Environmental Degradation, ICT and Inclusive Development in Sub-Saharan Africa

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Abstract

This study examines how information and communication technology (ICT) complements carbon dioxide (CO_2) emissions to influence inclusive human development in forty-four Sub-Saharan African countries for the period 2000-2012. ICT is measured with internet penetration and mobile phone penetration. The empirical evidence is based on Generalised Method of Moments. The findings broadly show that ICT can be employed to dampen the potentially negative effect of environmental pollution on human development. We establish that: (i) ICT complements CO_2 emissions from liquid fuel consumption to increase inclusive development; (ii) ICT interacts with CO_2 intensity to negatively affect inclusive human development and (iii) the net effect on inclusive human development is positive from the complementarity between mobile phones and CO_2 emissions per capita. Conversely, we also establish evidence of net negative effects. Fortunately, the corresponding ICT thresholds at which these net negative effects can be completely dampened are within policy range, notably: 50 (per 100 people) mobile phone penetration for CO_2 emissions from liquid fuel consumption and CO_2 intensity. Theoretical and policy implications are discussed.

JEL Classification: C52; O38; O40; O55; P37

Keywords: CO2 emissions; ICT; Economic development; Africa

Acknowledgments

-The authors are indebted to the editors and reviewers for their constructive comments.

1. Introduction

Four tendencies motivate the positioning of this inquiry, namely: the increasing information and communication technology (ICT) penetration trend in Sub-Saharan Africa (SSA); growing exclusive development in the sub-region; increasing environmental concerns in the light of the sustainable development agenda and gaps in the literature. The tendencies are substantiated in chronological order. First, recent ICT literature is consistent with the perspective that the greatest room for ICT penetration is in SSA, compared to other high-end economies in North America, Asia and Europe where the penetration of ICT has reached levels of saturation (see Penard et al., 2012; Asongu, 2013; Murphy & Carmody, 2015; Tchamyou, 2016). Such a high penetration opportunity naturally represents a policy instrument that can be leveraged by policy makers to address sobering sustainable development concerns like environmental pollution and global warming.

Second, in the transition from the Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs), many positions are consistent with the view that extreme poverty has been decreasing in all regions of the world with the exception of SSA, where close to half the countries in the sub-region have been substantially off-course from achieving the MDG extreme poverty threshold (World Bank, 2015; Asongu & Le Roux, 2017). Evidence of this extreme poverty trend substantially contrasts with the fact that the sub-region has been enjoying more than two decades of economic growth resurgence which began in the mid-1990s (Asongu & Nwachukwu, 2016a). It is therefore logical to infer that the fruits of economic prosperity are not substantially trickling down to unprivileged factions of the population in order to address absolute poverty. Moreover, it is also logical to associate the corresponding economic prosperity to green house gas emissions which have been documented to considerably represent a challenge to environmental sustainability in the post-2015 development era (see Akinyemi et al., 2015).

Third, there is consensus today that environmental sustainability is a key theme in the post-2015 development agenda (Akpan, 2012; Asongu et al., 2016a). The relevance of this theme to SSA can be articulated along four constructive lines, notably: the comparatively high economic growth record in the sub-region; growing energy crisis; poor management of energy crisis and negative externalities from global warming. Considering these points in detail, we can note that SSA has recently experienced over two decades of growth resurgence after decades lost in the quest for economic development (see Fosu, 2015), partly due to the ineffective formulation and failed implementation of Structural Adjustment Programmes. With more evidence that the continent has recently hosted seven of the ten fastest growing economies in the world (see Bradley, 2016), it is logical to assert that the underlying burgeoning economic prosperity has been associated with environmental degradation and pollution as well as emissions of green house gases.

While the energy crisis has been documented as another critical challenge in the post-2015 sustainable development agenda (Akinyemi et al., 2015), the crisis is most apparent in SSA, because the privileged part of the population in sub-regions with access to energy is about 5% (see Shurig, 2015). The narrative maintains that the total energy that is consumed in the sub-region is equivalent to that consumed in some states in more advanced economies like the state of New York, United States of America (USA). Furthermore, consumption of energy by the sub-region accounts for just about 17% of the global average.

Moreover, inefficiency is a common feature in the management of energy in most African countries (Soumoni & Sounmoni, 2011; Anyangwe, 2014). This perspective can be substantiated by considering Nigeria, the continent's most populous nation, where shortages of and outages in electricity are addressed with government subsidised petroleum fuel, which is used by electricity generators to compensate for underlying outages and shortages (see Apkan, 2012). Conversely, comparatively less investment has been allocated for renewable sources of energy in the country (Babatunde, 2011; Nigeria Electricity, 2017). Finally, the consumption of fossil fuels which is a direct cause of climate change and global warming represents a great challenge to sustainable development in the post-2015 development era (see Huxster et al., 2015). According to Kifle (2008), the most negative consequences of global warming will be borne by Africa. Carbon dioxide (CO_2) emissions represent about 75% of global greenhouse gas emissions (Akpan, 2012).

