LMCS	0.021	0.219	0.463	1						
	(0.639)	(0.000)	(0.000)							
LIU	-0.014	0.177	0.523	0.794	1					
	(0.749)	(0.000)	(0.000)	(0.000)						
LFBS	0.056	0.221	0.688	0.658	0.715	1				
	(0.224)	(0.000)	(0.000)	(0.000)	(0.000)					
INF	-0.107	-0.175	-0.252	-0.209	-0.056	-0.272	1			
	(0.019)	(0.000)	(0.000)	(0.000)	(0.220)	(0.000)				
Lny	-0.007	0.257	0.682	0.601	0.652	0.649	-0.060	1		
	(0.880)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.189)			
LGEXP	-0.014	0.158	0.332	0.158	0.168	0.164	-0.045	0.162	1	
	(0.765)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.315)	(0.000)		
LEXPT	0.030	0.265	0.343	0.370	0.282	0.343	-0.045	0.542	0.286	1
	(0.504)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.332)	(0.000)	(0.000)	

LINV = log of gross fixed capital formation as a ratio of GDP, $\frac{\Delta y}{y}$=Economic growth, LFTS= Log of fixed telephone subscriptions per 100 inhabitants, LMCS = Log of mobile cellular subscription per 100 inhabitants, LIU =Log of internet users as a percentage of the population, LFBS =Log of fixed broadband subscriptions per 100 inhabitants, lny=log of real income per capita, INF= inflation rate, LGEXP=log of general government final consumption expenditure, LEXPT=log of export of goods and services. Probability values are reported in parentheses next to the coefficients.

Source: Authors' computation

3.3. Estimates of the effect of ICT indicators on per capita output

The estimates for the equation of the basic per capita output level (Model 1) are given in Table 3. Equations I, II, III, and IV examine the impacts of FTS, MCS, IU, and FBS on per capita output level, respectively.

Given the Hausman test results in Table 3, we failed to reject the null hypothesis of RE being preferred to FE in Equations II, III, and IV ($p > 0.05$). The LM test confirmed that RE was preferred to pooled OLS regression. However, the null hypothesis was rejected for Equation I ($p < 0.05$). The test of poolability confirmed that the FE estimator is preferred to pooled OLS regression in Equation I ($p < 0.05$). For these reasons, the RE method was employed for estimating Equations II, III, and IV while the FE method was considered for Equation I.

Table 3. Estimates of the effect of ICT Indicators on per Capita Output (y)

	Equation I			Equation II			Equation III			Equation IV		
	No of Obs. = 420			No of Obs. = 443			No of Obs. = 438			No of Obs. = 409		
Variables	Coeff	T-stat.	p-value	Coeff	Z-stat.	p-value	Coeff	Z-stat.	p-value	Coeff	Z-stat.	p-value
LINV	0.102	2.23	0.031	0.099	2.76	0.006	0.082	2.04	0.041	0.114	2.65	0.008
LFTS	-0.030	-1.41	0.165									
LMCS				0.159	8.31	0.000						
LIU							0.717	10.25	0.000			
LFBS										0.043	7.09	0.000
LGEXP	-0.120	-1.37	0.179	-0.173	-3.14	0.002	-0.136	-1.95	0.051	-0.163	-2.85	0.004
LEXPT	-0.010	-0.21	0.837	0.021	0.79	0.431	0.032	1.13	0.257	0.046	1.39	0.166
INF	0.0002	0.13	0.901	0.0018	1.45	0.147	-0.0026	-2.27	0.023	0.0020	1.46	0.145
Hausman (P-value)			0.001			0.462			0.517			0.078
Poolability (P-value)			0.000			—			—			—
LM Test (P-value)			—			0.000			0.000			0.000
No of Countries	49			49			49			48		
Overall Rsquared	0.168			0.476			0.489			0.487		
Within Rsquared	0.103			0.434			0.475			0.280		
Between Rsquared	0.227			0.370			0.464			0.457		
F/Wald Chi-test (P-value)			0.061			0.000			0.000			0.000

LM Test (p-value) indicates probability values to select the preferred estimator between pooled OLS regression and Random Effect estimator. F/Wald Chi-test (p-value) shows the p-values of F-statistics in Fixed Effect estimator and p-values of Wald chi-test statistics in Random Effect estimator.

