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Article

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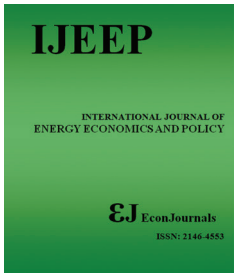

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Energy Consumption, Information and Communication Technology and Economic Growth in an African Context

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ABSTRACT

The study had two main objectives. Firstly, to investigate the impact of ICT on economic growth. Secondly, to explore whether energy consumption and human capital development are channels through which ICT influences economic growth in Africa. Whilst literature is unanimous when it comes to the positive impact of ICT on economic growth, not much has been investigated on the impact of the complementarity between (1) ICT and energy consumption and (2) ICT and human capital development on economic growth, especially in the African context. The current study used fixed effects, random effects, pooled OLS and the dynamic GMM with annual panel data ranging from 2001 to 2015. Whilst fixed and random effects show a significant positive relationship running from ICT towards economic growth, pooled OLS and the dynamic GMM produced results which show that ICT had a non-significant positive influence on economic growth in Africa. The interaction between ICT and energy consumption had a significant negative effect on economic growth across all the panel data analysis methods. The finding means that ICT enhanced economic growth through its energy efficiency impact in Africa, consistent with Lee and Brahmasrene (2014). The interaction between ICT and human capital development was found to have had a significant positive effect on economic growth in Africa, in line with Ortiz et al. (2015) whose study revealed that the complementarity between ICT and education enhanced economic growth. The study therefore urges the African continent authorities to develop, strengthen and implement sound human capital development in order to enhance the impact of ICT on economic growth. African countries are also urged to implement sound ICT growth policies in order to trigger energy efficiency led economic growth.

Keywords: ICT, Energy Consumption, Human Capital Development, Africa
JEL Classifications: N7, Q4, E44, O55

1. INTRODUCTION

To date, there is rather weak and ambiguous empirical evidence on the contribution of ICT investments on economic growth for emerging and especially developing countries (Niebel, 2014). Despite the rather ambiguous empirical evidence, the World Bank (2012) takes an optimistic view stating that ICT has great promise to reduce poverty, increase productivity and boost economic growth. Moreover, economists predict that economic growth is driven by investments in ICT (Saidi et al., 2015). The view is shared by the available theoretical literature (Nasab and Aghaei, 2009; Kirmani et al., 2015; Sibanda and Ramrathan, 2015).

Several recent empirical studies (Khalili et al., 2014; Niebel, 2014; Ortiz et al., 2015; Saidi et al., 2015; Aghael and Rezagholizadeh, 2017; Stanley et al., 2018; Karlsson and Liljevern, 2017; Das et al., 2016; Shahbaz et al., 2016; Tuyisabe et al., 2018) have investigated the impact of ICT on economic growth. The findings from these empirical studies are mixed, diverse and divergent. Some revealed that ICT had a positive impact on economic growth, others noted that the influence of ICT on economic growth is negative whilst some observed that the relationship between ICT and economic growth is negligible. It is therefore clear that the ICT-growth nexus is still unclear, not yet settled and inconclusive. It is against this background that the current study performed empirical tests to find out the impact of ICT on economic growth in the African context,

a continent that has so far largely been ignored by the majority existing empirical studies on ICT-growth.

To the best of the author's knowledge, there are two empirical studies (Sassi and Goaied, 2013 and Ortiz et al., 2015) that investigated the conditions that must be available in the country before ICT can enhance economic growth. The former investigated whether financial development must be available in the country in order to trigger significant positive influence of ICT on economic growth whilst the latter explored whether education is necessary to enhance ICT-led growth scenario. These two empirical studies also shied away from the African continent. In other words, the story of the conditions that must be available in the African continent in order to enhance ICT's positive impact on economic growth remains untold and this is the gap that the current study fills in. Moreover, a study by Ortiz et al. (2015) was narrow focused because it investigated whether education is necessary to enhance ICT-led growth. The current study is broad as it explored whether human capital development (education, skills and health) is a necessary condition that enhances ICT's positive influence on economic growth in the African continent. It is against this backdrop that the current study investigated whether energy consumption and human capital development are channels through which ICT influence economic growth in the African context.