This inquiry assesses how ICT can be tailored to reduce the effect of CO_2 emissions on sustainable development in the perspective of inclusive human development. It is important to note that inclusive development is part of sustainable development because for inclusive development to be sustainable it has to be sustained and in order for sustained development to be sustainable, it must be inclusive (see Amavilah et al., 2017). Hence, building on the intuition that CO_2 emissions, ICT and human development are connected, we argue that ICT could reduce CO_2 emissions by, *inter alia*: (i) preventing unnecessary transportation costs and (ii) consolidating the efficient management of households and corporations. For instance, transport costs could be saved by the availability of a mobile phone, that can be used to pay health bills and make other transactions which can improve the financial standing of a household. These corresponding human development dimensions are components of the inequality adjusted human development index (IHDI) used in this study as the outcome variable.

In the light of the above, the intuition underlying the current study falls within a scholarly framework of theory-building and provides consistency with recent empirical literature (see Narayan et al., 2011) in arguing that applied econometrics should not be exclusively based on the acceptance or rejection of existing theoretical underpinnings. This is essentially because an empirical exercise that is founded on a logically substantiated intuition could pave the way to theory-building, especially in the light of interactions between relevant phenomena like CO_2 emissions, ICT and inclusive human development. Therefore, we aim to provide both theoretical and practical implications.

The positioning of the inquiry is not in the same vein as recent literature on CO_2 emissions and ICT. With regard to CO_2 emissions, recent environmental degradation literature has largely focused on nexuses between energy consumption, CO_2 emissions and economic growth. The existing literature has been dominated by a discussion of the relationship between environmental pollution and economic growth, with a fundamental emphasis on the Environmental Kuznets Curve (EKC) hypothesis (see Akbostanci et al., 2009; Diao et al., 2009; He & Richard, 2010)[1]. Existing literature also considers the nexus between economic growth, environmental pollution and energy consumption (Jumbe, 2004; Ang, 2007; Odhiambo, 2009a, 2009b; Apergis & Payne, 2009; Menyah & Wolde-Rufael, 2010; Ozturk & Acaravci, 2010; Bölük & Mehmet, 2015; Begum et al., 2015) and connections between energy consumption and economic growth (Mehrara, 2007; Esso, 2010).

A shortcoming that is largely shared by the highlighted literature is the collective failure to engage a policy variable with which CO_2 emissions can be reduced, in order to enhance

[1] According to the EKC hypothesis, in the long term, there is an inverted U-shaped relationship between per capita income and environmental degradation.

human development and environmental sustainability. We argue that findings based on nexuses between energy consumption, CO_2 emissions and economic growth have limited practical significance for policy makers, unless policy makers are provided with instruments with which to address corresponding policy syndromes in order to improve human/economic development. Hence, this inquiry addresses the highlighted shortcoming by employing ICT as a policy variable with which CO_2 emissions can be dampened in order to improve human development. In order to make this assessment, ICT (mobile phone and internet penetrations) is interacted with CO_2 emissions indicators and the net effects on inclusive human development are subsequently computed from both conditional and unconditional effects.

The study also deviates from recent ICT inquiries which have largely focused on *inter alia*: economic prosperity (Qureshi, 2013a; Levendis & Lee, 2013); living standards (Chavula, 2013); externalities in welfare (Qureshi, 2013b, 2013c; Carmody, 2013); banking sector progress (Kamel, 2005); Africa's information revolution from the perspectives of production networks and technical regimes (Murphy & Carmody, 2015); life for all (Ponelis & Holmner, 2013a, 2013b; Kivuneki et al., 2011) and sustainable development (Byrne, 2011) in developing nations. Thus, while these studies consider the human and socioeconomic rewards from ICT, we know very little about the relationships between ICT, CO_2 emissions and human development.

In the light of the above, the two main hypotheses tested of this study are as follows.

Hypothesis 1: The mobile phone modulates the potentially negative effect of CO_2 emissions on human development.

Hypothesis 2: The internet modulates the potentially deleterious impact of CO_2 emissions on human development.

For each of the hypotheses to be valid, the net effect from the association between ICT and CO_2 emissions on human development should be positive. The positioning of this inquiry steers clear of recent energy policy studies on CO_2 emissions which have largely focused on: recalculating CO_2 emissions from an added value perspective (Xu et al., 2017); examining CO_2 emissions and economic effects of implementing energy efficient programs (Martinez et al., 2017); renewable energy and CO_2 abatement (Marcantonini & Valero, 2017); acceptance of CO_2-utilisation for plastic products (Van Heek et al., 2017) and decomposing inequality in energy-oriented CO_2 emissions (Chen et al., 2017). The last study is closest to the present paper because it directly engages inclusive development.

The rest of the paper is structured as follows. Section 2 engages the data and methodology. The empirical results are presented in Section 3, Section 4 concludes with implications and future research directions.

2. Data and Methodology

2.1 Data

This study investigates a panel of forty-four Sub-Saharan African (SSA) countries with data from: (i) African Development Indicators (ADI) of the World Bank and (ii) the United Nations Development Program (UNDP) for the period 2000-2012. The adopted periodicity is based on constraints in data availability and the motivation discussed in the introduction. Inclusive human development is measured with the inequality adjusted human development index (IHDI), in accordance with recent inclusive development literature on Africa (Asongu et al., 2015). The human development index (HDI) denotes a national mean of results in three principal dimensions, notably: health and long life, knowledge and basic living standards. The IHDI goes a step further by adjusting the HDI to prevalent levels of inequality in the aforementioned three dimensions. In other words, the IHDI also takes into consideration the manner in which the three underlying achievements are distributed within the population.