Source: Authors' computation

The overall R^2 is approximately 50 per cent in all the equations except Equation 1 and the p-value of the associated F-test statistics in Equation I is 0.061 and that of the Wald chi-test statistics in Equations II, III, IV are 0.000 each, indicating the overall statistical significance for all the Equations. This means that all the equations, except Equation I, have high goodness of fit or explanatory powers.

We carried out the Wooldridge test of autocorrelation for the four equations and concluded that autocorrelation was present in all the equations ($p = 0.0000$). As a result of this test, we estimated a robust version of the RE regression for Equations II to IV and the FE regression for Equation I to correct the autocorrelation problem.

Furthermore, in respect of the test of heteroscedasticity of the residuals, we conducted a panel modified Wald heteroscedasticity test for FE regression for only Equation I. with $p = 0.000$, we rejected the null hypothesis of homoscedasticity in Equation I and concluded that the errors were heteroscedastic. We thus estimated a robust FE regression to correct for the heteroscedasticity. Since Equations II, III, and IV were estimated by the RE estimator, and there was no specific heteroscedasticity test for the RE estimator, we estimated robust RE regression for Equations II, III, and IV to correct for the heteroscedasticity.

Next, we conducted a Galvao et al. (2013) test of normality, which showed that the error terms were normally distributed ($p > 0.05$) except in Equation III where $p = 0.042$. Given this, the study failed to reject the null hypothesis of normality of the residuals in all the equations except Equation III and concluded that the residuals in all the equations (Equation III) were normally distributed. This situation was corrected by running a robust version of the FE regression or the RE regression to correct for the non-normality of the residuals.

Lastly, on the diagnostic tests, the Tolerance test of multicollinearity of the explanatory variables was carried out. Given this, we failed to reject the hypothesis of the absence of multicollinearity in the equations as the Tolerance exceeds 0.1 in all cases and concluded that all the equations were devoid of severe multicollinearity.

Next, we proceeded to examine the significance of the specific explanatory variables in the models estimated in Table 3.

The p-values of the coefficients of the LINV are 0.031, 0.006, 0.041, and 0.008, respectively, indicating that the coefficients of *LINV* in all equations are positive and statistically significant (Table 3). These results, which support our a priori expectation, suggest that gross fixed capital formation had a positive effect on the per capita output level. Similar evidence

was found in Bahrini and Qaffas (2019) and Toader et al. (2018).

In Equation I, the coefficient of LFTS is -0.030 (p = 0.165), implying that the coefficient is negative and statistically insignificant (Table 3). This indicates that fixed telephone subscriptions had no effect on the per capita output level. However, in Equation II, the coefficient of LMCS is 0.159. The coefficient is positive and statistically significant (p = 0.000). This implies that mobile cellular subscription had a positive effect on per capita output level, with income elasticity of mobile cellular subscription of 0.159.

The coefficient of LIU in Equation III is positive and equals 0.717, which means that the coefficient is statistically different from zero (p = 0.000). This implies that internet usage had a positive effect on per capita output level, with income elasticity of internet usage of 0.717. Similarly, the coefficient of LFBS in Equation IV is positive and equals 0.043, indicating the coefficient is statistically significant (p = 0.000). This suggests that fixed broadband subscription had a positive effect on per capita output level, with income elasticity of fixed broadband subscription of 0.04.

In sum, all the ICT indicators, except fixed telephone subscription, had a positive effect on the per capita output level. Based on this preponderant evidence, this suggests that ICT indicators had positive effects on per capita output level. This is consistent with the a priori expectation formed based on the findings by Bahrini and Qaffas (2019), and Toader et al. (2018).