Section 2 deals with theoretical literature on the impact of ICT on economic growth, Section 3 focuses on empirical literature on ICT-led growth hypothesis whilst section 4 discusses the theoretical literature on the relationship between ICT and energy consumption. The nexus between energy consumption and economic growth was discussed in section 5 whilst pre-estimation diagnostics is covered in Section 6. Section 7 is research methodology. Section 8 discusses the research results. Section 9 is the summary of the study.

2. THEORETICAL LITERATURE–ICT AND ECONOMIC GROWTH RELATIONSHIP

Technology touches every aspect of people's lives, coping with all needs in a practical way. Economic growth theories predict that economic growth is driven by investments in Information and Communication Technology (ICT), consistent with Nasab and Aghaei (2009). Theoretically, the development in ICT may affect not only economic growth but employment as well, and economic growth and employment may affect ICT development. ICT development may positively affect productivity and growth, which eventually lead to a higher employment, as such economic growth positively affect labour market (Kim, 2007).

The question of whether ICT contributes to financial performance has not yet been clearly answered. There has been little evidence of strong improvements in financial performance derived from ICT (Shin et al., 2001). ICT refers to a wide range of computerized technologies that enables communication and the electronic capturing, processing, and transmission of information. ICT has contributed openly to eliminate time, distance and space constraints in order to furnish the business activities with ease and efficiency by integrating the capability of high-speed devices with high speed communication links carrying multimedia information (Kirmani et al., 2015).

ICT can provide office-wide management and control of telecommunication services and also providing efficient and cost-effective service relating to procurement, accommodation, health and safety, energy, printing, filling and other logistic matters (Kirmani et al., 2015). The main effect of ICT is to automate manual tasks to remove human error, create standard processes to enhance transparency and ensure compliance with regulations (Sibanda and Ramrathan, 2015). ICT has provided numerous ways in which to convert large amounts of data into information, such as by using management information systems (MIS), business intelligence (BI) solutions and analytical applications (Sibanda and Ramrathan, 2015).

3. EMPIRICAL LITERATURE ON ICT- GROWTH NEXUS

Empirical literature on ICT-growth nexus is presented in Table 1.

3.1. ICT and Energy Consumption Hypothesis

The growth of the ICT industry triggers more energy consumption and carbon emissions as many gadgets that uses electricity are used (Zhang and Liu, 2015). On the other hand, a study by Lee and Brahmasrene (2014) noted that ICT improves energy efficiency levels, lowers energy consumption and carbon emissions. Lastly, a rebound effect was argued by Houghton (2009) to be a significant force that shapes the nexus between ICT and energy consumption hence the relationship between the two variables is not clear. This is as a result of the fact that the energy consumption levels are likely to dissipate in response to more electrical gadgets being used in the day to day activities by the people.

3.2. Relationship between Energy Consumption on Economic Growth

According to Odhiambo (2009) and Ozturk (2010), four theoretical views that explains the relationship between energy consumption and economic growth include the growth hypothesis, conservation hypothesis, feedback hypothesis and the neutrality hypothesis. The growth hypothesis argue that energy consumption spurs economic growth whilst the conservation hypothesis explains that it is actually economic growth that enhances energy consumption. The feedback hypothesis mentions that economic growth and energy consumption affect each other whereas the neutrality hypothesis argues that there is no relationship between energy consumption and economic growth.

4. PRE-ESTIMATION DIAGNOSTICS

Trend analysis, correlation and descriptive statistics are the three pre-estimation diagnostics covered under this section.

4.1. Trend Analysis – ICT and Economic Growth in Africa

Table 2 shows ICT and economic growth trends in Africa during the period ranging from 2001 to 2015.