Four main CO_2 emission variables are used, namely: CO_2 emissions per capita; CO_2 emissions from electricity and heat production; CO_2 emissions from liquid fuel consumption and CO_2 intensity. ICT is measured with mobile phone and internet penetration. The choice of the ICT variables is consistent with recent literature (Penard et al., 2012; Tchamyou, 2016; Amavilah et al., 2017). Hence, the internet penetration rate (per 100 people) and the mobile phone penetration rate (per 100 people) are used as ICT policy variables.

Four control variables are used to avoid variable omission bias, namely: education quality, foreign aid, private domestic credit and foreign direct investment. With the exception of foreign aid, the other control variables are intuitively expected to positively affect inclusive human development. In essence, compared to other levels of education, primary education has been documented to be more associated with development externalities and social returns when countries are at early stages of industrialisation (see Asiedu, 2014; Petrakis & Stamakis, 2002). Education has been established to positively affect inclusive development (Dunlap-Hinkler et al., 2010). Moreover, it is a component of the IHDI. Hence, in the light of the construction of the pupil-teacher ratio, we expect a negative effect from primary education. This is essentially because an increasing ratio denotes decreasing quality in primary education.

Asongu (2014) concludes that foreign aid negatively affects the IHDI in Africa, while a recent broad stream of literature is consistent with the positive inclusive development externalities from private domestic credit and foreign direct investment. This is essentially because they create favourable conditions for unemployment reduction and social mobility (Mishra et al., 2011; Anand et al., 2012; Seneviratne & Sun, 2013; Mlachila et al., 2014).

Given the above clarifications, the selection of control variables is motivated by the intuition on the constituents of the IHDI on the one hand and inclusive development literature on the other hand. Details of the definitions of variables and sources can be found in Appendix 1. Appendix 2 provides the summary statistics. The correlation matrix is presented in Appendix 3.

2.2 Methodology

Many reasons motivate the choice of a system GMM estimation strategy, notably, it considers cross-country variations; accounts for potential endogeneity in all regressions via instrumentation and controls for the unobserved heterogeneity and eliminates potential small sample biases from the *difference* estimator. Furthermore, basic conditions for the use of the GMM strategy are also fulfilled, notably: the condition for persistence is apparent because the correlation coefficient between the IHDI and its first lag is higher than 0.800, which is the rule of thumb for establishing persistence in a dependent variable and the number of cross sections (i.e., 44 countries) is higher than the number of periods in each cross section (i.e., 13 years).

In this study, we adopt the Roodman (2009a, 2009b) extension of Arellano and Bover (1995), which has been established to restrict over-identification and limit the proliferation of instruments (Love & Zicchino, 2006; Baltagi, 2008). Hence, the corresponding specification is a *two-step* GMM with forward orthogonal deviations instead of differencing. We prefer the *two-step* to the *one-step* procedure because the latter is homoscedasticity-consistent while the former controls for heteroscedasticity.

The following equations in level (1) and first difference (2) summarise the standard *system* GMM estimation procedure.

$$IHD_{i,t} = \sigma_0 + \sigma_1 IHD_{i,t-\tau} + \sigma_2 CO_{i,t} + \sigma_3 I_{i,t} + \sigma_4 COI_{i,t} + \sum_{h=1}^{4} \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$IHD_{i,t} - IHD_{i,t-\tau} = \sigma_1 (IHD_{i,t-\tau} - IHD_{i,t-2\tau}) + \sigma_2 (CO_{i,t} - CO_{i,t-\tau}) + \sigma_3 (I_{i,t} - I_{i,t-\tau}) + \sigma_4 (COI_{i,t} - COI_{i,t-\tau}) + \sum_{h=1}^{4} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + \varepsilon_{i,t-\tau}$$

(2)

where, $IHD_{i,t}$ is the inequality adjusted human development indicator of country i at period t, σ_0 is a constant, CO represents a CO_2 emissions variable (CO_2 emissions per capita; CO_2 emissions from electricity and heat production; CO_2 emissions from liquid fuel consumption and CO_2 intensity), I is information and communication technology (mobile phone penetration and internet penetration), COI is the interaction between a CO_2 emissions variable and an ICT policy variable, W is the vector of control variables (education quality, foreign aid, private domestic credit and foreign direct investment), τ represents the coefficient of auto-regression (which is one for the specification), ξ_t is the time-specific constant, η_i is the country-specific effect and $\varepsilon_{i,t}$ is the error term.