The coefficients of the Log of General Government Final Consumption Expenditure (LGEXP) are -0.120, -0.173, -0.136, and -0.163 in Equations I to IV, respectively, with respective p-values of 0.179, 0.002, 0.051, and 0.004. Equations II and IV are negative and statistically significant while Equations I and III are also negative but statistically insignificant. This provides somewhat weak evidence that general government final consumption expenditure had a negative effect on per capita income level. These results do not conform to our a priori expectation. They are, however, in consonance with the findings confirmed by Asongu and Odhiambo (2019) and Bahrini and Qaffas (2019).

Also found against our a priori expectation are the coefficients of Log of Export of Goods and Services (LEXPT) which are -0.010 (p = 0.837), 0.021 (p = 0.431), 0.032 (p = 0.257), and 0.046 (p = 0.166) in Equations I to IV, respectively. Although the coefficient of LEXPT in Equation I is negative and those in Equations II through IV are positive, they are all statistically insignificant. This indicates that the exportation of goods and services had no effect on the per capita income level. This result is consistent with the studies by Pham and Martin (2007), and Hesse (2008). This finding emanates probably because the effect of export on per capita income level was crowded

out by excessive borrowing from private and public foreign sources which led to a distortion of the balance of trade and devaluation of the domestic currency.

The coefficients of Inflation Rate (INF) are 0.0002 (p = 0.901), 0.0018 (p = 0.147), -0.0026 (p = 0.023), and 0.002 (p = 0.145) in Equation I to IV respectively. While its coefficient in Equation III is negative, it is positive in Equations I, II, and IV. Except for Equation III, all the coefficients are statistically insignificant. Contrary to our a priori expectation and the findings by Toader et al. (2018), this tells us that the inflation rate did not have a negative significant effect on per capita output level. Inflation failed to affect the income level probably because the production capacity was at a low level while unemployment was high, leading to stagflation.

3.4. Joint effect of ICT and real per capita income (y) on per capita output (y)

The estimates of the four alternative equations of Model 2 are reported in Table 4. Equation 1 examines whether real per capita income influences the effect of the FTS on per capita output level, while Equations II, III, and IV replace the FTS with the MCS, IU and, FBS, respectively.

Given the Hausman test results in Table 4, we failed to reject the null hypothesis of RE is preferred to FE in Equation I (p = 0.903) while we rejected the null hypothesis in Equations II, III, and IV (p = 0.007, 0.018, and 0.042, respectively). Furthermore, the LM test confirmed that the RE estimator is preferred to pooled OLS regression in Equation I, and the poolability test confirmed that FE is preferred to pooled OLS regression in Equations II, III, and IV. Consequently, we employed the RE method for Equation I and the FE method for Equations II, III, and IV.

Table 4. Estimates of the Joint Effect of ICT and Real Per Capita Income (y) on Per Capita Output (y)'

	Equation I No of Obs. = 420			Equation II No of Obs. = 443			Equation III No of Obs. = 438			Equation IV No of Obs. = 409		
Variables	Coeff	Z-stat.	p-value	Coeff	T-stat.	p-value	Coeff	T-stat.	p-value	Coeff	T-stat.	p-value
LINV	0.093	2.39	0.017	0.068	2.71	0.009	0.080	2.15	0.037	0.097	2.53	0.015
LFTS	-0.0511	-1.60	0.110									
LFTSy	0.000013	2.67	0.007									
LMCS				0.109	6.36	0.000						
LMCSy				0.0000088	6.03	0.000						
LIU							0.069	7.67	0.000			
LIUy							0.00000012	0.06	0.950			
LFBS										0.045	6.62	0.000
LFBSy										-0.0000017	-1.85	0.070
LGEXP	-0.102	-1.47	0.143	-0.129	-2.84	0.007	-0.138	-2.06	0.045	-0.135	-2.69	0.010
LEXPT	-0.010	-0.22	0.826	0.016	0.66	0.513	0.021	0.80	0.429	0.017	0.48	0.631
INF	0.00051	0.29	0.773	0.0017	1.56	0.124	-0.0026	-2.27	0.028	0.0019	1.39	0.170
Hausman (P-value)			0.903			0.007			0.018			0.042
Poolability (P-value)			—			0.000			0.000			0.000
LM Test (P-value)			0.000			—			—			—
No of Countries	49			49			49			48		
Overall Rsquared	0.284			0.852			0.669			0.501		
Within Rsquared	0.117			0.569			0.476			0.301		
Between Rsquared	0.345			0.848			0.438			0.468		
F/Wald chi-test			0.000			0.000			0.000			0.000

y= LFTSy, LMCSy, LIUy, and LFBSy indicate the interaction of per capita income with each ICT indicator.