Countries such as Algeria, Morocco, Tunisia, Nigeria, Gabon and South Africa had their mean ICT during the period under study greater than the overall mean of 9.03% of the population. The remaining countries such as Burundi, Comoros, Kenya,

Table 1: A summary of the relationship between ICT and economic growth –Empirical Literature

Author	Country/Countries of study	Methodology	Findings
Khalili et al. (2014)	Sweden, Iceland, Denmark, Finland, Luxembourg and Switzerland	Error correlation model (ECM)	ICT contribution did not have a robust short-run causality relationship with economic growth. The negative and statistically significant coefficient of ICT confirms the slow acceleration of TFP among the EU countries
Niebel (2014)	Developed, emerging and developing countries	Various panel data regressions used	Various panel data regressions confirm the positive relationship between ICT capital and GDP growth. The regressions for the subsamples of developing, emerging and developed countries did not reveal statistically significant differences of the output elasticity of ICT between these three country groups
Ortiz et al. (2015)	12 countries divided into three groups according to their educational levels. High (Australia, Norway, Finland, The Netherlands); medium (Bolivia, Colombia, Mexico, Venezuela) and low (China, India, El Salvador and Paraguay)	Panel data analysis	The role of telecommunications alone on economic growth was found to be limited unless it is accompanied by parallel investments in education. Only this joint effort can provide a deep impact on growth due to a more efficient use of those technologies
Nasab and Aghaei (2009)	OPEC member countries	Generalized Method of Moments (GMM)	According to Nasab and Aghaei (2009), economic growth theories predict that economic growth is driven by investments in Information and Communication Technology (ICT). The estimates reveal a significant impact on economic growth of investments in ICT in the OPEC member countries. This implies that if these countries seek to enhance their economic growth, they need to implement specific policies that facilitate investment in ICT
Saidi et al. (2015)	Tunisia	Econometric Analysis	The results indicate that there is a positive relationship between the growth rate of GDP and the index of ICT use (as measured by the number of user mobile and fixed phone lines in Tunisia)
Aghael and Rezagholizadeh (2017)	Organization Islamic (OIC) Countries	Dynamics and static panel data approach	The estimates reveal a significant impact of investments in ICT on economic growth in the OIC countries. The results of the growth model estimations with ICT as an explanatory variable using Panel Data method in the context of the OIC countries show that ICT has a meaningful effect on the economic growth of these countries
Stanley et al. (2018)	Developing and developed countries	Meta-regression analysis	ICT contributed positively to economic growth. Both developed and developing countries benefited from landline and cell technologies. Developed countries gained significantly more from ICT than do developing countries. Little evidence was found that the internet has a positive impact on growth
Karlsson and Liljevern (2017)	101 Countries	Descriptive statistics, Regression	The findings show that there are only significant ICT contributions to growth in the top-three richest countries
Das et al. (2016)	43 developing Countries	System generalized method of moments (GMM) technique	Their findings were threefold: Firstly, when all developing countries are included in the same panel, on average, ICT diffusion had a positive and significant impact on economic growth. Secondly, the joint effect of ICT and finance on economic growth is positive, suggesting that the direct effect of ICT diffusion on economic growth in developing countries is realized because of development of the financial sector. Thirdly, the ICT-finance joint effect is found to be positive and significant in low income countries
Omid et al. (2009)	World	Panel data and GMDH-neural method	The study found out that there is a significant relationship between investment in information and communication technology (ICT) and economic growth
Andrianaivo and Kpodar (2011)	African Countries from 1988 to 2007	System Generalized Method of Moment (GMM) estimator	The results confirm that ICT, including mobile phone development, contribute significantly to economic growth in African countries. Part of the positive effect of mobile phone penetration on growth comes from greater financial inclusion. At the same time, the development of mobile phones consolidates the impact of financial inclusion on economic growth, especially in countries where mobile financial services take hold

(*Contd...*)

Table 1: (*Continued*)