We now briefly engage identification and exclusion restrictions which are pertinent for a sound GMM estimation. In accordance with recent literature (~~Boateng et al., 2016;~~ Asongu & Nwachukwu, 2016b), All explanatory variables are considered as predetermined or suspected to be endogenous, while only years or time-invariant indicators are used as strictly exogenous variables. This identification strategy is consistent with Roodman (2009b) who has argued that it is not very likely for time-invariant variables to be endogenous after the first difference.[2]

As concerns exclusion limitations or restrictions, consistent with the identification process, time invariant variables affect the IHDI exclusively via the suspected endogenous variables. Furthermore, the statistical validity of the suggested exclusion restriction is examined with the Difference in Hansen Test (DHT) for instrument exogeneity. Under this framework,

[2] Hence, the procedure for treating *ivstyle* (years) is 'iv (years, eq(diff))' whereas the *gmmstyle* is employed for predetermined variables.

the null hypothesis of the DHT should not be rejected in order for the exclusion restriction hypothesis to hold, notably: the time invariant variables affect the IHDI exclusively through suspected endogenous variables. Hence, in the findings that are reported in the empirical results section, the hypothesis of exclusion restriction is validated if the null hypothesis of the DHT related to instrumental variables (IV) (year, eq(diff)) is not rejected. This process of assessing the validity of exclusion restriction is not different from the standard IV procedure where-by, the failure to reject the null hypothesis of the Sargan Overidentifying Restrictions (OIR) test is an indication that strictly exogenous variables affect the IHDI exclusively, through the suspected endogenous variable mechanisms (see Beck et al., 2003~~; Asongu & Nwachukwu, 2016c~~).

It is important to note that the empirical strategy is not specific to energy policy in relation to other development fields (e.g. environmental policy). As explained above, the estimation approach is consistent with data behaviour, notably: there is persistence in the outcome variable; the N>T condition required for the application of the Generalised Method of Moments is present and we employ interactive regressions that assess net effects of the role of ICT in modulating the effect of CO_2 emissions on inclusive development. Hence, the choice of estimation technique is more aligned with the problem statement being engaged than with any particular difference between development fields (e.g. "energy policy" versus "environmental policy"). It follows that, the estimation strategy can be applied to both energy policy and climate policy studies.

3. Empirical Results

Table 1 below presents the empirical results on mobile phone-oriented regressions whereas Table 2 focuses of internet-related specifications. As such, Table 1 is focused on testing Hypothesis 1, while Table 2 tests Hypothesis 2. There are two main sets of specifications pertaining to each of the CO_2 emission variables: one without the conditioning information set (or set of control variables) and another with the conditioning information set. For each table, four principal information criteria are used to investigate if the GMM models are valid.[3] In addition, it is important to note that the second-order Arellano and Bond autocorrelation test (AR(2)) is more relevant as an information criterion than the corresponding first-order test, because some studies have exclusively reported a higher order with no disclosure of the first order (e.g. see Narayan et al., 2011; Asongu & Nwachukwu, 2016d).

Net impacts are computed in order to assess the overall effect from the complementarity between ICT and CO_2 emissions in influencing inclusive human development. For example, in the second column of Table 1, the net effect from the interaction between mobile phones and CO_2 per capita is 0.0045 ([-0.00006 × 24.428] + [0.006]). In the computation, the mean value of mobile phone penetration is 24.428, the unconditional effect of CO_2 emissions per capita is 0.006 while the conditional impact from the interaction between CO_2 emissions per capita and mobile phones is -0.00006. In the light of the above, for either table, a positive net effect confirms the validation of the tested hypothesis, while a negative net effect implies that the investigated hypothesis is rejected. It is apparent from the tables that the tested hypotheses are valid/invalid contingent on CO2 emissions and ICT dynamics.

"Insert Table 1 here"

"Insert Table 2 here"

The following findings are established from Table 1 on the relationship between the mobile phone, CO_2 emissions and inclusive human development. First, the net effect on

[3] "*First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second, the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fischer test for the joint validity of estimated coefficients is also provided*" (Asongu & De Moor, 2017, p.200).

inclusive human development is positive from the complementarity between mobile phones and: (i) CO_2 emissions per capita (second column) and (ii) CO_2 emissions from liquid fuel consumption (seventh column). Second, the net effect on inclusive human development is negative from the complementarity between mobile phones and: (i) CO_2 emissions from liquid fuel consumption (sixth column) and (ii) CO_2 intensity (eighth column). Third, it can be seen that most of the significant control variables have the signs as expected, consistent with economic intuition.

The following findings are established from Table 2 on the relationship between the internet, CO_2 emissions and inclusive human development. First, the net effect on inclusive human development is positive from the complementarity between internet penetration and CO_2 emissions from liquid fuel consumption (seventh column). Second, the net effect on inclusive human development is negative from the complementarity between internet penetration and CO_2 intensity (eighth column). Unfortunately, the marginal effects are also negative, so modifying thresholds cannot be feasibly established. Third, the significant control variables have the expected signs.

When the findings from Table 1 are cross examined with those of Table 2, two overall conclusions emerge: (i) ICT complements CO_2 emissions from liquid fuel consumption to increase inclusive development and (ii) ICT interacts with CO_2 intensity to negatively affect inclusive human development.