Source: Authors' computation

The overall R^2 is larger than 50 per cent in the equations except Equation 1. The p-value of the associated Wald chi-test statistics in Equation I is 0.000 and that of the F-test statistics in Equations II, III, IV are 0.000, 0.000, and 0.000 respectively. This means that all four equations have high explanatory power except Equation I.

We conducted the Wooldridge test of autocorrelation for the four equations and concluded that the residuals of the equations were autocorrelated ($p = 0.000$) was present in all the equations ($p = 0.0000$). We, therefore, estimated a robust version of the FE regressions to correct for the autocorrelation. As regards the heteroscedasticity of the residuals, we carried out a panel modified Wald heteroscedasticity test and rejected the null hypothesis of homoscedasticity in Equations II, III, and IV ($p = 0.000$ for each equation) and concluded that the residuals of the equations were heteroscedastic. Given this result, we estimated a robust FE regression to correct for the heteroscedasticity in Equations I, II, and III. Since there is no specific heteroscedasticity test for the RE estimator, a robust RE regression was estimated for Equation I to correct for the heteroscedasticity.

Next, Galvao et al. (2013) test of normality test was conducted. The test result indicated that the error terms in Equations I, III, and IV were normally distributed ($p > 0.05$) while that of Equation II were not normally distributed ($p = 0.000$). This situation was corrected by running a robust version of FE regression or RE regression to correct for the non-normality of residuals. The final validity test we carried out was a test of multicollinearity of the explanatory variables. Using the Tolerance test, we failed to reject the hypothesis of the absence of multicollinearity in the equations (Tolerance > 0.1 in all cases). This implies that all equations are devoid of severe multicollinearity.

Having just evaluated the overall diagnostic statistics of each of the equations, we advanced to examine the performance of the specific explanatory variables in the equations as follows.

From Table 4, the coefficients of the Log of Gross Fixed Capital Formation (LINV) are 0.093 ($p = 0.017$), 0.068 ($p = 0.009$), 0.080 ($p = 0.037$), and 0.097 ($p = 0.015$) in Equations I through IV, respectively. This indicates that the coefficients of LINV in all the equations are positive and statistically significant. In line with our a priori expectation, this indicates that gross fixed capital formation had a positive effect on the per capita output level. Similar findings were reported by Bahrini and Qaffas (2019), Hodrab, Maitah and, Lubos (2016), and Shanmugam and Kuppusamy (2007).

In Equation I (Table 4), the coefficients of the Log of Fixed Telephone Subscriptions (LFTS) and its interaction with per capita income (LFTSy) are

respectively –0.0511(p = 0.110) and –0.000013 (p = 0.007), which shows that both coefficients are negative and only LFTSy is statistically significant. This implies that the fixed telephone subscription, in its own right, did not have an effect on per capita output level but per capita income made it affect per capita output level.

In Equation II of Table 4, the coefficients of the Log of Mobile Cellular Subscriptions (LMCS) and its interaction with per capita income (LMCSy) are 0.109 (p = 0.000) and 0.00001 (p = 0.000), respectively. This indicates that both coefficients are positive and statistically significant. This suggests that mobile cellular subscription had a positive effect on per capita output level and that mobile cellular subscription was more effective in promoting per capita output level in higher income group countries than in their lower-income counterparts.