Author	Country/Countries of study	Methodology	Findings
Vu (2011)	102 countries	Traditional cross-country regression Generalized Method of Moment (GMM)	The marginal effect of the penetration of internet users was larger than that of mobile phones, which in turn is larger than that of personal computers. The marginal effect of ICT penetration however lessens as the penetration increases
Dimelis and Papaioannou (2010)	42 developing and developed countries during the period 1993-2001	Econometrics	The econometric results showed a positive and significant impact of ICT in all groups, the effect being larger among developing countries
Avgerou (2003)	Developing countries	Theories and policies	The paper examined the validity of the relationship between ICT and economic development that has been constructed in the discourse of some influential international development organizations. It argues that the stool-and-effect association suggested in the relationship between ICT and growth discourse is dubious and misleading. It observed that it is based on narrow economic theory that ignores both the controversies that surround it and empirical evidence of alternative development policies
Haghshenas et al. (2013)	Iran	Granger causality analysis	The results indicate that a long-run equilibrium relationship exists between ICT development and economic growth. Furthermore, the findings provide evidence of significant uni-directional short-run causality running from economic growth to ICT development in the Iranian economy
Tuyisabe et al. (2018)	Rwanda	Multiple regression model	Results show that mobile banking adherence and e-health are statistically significant to economic growth
Sassi and Goaied (2013)	MENA countries	GMM estimators	The results reveal a positive and significant direct effect of ICT proxies on economic growth. The interaction between ICT penetration and financial development was found to be positive and significant in the growth regression. This implies that economies in the Mena region can benefit from financial development only once a threshold of ICT development is reached
Yousefi (2011)	62 countries	Traditional growth model	For the period of 2000–2006, the study revealed that economic growth effect of ICT differs across different income groups of countries. The study concluded that ICT plays a major role in the growth of high and upper-middle income groups but fails to contribute to the growth of the lower-middle income group countries
Pohjola (2001)		Surveying previous studies	The results show that in recent years the use of ICT in the production of goods and services has had a strong positive influence on productivity and economic growth in industrial and in newly industrialized countries

Source: Author compilation

Rwanda, Burkina Faso, Ghana, Senegal, Cameroon, Central African Republic, Democratic Republic of the Congo, Namibia, Madagascar and Mozambique had their mean ICT lower than the overall mean during the period under study. Burundi, Comoros, Rwanda, Morocco, Tunisia, Burkina Faso, Cameroon, Central African Republic, Democratic Republic of the Congo, South Africa Madagascar and Mozambique are outliers because their mean ICT values are far away from the overall mean of 9.03% of the population.

Burundi, Comoros, Kenya, Rwanda, Burkina Faso, Ghana, Nigeria, Senegal, Cameroon, Central African Republic, Democratic Republic of the Congo, Madagascar and Mozambique had mean GDP per capita values lower than the overall mean GDP per capita of US$ 1 899.79. The remaining countries' mean GDP per capita was higher than the overall mean GDP per capita. Only Nigeria is not an outlier since its mean GDP per capita value during the period under study is closer to the overall mean GDP per capita. In order to deal away with the effects of the outliers on the quality of the final results, the study transformed all the data sets into natural logarithms before main data analysis, consistent with Aye and Edoja (2017).

4.2. Correlation Analysis

Consistent with literature, as shown in Table 3, a significant positive relationship was established between the following variables under study: (1) ICT and economic growth, (2) energy consumption (proxied by energy use, kg of oil equivalent per capita) and economic growth, (3) trade openness and economic growth, (4) natural resources and economic growth and (5) human capital development and economic growth. In line with Bornschier and Chase-Dunn (1985), FDI and economic growth were found to be negatively but non-significantly related with economic growth. A negative but significant relationship between population and economic growth was detected, consistent with Tsaurai (2018a).

4.3. Descriptive Statistics

Only economic growth data (GDPPC) is an outlier because its standard deviation value from the mean is well over 100 as shown in Table 4 above. The probability values (equal to zero) of the Jarque-

Bera criterion provides evidence that the data for all the variables under study is not normally distributed, consistent with Tsaurai (2018b. p. 9). Transforming the data into natural logarithms before main data analysis was done in this study in order to deal away with the effects of abnormally distributed data (Aye and Edoja. 2017).

5. RESEARCH METHODOLOGY

5.1. Data, Data Sources and Sample

Annual secondary panel data ranging from 2001 to 2015 was used for the purposes of this study. The data was extracted from World Bank Indicators, International Monetary Fund, African Development Bank databases. African countries studied include Burundi, Comoros, Kenya, Rwanda, Algeria, Morocco, Tunisia, Burkina Faso, Ghana, Nigeria, Senegal, Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, Namibia, South Africa, Madagascar and Mozambique.