4. Concluding implications, caveats and future research directions

This study has examined how information and communication technology (ICT) complements CO_2 emissions to influence inclusive human development in 44 Sub-Saharan African countries for the period 2000-2012. ICT is measured with internet penetration and mobile phone penetration whereas CO_2 emissions are examined in terms of: CO_2 emissions per capita; CO_2

emissions from electricity and heat production; CO_2 emissions from liquid fuel consumption and CO_2 intensity. The empirical evidence is based on Generalised Method of Moments. The findings have broadly shown that ICT can be employed to dampen the potentially negative effect of environmental pollution on inclusive human development. Accordingly, we have established that: (i) ICT complements CO_2 emissions from liquid fuel consumption to increase inclusive development; (ii) ICT interacts with CO_2 intensity to negatively affect inclusive human development and (iii) the net effect on inclusive human development is positive from the complementarity between mobile phones and CO_2 emissions per capita.

Conversely, we have also established evidence of net negative effects. Fortunately, in two of the three cases, the unconditional effects associated with the net negative effects are positive. For these positive marginal effects, the corresponding thresholds are within policy range, notably: 50 (0.0001/0.00002) mobile phone penetration per 100 people, for CO_2 emissions from liquid fuel consumption and CO_2 intensity. The threshold represents the level of mobile phone penetration at which the unconditional negative effects of CO_2 emissions can become positive. The computed threshold makes economic sense essentially because it is within the range of mobile phone penetration (0.000 to 147.202) provided by the summary statistics. Before we discuss the practical and policy implications, it is important to clarify the notion of thresholds employed above.

The notion of threshold or critical mass represents a point at which *further* mobile phone penetration interacts with CO_2 emissions, to yield a net positive effect on inclusive human development. Therefore, when the computed thresholds are within statistical range, policy makers can practically increase mobile phone penetration beyond the established thresholds in order to achieve the desired effect on inclusive human development. This conception of 'threshold' is in accordance with the literature, notably: minimum conditions for desired impacts (Cummins, 2000); critical masses for appealing effects (Roller & Waverman, 2001; Batuo, 2015) and requirements for inverted U-shaped and U-shaped patterns (see Ashraf & Galor, 2013).

As concerns practical implications, the findings show that improving ICT can substantially reduce the potentially detrimental effect of CO_2 emissions on inclusive human development. This evidence is broadly consistent with the literature supporting the view that ICT through network opportunities decease the cost or traffic per minute associated with economic activities (Gille et al., 2002; Esselaar et al., 2007; Gilwald & Stork, 2008; Gutierrez et al., 2009). For instance, the mobile phone can be employed to make a quick communication which can save energy and transport expenditure from economic activities. The consequence is a reduction in CO_2 emissions and saving income that can be used to improve basic components of human development, notably: living standards, education and health.

In the light of the above, in the sustainable development era, in order to address the negative consequences of environmental degradation on inclusive human development, it will be important for nations to address issues surrounding adequate ICT infrastructure, in particular: access and affordability. By tackling these critical barriers to ICT access, CO_2 emissions can be reduced and inclusive human development simultaneously improved. Furthermore, schemes that promote low pricing and universal coverage of ICT are worth the initial investment. In summary, the advantages discussed in this study would be maintained/enhanced if such ICT policies are designed to increase the adoption, reach, access, effectiveness and interactions of ICT. This is consistent with the World Trade Organization's recommendation that effective coordination through communication is indispensable for enhancing ecological sustainability (see Chemutai, 2009).

The principal theoretical contribution of this study is that by sharing information, ICT reduces information asymmetry that is associated with CO_2 emissions and hence, ex-post of reducing information asymmetry; the saved informational rents can be used to improve human development. The theoretical role of ICT is broadly consistent with the theoretical underpinnings of information sharing offices (public credit registries and private credit bureaus) in mitigating information asymmetry for banking intermediation efficiency (see Tchamyou & Asongu, 2017). Hence, in the light of this analogy, the theoretical underpinning for improving financial efficiency by means of information sharing offices is broadly consistent with the relevance of using ICT to reduce or dampen information asymmetry or informational rents which are associated with the potentially negative effect of environmental degradation on inclusive human development.

In summary the main implications for energy policy in sub-Saharan Africa are that: (i) ICT can modulate the effect of energies emitting CO_2 on human development, to achieve inclusiveness and (ii) certain thresholds or critical masses of ICT are necessary to dampen the negative effect of energies emitting $CO_{2,}$ on human development.

Two main caveats are apparent. First, some readers could consider the positioning on CO_2 emissions to be a bit out of scope, given that although CO_2 emissions are correlated with energy but there are also energies not emitting much CO_2 which are important in Africa. Therefore, the scope of the inquiry is limited to energies resulting in high CO_2 emissions. Moreover, in the introduction, we have articulated how the study is not in a similar vein as recent energy policy literature on CO_2 emissions. Second, concerns may arise on the bold conclusions which could be substantiated with country-specific fundamentals, *inter alia*: different countries having different carbon footprints in relation to the fuel source available to them. The conclusions of this study are relevant to all 44 countries sampled in the panel and the corresponding estimation technique employed. Articulating country-specific features is not consistent with the estimation approach because country-specific effects are not involved in the modelling exercise. This is essentially because country-specific effects are eliminated in order to reduce endogeneity: the correlation between the lagged dependent variable and country-specific effects.