The coefficients of the Log of Internet Users as a percentage of total population (LIU) and its interaction with per capita income (LIUy) are 0.069 (p = 0.000) and 0.0000001 (p = 0.950), respectively (Table 4, Equation III). This points out that both the coefficients of LIU and LIUy are positive but only the former is statistically significant, suggesting that internet usage had a positive effect on per capita output level and did not have an effect on per capita output level in higher income group countries.

The coefficients of the Log of Fixed Broadband Subscriptions (LFBS) and its interaction with per capita income (LFBSy) in Equation IV of Table 4 respectively are 0.045 (p = 0.000) and -0.00002 (p = 0.070), respectively. This depicts that the coefficient of LFBS and LFBSy are positive and negative, respectively but only LFBS is statistically significant. This points out that internet usage had a positive effect on per capita output level and per capita income does not influence the effect of internet usage on per capita output level.

In all, out of all ICT indicators, only mobile cellular subscriptions and fixed telephone subscriptions have an effect on per capita output level in higher income group countries. Thus, the overall picture emerging from the findings is that there is somewhat weak evidence to conclude that ICT indicators affect per capita output level in higher income group countries.

The coefficients of the Log of General Government Final Consumption Expenditure (LGEXP) were estimated to be –0.102 (p = 0.143), –1.129 (p = 0.007), –0.138 (p = 0.045), and –0.135 (p = 0.010) in Equations I, II, III, and IV, respectively (Table 4). This indicates that the coefficients of LGEXP in all the equations are negative and statistically significant except in Equation I. In consonance with our a priori expectation and the findings reported by Asongu and Odhiambo (2019) and Bahrini and Qaffas (2019),

this portrays that general government final consumption expenditure had a robust negative effect on per capita output level.

In Table 4, the coefficients of the Log of Export of Goods and Services (LEXPT) were estimated to be -0.010 (p = 0.826), 0.016 (p = 0.513), 0.021 (p = 0.429), and 0.017 (p = 0.631) in Equations I through IV, respectively. This indicates that the coefficients of LEXPT in all equations are positive (except in Equation I) and statistically insignificant, and hence indicates that the exportation of goods and services had no effect on per capita output level. This result is with our a priori expectation and the literature, especially the findings reported by Pham and Martin (2007), and Hesse (2008). This could be that the effect of export on per capita income level had been crowded out by excessive borrowing from private and public foreign sources which led to a distortion of the balance of trade and devaluation of the domestic currency.

The coefficients of Inflation rate (INF) are 0.0005 (p = 0.773), 0.0017 (p = 0.124), -0.0026 (p = 0.028), and 0.0019 (p = 0.170) in Equations I to IV, respectively, indicate that only the coefficient of Equation III is statistically significant while other coefficients are not statistically significant. Against our a priori expectation and findings by Asongu and Odhiambo (2019), and Eboagu and Adeleye (2019), this suggests that the inflation rate did not have a robust negative effect on per capita output level. As the inflation rate rose over time, it failed to have an effect on the income level because the production capacity is at a low level and unemployment became high.

3.5. Estimates of the joint effect of ICT and region on per capita output (y)

The estimates of the four versions of Model 6 are reported in Table 5. Equations I, II, III, and IV are respectively concerned with the effects of the FTS, MCS, IU, and FBS on per capita output levels across the sub-regions of African countries.

The Hausman test results shown in the table indicate that we failed to reject the null hypothesis that RE has preferred to FE estimator in Equation IV (p = 0.324), but we reject the hypothesis in Equations I (p = 0.000), II (p = 0.000), and III (p = 0.000). The poolability test confirmed that the FE estimator was preferred to pooled OLS regression in Equations I, II, and III ($p < 0.05$). Given these results, we employed the FE method for Equations I, II, and III, and the RE method for Equation IV.