Table 2: ICT and growth trends for African countries (2001-2015)

Countries	ICT (individuals using internet (% of population)	GDP per capita
Burundi	1.01	202.53
Comoros	3.59	690.54
Kenya	6.85	840.67
Rwanda	5.23	459.06
Algeria	12.60	3 868.86
Morocco	31.52	2 452.16
Tunisia	25.31	3 606.16
Burkina Faso	2.94	501.48
Ghana	8.09	1 021.85
Nigeria	9.43	1 593.54
Senegal	8.10	877.58
Cameroon	5.30	1 192.77
Central African Republic	1.49	370.80
Democratic Republic of the Congo	1.00	305.05
Gabon	14.10	7 645.37
Namibia	8.55	4 090.17
South Africa	21.10	5 569.67
Madagascar	1.56	370.79
Mozambique	3.75	436.87
Overall mean	9.03	1 899.79

Source: Author compilation

5.2. Econometric Model Description

$$GROWTH_{i,t}=\beta_0+\beta_1 ICT_{i,t}+\beta_2 X_{i,t}+\mu+\varepsilon \quad (1)$$

GROWTH stands for economic growth whilst ICT represents information and communication technology. X is a matrix of control variables such as energy consumption (ENEG), human capital development (HCD), foreign direct investment (FDI), trade openness (OPEN), natural resources (NAT) and population growth (POP). β_0, β_1 and β_2 stands for the intercept term, co-efficient for ICT and matrix of control variables respectively. Time and country are represented by the subscripts t and i respectively. ε is error term and μstands for time invariant and unobserved country specific effect.

The study introduced the interaction term ($ICT_{i,t}$, $x_{i,t}$) into equation 1 in order to allow an investigation on whether energy consumption and human capital development are channels through which ICT influence economic growth in Africa. The new equation 2 is shown below.

$$GROWTH_{i,t}=\beta_0+\beta_1 ICT_{i,t}+\beta_2 X_{i,t}+\beta_3 (ICT_{i,t}, x_{i,t})+\mu+\varepsilon \quad (2)$$

Consistent with Tsaurai (2018c), $\chi_{i,t}$ corresponds to the level of energy consumption and human capital development in country i at time t. A significant positive impact of the interaction term on economic growth means that the conditions being investigated are channels through which ICT enhances economic growth in African countries studied.

Table 3: Correlation analysis

Variables	GDPPC	ICT	FDI	ENEG	OPEN	NAT	POP	HCD
GDPPC	1.00							
ICT	0.5531***	1.00						
FDI	−0.0236	0.0070	1.00					
ENEG	0.4208***	0.6795***	0.0126	1.00				
OPEN	0.4078***	0.3192***	0.4895***	0.3642***	1.00			
NAT	0.1935***	−0.1501**	0.0486	-0.3506***	0.0165	1.00		
POP	−0.3041***	−0.3596***	0.1253**	−0.6393***	−0.1601***	0.4078***	1.00	
HCD	0.5519***	0.9997***	0.0063	0.6788***	0.3179***	−0.1512**	−0.3591***	1.00

Source: Author compilation from E-views. ***/**/*denotes statistical significance at the 1%/5%/10% level respectively

Table 4: Descriptive statistics

Statistical variables	GDPPC	ICT	FDI	ENEG	OPEN	NAT	POP	HCD
Mean	1900	9.03	3.38	36.4	65.3	11.77	2.33	9.05
Median	834	4.27	2.13	27.88	64.28	8.05	2.61	4.27
Maximum	10716	57.08	41.81	117.4	125.5	44.6	3.71	57.1
Minimum	113	0.01	0.01	2.86	20.96	0.35	0.21	0.01
Standard. deviation	2211	12.51	4.9	23.95	21.48	10.17	0.76	12.55
Jarque-Bera	220	421	9750	137	6.09	78.5	29.6	418
Probability	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Observations	285	285	285	285	285	285	285	285