Future studies may focus further efforts on assessing whether the established linkages in the study withstand empirical scrutiny, when assessed within the framework of country-specific settings. Such country-oriented inquiries are essential for more targeted policy implications.

Table 1: 'Mobile phone'-oriented regressions (Hypothesis 1)

	Dependent variable: Inequality Adjusted Human Development (IHDI)							
	CO2 emissions per capita (CO2mtpc)		CO_2 emissions from electricity and heat production(CO2elehepro)		CO_2 emissions from liquid fuel consumption (CO2lfcon)		CO_2 intensity (CO2inten)	
Constant	0.010	**-0.024****	0.014	0.458	**0.027***	-0.007	**0.023*****	0.122
	(0.205)	**(0.049**	(0.333)	(0.113)	**(0.066)**	(0.334)	**(0.000)**	(0.354)
IHDI (-1)	**0.981*****	**1.018*****	**0.975*****	-0.566	**0.971*****	**0.984*****	**0.954*****	**0.781*****
	(0.000)	**(0.000)**	**(0.000)**	(0.554)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.005)**
Mobile Phone (Mob)	0.0001	0.0001	0.0001	0.005	-0.00004	**0.0004*****	**0.0002*****	0.0006
	(0.169)	(0.168)	(0.239)	(0.109)	(0.763)	**(0.000)**	**(0.000)**	(0.397)
CO2mtpc	**0.006****	-0.002	---	---	---	---	---	---
	(0.018)	(0.665)						
CO2elehepro	---	---	0.00004	-0.0001	---	---	---	---
			(0.645)	(0.743)				
CO2lfcon	---	---	---	---	**-0.0001****	**0.00009***	---	---
					(0.025)	**(0.067)**		
CO2inten	---	---	---	---	---	---	**-0.0001*****	-0.0003
							(0.002)	(0.652)
CO2mtpc× Mob	**-0.00006 *** **	-.00001	---	---	---	---	---	---
	(0.007)	(0.614)						
CO2elehepro ×Mob	---	---	-0.000001	-0.000005	---	---	---	---
			(0.454)	(0.700)				
CO2lfcon ×Mob	---	---	---	---	**0.000002 ** **	**-0.000003 *** **	---	---
					(0.029)	**(0.001)**		
CO2inten× Mob	---	---	---	---	---	---	**0.000002***	0.00001
							(0.084)	(0.719)
Education	---	**0.0003*****	---	-.0005	---	**0.0002*****	---	-0.0005
		(0.001)		(0.716)		**(0.003)**		(0.459)
Credit	---	**0.0001****	---	0.002	---	0.00004	---	0.0002
		(0.015)		(0.231)		(0.489)		(0.593)
Foreign Aid	---	-0.000009	---	-0.009	---	0.000006	---	-0.001
		(0.764)		(0.109)		(0.878)		(0.401)
FDI	---	**0.0003*****	---	0.002	---	**0.0003*****	---	-0.0004
		(0.000)		(0.290)		**(0.000)**		(0.445)
Net Effects	0.0045	na	na	na	-0.00005	0.00001	-0.00005	na
AR(1)	(0.120)	(0.031)	**(0.163)**	(0.042)	**(0.108)**	(0.015)	**(0.115)**	**(0.333)**
AR(2)	**(0.479)**	**(0.963)**	**(0.434)**	**(0.404)**	**(0.512)**	**(0.571)**	**(0.400)**	**(0.834)**
Sargan OIR	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen OIR	**(0.122)**	**(0.908)**	**(0.858)**	**(1.000)**	**(0.104)**	**(0.700)**	**(0.138)**	**(1.000)**
DHT for instruments								
(a)Instruments in levels								
H excluding group	**(0.600)**	**(0.531)**	**(0.351)**	**(1.000)**	**(0.291)**	**(0.306)**	**(0.459)**	**(0.926)**
Dif(null, H=exogenous)	(0.063)	**(0.934)**	**(0.949)**	**(1.000)**	(0.097)	**(0.833)**	(0.093)	**(1.000)**
(b) IV (years, eq(diff))								
H excluding group	n.a	**(0.460)**	n.a	**(1.000)**	na	**(0.308)**	na	**(0.982)**
Dif(null, H=exogenous)	**(0.122)**	**(0.996)**	**(0.858)**	**(1.000)**	**(0.104)**	**(0.937)**	**(0.138)**	**(1.000)**
Fisher	**19912*****	**1.62e+06*****	**4298.58*****	**1897.96*****	**3292.89*****	**40401*****	**112996*****	**27062*****
Instruments	25	41	25	41	25	41	25	41
Countries	42	38	22	19	42	38	26	23
Observations	353	271	202	151	353	271	215	162

*,**,***: indicate significance levels of 10%, 5% and 1% respectively.
DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test.
The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and b) the validity of the instruments in the Sargan and Hansen OIR tests.
na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant.
The mean of mobile phone penetration is 24.428.