Table 5. Estimates of the Joint Effect of ICT and Region on Per Capita Output (y)

	Equation I No of Obs. = 420			Equation II No of Obs. = 443			Equation III No of Obs. = 438			Equation IV No of Obs. = 409		
Variables	Coeff	T-stat.	p-value	Coeff	T-stat.	p-value	Coeff	T-stat	p-value	Coeff	Z-stat.	p-value
LINV	0.098	2.09	0.042	0.104	2.84	0.007	0.09	2.61	0.012	0.122	3.09	0.002
LFTS	0.007	0.18	0.860									
LFTSE	-0.025	-0.44	0.662									
LFTSW	-0.050	-1.07	0.289									
LFTSS	-0.068	-1.44	0.157									
LFTSN	-0.123	-1.79	0.080									
LMCS				0.091	1.91	0.062						
LMCSE				0.068	0.96	0.344						
LMCSW				0.055	1.01	0.316						
LMCSS				0.143	2.47	0.017						
LMCSN				0.127	1.64	0.107						
LIU							0.01	0.50	0.620			
LIUE							0.09	2.48	0.017			
LIUW							0.05	1.78	0.081			
LIUS							0.08	2.58	0.013			
LIUN							0.12	2.24	0.029			
LFBS										0.012	1.02	0.309
LFBSE										0.040	2.51	0.012
LFBSW										0.021	1.33	0.184
LFBSS										0.055	3.01	0.003
LFBSN										0.115	4.06	0.000
LGEXP	-0.103	-1.31	0.197	-0.165	-3.23	0.002	-	-2.33	0.024	-0.162	-3.25	0.001
LEXPT	-	-0.04	0.965	0.018	0.63	0.532	0.02	0.93	0.355	0.060	1.79	0.073
INF	0.0002	0.10	0.922	0.0017	1.39	0.172	-	-2.28	0.027	0.0021	1.78	0.076
Hausman			0.000			0.000			0.000			0.324
Poolability			0.000			0.000			0.000			—
LM Test (P-value)			—			—			—			0.000
No of Countries	49			49			49			48		
Overall Rsquared	0.504			0.583			0.501			0.572		
Within Rsquared	0.119			0.453			0.549			0.335		
Between Rsquared	0.278			0.340			0.357			0.365		
F/Wald chi-test (P-value)			0.014			0.000			0.000			0.000

E, W, S, N, and M indicate the dummy variables for the Sub-regional African countries. LFTS, LFTSE, LFTSW, LFTSS, LFTSN, LMCS, LMCSE, LMCSW, LMCSS, LMCSN, LIU, LIUE, LIUW, LIUS, LIUN, LFBS, LFBSE, LFBSW, LFBSS, and LFBSN indicate both the reference categories and the ICT indicators interacted with the Sub-regional dummy variables

Source: Authors' computation

In Table 5, the overall R^2 is approximately 50 per cent in each equation and the p-value of the associated Wald chi-test statistics in Equation IV is 0.000 and, that of the F-test statistics in Equations I, II, III are 0.014, 0.000, and 0.000, respectively, indicating that all the four equations have high goodness of fit or explanatory power.

A test of autocorrelation of the residuals (Wooldridge test) was carried out for Equations 1 through IV. The Wooldridge test (p = 0.000) suggested that autocorrelation was present in all the equations. We, therefore, estimated a robust version of the FE regression to correct for the autocorrelation.

A test of heteroscedasticity of the residuals was also carried out using panel modified Wald heteroscedasticity test for FE regression, which shows a p-value of 0.000 for only Equations I, II, and III. Given these results, we rejected the null hypothesis of homoscedasticity for Equations I, II, and III and concluded that the residuals were heteroscedastic in these three equations. Consequently, we estimated a robust FE regression to correct for the heteroscedasticity in Equations I through III while a robust RE regression was also estimated for Equation IV.

Galvao et al. (2013) test of normality conducted shows that the error terms were normally distributed {p (chi-square) > 0.05}. However, a robust version of Fixed Effect (FE) regression was employed for the estimation.

We also conducted a test for multicollinearity of the explanatory variables, using the Tolerance test. Since the Tolerance exceeds 0.1 for all equations, we did not reject the null hypothesis of the absence of multicollinearity in the equations and concluded that all equations were devoid of severe multicollinearity.