Source: Author compilation from E-views

Table 5: Panel stationarity tests–individual intercept

Variables	Level				First difference			
	LLC	IPS	ADF	PP	LLC	IPS	ADF	PP
GDPPC	−8.75***	−4.69***	91.73***	110.13***	−3.34***	−2.57***	57.97**	88.34***
ICT	−2.64***	1.41	34.52	99.52***	−9.79***	−5.67***	92.19***	145.09***
FDI	−11.29***	−4.44***	84.62***	101.41***	−10.32***	−8.28***	139.60***	271.85***
ENEG	−1.28	2.06	24.64	29.38	−7.53***	−5.69***	101.29***	169.53***
OPEN	−4.55***	−1.84**	57.83**	39.25	−6.73***	−5.62***	104.37***	171.57***
NAT	−0.51	0.40	32.54	36.69	−8.45***	−6.01***	107.61***	167.12***
POP	−10.88***	−5.88***	118.08***	77.72***	−6.57***	−3.01***	79.83***	67.05***
HCD	−2.52***	1.57	33.50	97.33***	−15.95***	−6.94***	85.03***	145.77***

Source: Author's compilation from E-views. LLC, IPS, ADF and PP stands for Levin et al. (2002); Im et al. (2003); ADF Fisher Chi Square and PP Fisher Chi Square tests respectively. *, ** and *** denote 1%, 5% and 10% levels of significance, respectively

6. DATA ANALYSIS –RESULTS DISCUSSION AND INTERPRETATION

Table 5 shows that all the variables under study were stationary at first difference. According to Tsaurai (2018c. p. 96), such a condition is necessary in order to avoid spurious results. In other words, all the variables studied were integrated of order 1 hence paving way for co-integration tests.

6.1. Panel Co-integration Tests

Using Kao Residual co-integration approach, the alternative hypothesis which states that the variables studied are co-integrated was not rejected (see results in Table 6) thus paving way for main data analysis to be done.

Table 7 presents main data analysis results.

Consistent with Nor et al. (2015), the lag of economic growth had a significant positive influence on economic growth in African countries studied. Fixed and random effects show that ICT had an insignificant negative impact on economic growth in African countries studied, a result that is in line with Khalili et al. (2014) findings. On the other hand, the pooled OLS and dynamic GMM approaches indicates a non-significant positive relationship running from ICT towards economic growth, a finding that resonates with other studies such as Nasab and Aghaei (2009), Kim (2007), Kirmani et al. (2015), Sibanda and Ramrathan (2015), Saidi et al. (2015), Stanley et al. (2018) and Niebel (2014), among others.

Energy consumption had a significant positive effect on economic growth under the fixed effects approach and a non-significant positive influence on economic growth under the random effects, pooled OLS and the dynamic GMM methods. The results resonate with literature (Odhiambo, 2009).

Human capital development was found to have had an insignificant positive impact on economic growth in African countries studied under the fixed effects, random effects and pooled OLS in line with Romer (1990), Rosen (1999) and Adeyemi and Ogunsola (2016), whose studies noted that human capital development is an engine for economic growth and development as it improves productivity in the economy. On the other hand, the dynamic GMM method shows that human capital development had a non-significant negative effect on economic growth in African nations. The result contradicts majority literature (Isola and Alani. 2012; Adeyemi and Ogunsola. 2016; Aghion and Howitt, 1998; Rosen, 1999; Romer, 1990) on the subject matter.

Table 6: Kao residual co-integration test-individual intercept

Statistical indicators	t-statistic	Probability
Augmented Dickey-Fuller (ADF)	−4.0585	0.0000

Source: Author's compilation from E-views

FDI was found to have had a significant positive impact on economic growth under both the fixed and random effects, consistent with Nath (2005). The dynamic GMM shows a non-significant positive relationship running from FDI towards economic growth. However, consistent with the dependency theory propagated by Bornschier and Chase-Dunn (1985) and Amin (1974), FDI was found to have had an insignificant negative influence on economic growth under the pooled OLS approach.

In support of Baltagi et al.'s (2009) argument, trade openness had a significant negative impact on economic growth in African countries under the fixed and random effects. According to the dynamic GMM approach, a negative but non-significant relationship running from trade openness towards economic growth was detected. On the contrary, pooled OLS approach show that trade openness had a significant positive effect on economic growth in line with Balassa (1978) whose study argued that exports revenue is a source of foreign currency, a key source or engine for economic growth.