Table 2: Internet-oriented regressions (Hypothesis 2)

	Dependent variable: Inequality Adjusted Human Development (IHDI)							
	CO2 emissions per capita (CO2mtpc)		CO_2 emissions from electricity and heat production(CO2elehepro)		CO_2 emissions from liquid fuel consumption (CO2lfcon)		CO_2 intensity (CO2inten)	
Constant	0.017	-0.004	0.015	0.103	**0.031*** **	**-0.026** **	**0.023*** **	0.058
	(0.112)	(0.648)	(0.142)	(0.848)	**(0.007)**	**(0.035)**	**(0.000)**	(0.169)
IHDI (-1)	**0.965*** **	**0.986*** **	**0.977*** **	0.690	**0.934*** **	**1.013*** **	**0.952*** **	**0.929** **
	(0.000)	**(0.000)**	**(0.000)**	(0.612)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Internet (Inter)	**0.0006* **	0.0004	-0.0002	0.007	**0.0009* **	**0.001** **	**0.0006*** **	0.001
	(0.074)	(0.154)	(0.745)	(0.720)	**(0.079)**	**(0.023)**	**(0.000)**	(0.152)
CO2mtpc	0.003	0.0004	---	---	---	---	---	---
	(0.397)	(0.897)						
CO2elehepro	---	---	-0.0001	0.0004	---	---	---	---
			(0.396)	(0.840)				
CO2lfcon	---	---	---	---	-0.000008	**0.0001*** **	---	---
					(0.926)	**(0.006)**		
CO2inten	---	---	---	---	---	---	**0.0003*** **	0.0005
							(0.001)	(0.657)
CO2mtpc× Inter	**-0.0002** **	-0.0001	---	---	---	---	---	---
	(0.049)	(0.167)						
CO2elehepro × Inter	---	---	0.00001	-0.0001	---	---	---	---
			(0.241)	(0.546)				
CO2lfcon × Inter	---	---	---	---	-0.000005	**-0.00002 *** **	---	---
					(0.390)	**(0.001)**		
CO2inten× Inter	---	---	---	---	---	---	**-0.0001*** **	-0.0001
							(0.000)	(0.590)
Education	---	**0.0002*** **	---	0.0006	---	**0.0001** **	---	-0.0005
		(0.001)		(0.600)		**(0.023)**		(0.138)
Credit	---	0.0001	---	0.0009	---	0.00004	---	-0.0002
		(0.111)		(0.503)		(0.569)		(0.598)
Foreign Aid	---	0.000005	---	-0.0008	---	0.000004	---	-0.00009
		(0.842)		(0.908)		(0.867)		(0.785)
FDI	---	**0.0003*** **	---	-0.001	---	**0.0002*** **	---	-0.0004
		(0.000)		(0.155)		**(0.000)**		(0.284)
Net Effects	na	na	na	na	na	0.00001	-0.00012	na
AR(1)	**(0.131)**	(0.026)	**(0.218)**	**(0.902)**	**(0.150)**	(0.091)	**(0.264)**	**(0.312)**
AR(2)	**(0.614)**	**(0.893)**	**(0.966)**	**(0.884)**	**(0.614)**	**(0.848)**	**(0.237)**	**(0.691)**
Sargan OIR	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen OIR	(0.046)	**(0.754)**	**(0.600)**	**(1.000)**	**(0.099)**	**(0.608)**	**(0.249)**	**(0.999)**
DHT for instruments								
(a)Instruments in levels								
H excluding group	**(0.526)**	**(0.569)**	**(0.156)**	**(1.000)**	**(0.212)**	**(0.259)**	**(0.481)**	**(0.780)**
Dif(null, H=exogenous)	(0.022)	**(0.723)**	**(0.879)**	**(1.000)**	**(0.118)**	**(0.774)**	**(0.183)**	**(1.000)**
(b) IV (years, eq(diff))								
H excluding group	na	**(0.277)**	na	**(1.000)**	na	**(0.667)**	na	**(0.883)**
Dif(null, H=exogenous)	(0.046)	**(0.986)**	**(0.600)**	**(1.000)**	(0.099)	**(0.425)**	**(0.249)**	**(1.000)**
Fisher	**5601.50*** **	**151412*** **	**47716*** **	**8000*** **	**1483.98*** **	**394975*** **	**351270*** **	**42247*** **
Instruments	25	41	25	41	25	41	25	41
Countries	41	37	22	19	41	37	26	23
Observations	347	267	200	149	347	267	213	160

*,**,***: indicate significance levels of 10%, 5% and 1% respectively.
DHT: Difference in Hansen Test for Exogeneity of Instruments' Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test.
The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and b) the validity of the instruments in the Sargan and Hansen OIR tests.
na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant.
The mean of internet penetration is 4.222.