Having evaluated the overall diagnostic statistics of each of the equations, we proceeded to examine the performance of the specific explanatory variables in the equations.

In Table 5, the coefficients of the Log of Gross Fixed Capital Formation (LINV) are 0.098 (p = 0.042), 0.104 (p = 0.007), 0.093 (p = 0.012), and 0.122 (p = 0.002) in Equations I, II, III, and IV respectively, indicating that the coefficients of LINV in all the equations are positive and statistically significant. In consonance with our a priori expectation and findings reported by Bahrini and Qaffas (2019), Hodrab, Maitah and Lubos (2016), and Shanmugam and Kuppusamy (2007), these results suggest that gross fixed capital formation had a positive effect on per capita output level.

The coefficients of the log of General Government Final Consumption Expenditure (LGEXP) are -0.103 (p = 0.197), -0.165 (p = 0.002), -0.122 (p = 0.024), and -0.162 (p = 0.001) in Equations I, II, III, and IV, respectively, depicting that the coefficients are negative in all equations. However, while

its coefficients in all Equations II, III, and IV are statistically significant, its coefficient in Equation I is statistically insignificant. This indicates that general government final consumption expenditure had a robust negative effect on per capita output level. These results agree with our a priori expectation and the findings reported by Asongu and Odhiambo (2019) and Bahrini and Qaffas (2019). These results are obtained probably because the government recurrent expenditures are small relative to capital expenditure. The effect recurrent expenditure was supposed to have on GDP might have been crowded out by imposing high commodity and income taxes.

The coefficients of the log of Export of Goods and Services (LEXPT) are -0.0021 (p = 0.965), 0.018 (p = 0.532), 0.024 (p = 0.355), and 0.060 (p = 0.073) in Equations I, II, III, and IV respectively, depicting that all the coefficients are positive (except for Equation I) though statistically insignificant. This indicates that the exportation of goods and services had no effect on the per capita output level, the finding which does not conform to our a priori expectation and finding from previous studies such as Pham and Martin (2007), and Hesse (2008). It could be that the effect of export on per capita income level had been crowded out by excessive borrowing from private and public foreign sources which led to a distortion of the balance of trade and devaluation of the domestic currency.

The coefficients of inflation rate (INF) are 0.0002 (p = 0.922), 0.0017(p = 0.172), -0.0024 (p = 0.027), and 0.0021 (p = 0.076) in Equations I, II, III, and IV, respectively, depicting that the coefficients of INF in Equation III is negative but positive in Equation I, II, and IV. For Equations I, II, and IV, the coefficients are not statistically significant but significant in Equation III. These results do not provide strong evidence that the inflation rate had a negative effect on per capita output level, which was our a priori expectation though. Similar findings were reported by Asongu and Odhiambo (2019), and Eboagu and Adeleye (2019).

As regards the effect of ICT indicators on per capital output level, Equation I indicates that the effect (negative) of the fixed telephone subscription on per capita output level did not differ among the sub-region of African countries. This is because the probability values of the reference category and the FTS interacted with sub-regional dummy variables are all greater than 0.05 significant levels. While Equation II shows that the effect of mobile cellular subscriptions on per capita output level is higher for only Southern African countries when compared with reference group countries and other sub-regional countries, Equation III indicates that the effect of the internet usage on per capita output levels are higher in Eastern, Southern, and Northern African countries compared to reference group countries (Middle

African countries) and other sub-regional countries. Equation IV similarly indicates that the effect of the fixed broadband subscription on per capita output level is higher for Eastern, Southern, and Northern African countries compared to reference group countries (Middle African countries) and other sub-regional countries.

4. Conclusion

Based on the objectives and findings above, three main conclusions are drawn from this study: (1) ICT positively affects income level in Africa; (2) real income per capita influences the effect of ICT on income level (3) the effect of ICT on income level differs among African regions, and that the effect is larger in Eastern, Southern and Northern African countries than other regions.

Given this empirical evidence, policies should be targeted toward improving the ICT indicators development in each African country in order to uplift countries within the category of the low-income group to that of the higher-income group. Authorities in Western and Middle African countries should beef up investment in ICT to optimally exploit the benefits of ICT.