Natural resources were found to have had a significant positive influence on economic growth under the fixed and random effect whilst pooled OLS and dynamic GMM produced results which shows a non-significant positive relationships running from natural resources towards economic growth in African nations. These results are in line with Dunning's (1973) hypothesis which argued that natural resources are one of the FDI's location advantages in the host country thereby indirectly influencing economic growth. Population growth was found to have had a significant positive impact on economic growth across all the four econometric estimation methods. The finding is in sync with Becker et al. (1999) whose study revealed that increased population lead to more positive spill overs for economic growth.

The study found out that the interaction between ICT and energy consumption had a significant negative influence on economic growth in African nations studied across all the four panel data analysis methods (fixed effects, random effects, pooled

Table 7: Impact of ICT on economic growth – main results

Variables	Economic growth			
	Fixed effects	Random effects	Pooled OLS	Dynamic GMM
GDP Lag	-	-	-	0.9912***
ICT	0.1225*	0.1171*	0.3217	0.2044
ENEG	0.1125**	0.0760	0.0442	0.0040
HCD	0.4960	0.4643	0.1989	−0.1808
FDI	0.0291***	0.0285***	−0.0387	0.0016
OPEN	−0.4116***	−0.3483***	0.7573***	−0.0138
NAT	0.0988***	0.0591*	0.0426	0.0100
POP	0.2074***	0.1627***	0.5412***	0.0036*
ICT*ENEG	−0.0252**	−0.0164***	−0.0523***	−0.0072*
ICT*HCD	0.0004*	0.0003*	0.0539***	0.0225***
Number of countries	19	19	19	19
Adjusted R-squared	0.9746	0.7551	0.6644	0.9858
F-statistic	402.62	97.97	63.26	J-statistic=273.00
Prob. (F-statistic)	0.0000	0.0000	0.0000	Prob. (J-statistic)=0.0000

Source: Author's compilation from E-Views. ***, ** and * denote 1%, 5% and 10% levels of significance, respectively

OLS, dynamic GMM). The finding means that ICT enhanced economic growth through its energy efficiency (lowering energy consumption) impact in Africa, consistent with Lee and Brahmasrene (2014) whose study noted that ICT improves energy efficiency levels.

All the four econometric estimation methods show that human capital development is a channel through which ICT has a significant positive influence on economic growth, in line with Ortiz et al. (2015) whose study noted that the role of telecommunications alone on economic growth is limited unless it is accompanied by parallel investments in education. The study further revealed that only a complementarity between ICT and education can provide a deep impact on growth due to a more efficient use of those technologies.

7. CONCLUSION

The study had two main objectives. Firstly, to investigate the impact of ICT on economic growth. Secondly, to explore whether energy consumption and human capital development are channels through which ICT influences economic growth in Africa. Whilst literature is unanimous when it comes to the positive impact of ICT on economic growth, not much has been investigated on the impact of the complementarity between (1) ICT and energy consumption and (2) ICT and human capital development on economic growth, especially in the African context. The current study used fixed effects, random effects, pooled OLS and the dynamic GMM with annual panel data ranging from 2001 to 2015. Whilst fixed and random effects show a significant positive relationship running from ICT towards economic growth, pooled OLS and the dynamic GMM produced results which show that ICT had a non-significant positive influence on economic growth in Africa.

The interaction between ICT and energy consumption had a significant negative effect on economic growth across all the panel data analysis methods. The finding means that ICT enhanced economic growth through its energy efficiency impact in Africa, consistent with Lee and Brahmasrene (2014). The interaction between ICT and human capital development was found to have had a significant positive effect on economic growth in Africa, in line with Ortiz et al. (2015) whose study revealed that the complementarity between ICT and education enhanced economic growth. The study therefore urges the African continent authorities to develop, strengthen and implement sound human capital development in order to enhance the impact of ICT on economic growth. African countries are also urged to implement sound ICT growth policies in order to trigger energy efficiency led economic growth.

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