As for the control variables, general government final consumption expenditure has a negative effect on income level while gross fixed capital formation has a positive effect on income level. Inflation, as well as the export of goods and services, does not exert a perceptible influence on the per capita output level. Hence, authorities need to embark on policies that will increase gross fixed capital formation. We recommend that policymakers should not rely on general government final consumption expenditure as a factor that raises per capita output.

References

Aghaei, M., & Mahdieh, R. (2017). The impact of information and communication technology (ICT) on economic growth in the OIC countries. *Environmental and Socio-Economic Studies 17*(2), 255–76. https://doi.org/10.25167/ees.2017.42.7

Asongu, S., & Odhiambo, N. (2019). Foreign direct investment, information technology and economic growth dynamics in sub-Saharan Africa. *EXCAS Working Paper WP/19/038*. SSRN. https://doi.org/10.2139/ssrn.3417047

Asteriou D., & Hall, S.G. (2006). *Applied econometrics, A modern approach* (Rev. ed.). Palgrave Macmillan.

Bahrini, R., & Qaffas A. A. (2019). Impact of information and communication technology on economic growth: evidence from developing countries. *Economies*, *7*(1), 21. https://doi.org/10.3390/economies7010021

Baltagi, B. H. (2005). Econometric analysis of panel data (3rd ed.). John Wiley & Sons Ltd.

Can, H., & Terziev, V. (2016). The relationship economic growth and information

technologies. SSRN. http://dx.doi.org/10.2139/ssrn.3383899

Eboagu, C., & Adeleye, N. (2019). Evaluation of ICT development and economic growth in Africa. *Netnomics, 20*, 31–53. https://doi.org/10.1007/s11066-019-09131-6

Farhadi, M., Ismail, R., & Fooladi, M. (2012). Information and communication technology use and economic growth. PLoS ONE 7(11), e48903. https://doi.org/10.1371/journal.pone.0048903

Galvao, A. F., Montes-Rojas, G., Sosa-Escudero, & Wang, L. (2013). Test for skewness and kurtosis in the one-way error component model. *Journal of Multivariate Analysis, 122, 35–52. https://doi.org/10.1016/j.jmva.2013.07.002*

Hesse, H. (2008). Export Diversification and economic growth. Commission on Growth and Development Working Paper; No. 21. World Bank, Washington. https://openknowledge.worldbank.org/handle/10986/28040

Hodrab, R., Maitah M., & Lubos S. (2016). The effect of information and communication technology on economic growth: Arab world case. *Journal of Economics and Financial Issues, 6*(2), 765–775.

Kalita, G. & India, R. T. (2013). *Panel regression in Stata: An introduction to type of models and tests*. STATA Users Group Meeting 1st August 2013, Mumbai. https://www.stata.com/meeting/india13/materials/in13_kalita.pdf

Pham, C., & Martin W. (2007). *Extensive and intensive margin growth and developing country exports*. World Bank, Washington D.C.

Sezer, S., & Abasiz, T., (2018). The effect of information and communication technologies on economic growth in OECD Countries. *Annals of the Constantin Brâncuşi University of Târgu Jiu, Economy Series, 6*, 31–36.

Shanmugam, B., & Kuppusamy, M. (2007). Islamic countries economic growth and ICT development: The Malaysian case. *Journal of Economic Cooperation*, *28*(1), 99–114.

Toader, E., Firtescu, B., Roman, A., & Anton, S. (2018). Impact of Information and Communication Technology Infrastructure on Economic Growth: An Empirical Assessment for the EU Countries. *Sustainability*, *10*(10), 3750. https://doi.org/10.3390/su10103750

Veeramacheneni, B., Ekanayake, E. M., & Vogel, R. (2011). Information technology and economic growth: A causal analysis. *Southwestern Economic Review*, 34, 75–88.

World Bank. (2019). World development indicators. World Bank, Washington, DC. https://datatopics.worldbank.org/world-development-indicators