Appendix 1: Variable Definitions

Variables	Signs	Variable Definitions (Measurement)	Sources
Inclusive development	IHDI	Inequality Adjusted Human Development Index	UNDP
CO_2 per capita	CO2mtpc	CO_2 emissions (metric tons per capita)	World Bank (WDI)
CO_2 from electricity and heat	CO2elehepro	CO_2 emissions from electricity and heat production, total (% of total fuel combustion)	World Bank (WDI)
CO_2 from liquid fuel	CO2lfcon	CO_2 emissions from liquid fuel consumption (% of total)	World Bank (WDI)
CO_2 intensity	CO2inten	CO_2 intensity (kg per kg of oil equivalent energy use)	World Bank (WDI)
Internet	Internet	Internet penetration (per 100 people)	World Bank (WDI)
Mobile phones	Mobile	Mobile phone subscriptions (per 100 people)	World Bank (WDI)
Educational Quality	Educ	Pupil teacher ratio in Primary Education	World Bank (WDI)
Foreign Aid	Aid	Total Official Development Assistance (% of GDP)	World Bank (WDI)
Private Credit	Credit	Private credit by deposit banks and other financial institutions (% of GDP)	World Bank (WDI)
Foreign investment	FDI	Foreign Direct Investment inflows (% of GDP)	World Bank (WDI)

WDI: World Development Indicators. UNDP: United Nations Development Programme.

Appendix 2: Summary statistics (2000-2012)

	Mean	SD	Minimum	Maximum	Observations
Inequality Adj. Human Development	0.450	0.110	0.219	0.768	431
Mobile phone penetration	24.428	28.535	0.000	147.202	525
Internet Penetration	4.222	6.618	0.005	43.605	521
CO_2 per capita	0.901	1.820	0.016	10.093	567
CO_2 from electricity and heat	23.730	18.870	0.000	71.829	286
CO_2 from liquid fuel	78.880	23.092	0.000	100	567
CO_2 intensity	2.044	6.449	0.058	77.586	321
Educational Quality	43.784	14.731	12.466	100.236	425
Private Credit	19.142	23.278	0.550	149.78	458
Foreign aid	11.944	14.712	-0.253	181.187	531
Foreign direct investment	5.381	8.834	-6.043	91.007	529

S.D: Standard Deviation. Adj: Adjusted.

Appendix 3: Correlation matrix (uniform sample size: 171)

CO_2 emissions dynamics				Control variables				ICT			
CO2mtpc	CO2elehepro	CO2lfcon	CO2inten	Educ	Credit	Aid	FDI	Mobile	Internet	IHDI	
1.000	0.574	-0.507	0.773	-0.441	0.851	-0.370	-0.101	0.474	0.438	0.616	CO2mtpc
	1.000	-0.544	0.637	-0.595	0.558	-0.446	-0.272	0.315	0.477	0.398	CO2elehepro
		1.000	-0.342	0.274	-0.337	0.231	0.191	-0.265	-0.226	-0.138	CO2lfcon
			1.000	-0.542	0.702	-0.486	-0.181	0.485	0.543	0.740	CO2inten
				1.000	-0.456	0.512	0.151	-0.338	-0.417	-0.499	Educ
					1.000	-0.321	-0.181	0.518	0.642	0.616	Credit
						1.000	0.114	-0.286	-0.321	-0.629	Aid
							1.000	0.119	-0.022	-0.046	FDI
								1.000	0.694	0.597	Mobile
									1.000	0.636	Internet
										1.000	IHDI

CO_2: carbon dioxide. ICT: Information and Communication Technology. CO2mtpc: CO_2 emissions (metric tons per capita). CO2elehepro: CO_2 emissions from electricity and heat production, total (% of total fuel combustion). CO2lfcon: CO_2 emissions from liquid fuel consumption (% of total). CO2inten: CO_2 intensity (kg per kg of oil equivalent energy use). Educ: Quality of primary education. Credit: Private domestic credit. Aid: Foreign aid. FDI: Foreign Direct Investment. Mobile: Mobile phone penetration. Internet: Internet penetration. IHDI: Inequality Adjusted Human Development Index.

References

Akbostanci, E., S. Turut-Asi & Tunc, G. I., (2009). "The Relationship between Income and Environment in Turkey: Is there an Environmental Kuznets Curve?", *Energy Policy*, 37(3), pp. 861-867.

Akinlo, A. E., (2008). "Energy consumption and economic growth: evidence from 11 Sub-Sahara African countries". *Energy Economics,* 30(5), pp. 2391–2400.

Akinyemi, O., Alege, P., Osabuohien, E., & Ogundipe, A., (2015). "Energy Security and the Green Growth Agenda in Africa: Exploring Trade-offs and Synergies", Department of Economics and Development Studies, Covenant University, Nigeria.

Akpan, G. E. & Akpan, U. F. (2012). "Electricity Consumption, Carbon Emissions and Economic Growth in Nigeria", *International Journal of Energy Economics and Policy*, 2(4), pp. 292-306.

Amavilah, V., Asongu, S. A., & Andrés, A. R., (2017). "Effects of Globalization on Peace and Stability: Implications for Governance and the Knowledge Economy of African Countries", *Technological Forecasting and Social Change*. DOI: 10.1016/j.techfore.2017.04.013.

Anand, R., Mishra, S., & Spatafora, N., (2012). "Structural Transformation and the Sophistication of Production," *IMF Working Paper* No. 12/59, Washington.

Ang, J. B. (2007). "CO2 emissions, energy consumption, and output in France", *Energy Policy*, 35(10), pp. 4772-4778.

Anyangwe, E. (2014). "Without energy could Africa's growth run out of steam?" *theguardian*, http://www.theguardian.com/global-development-professionals-network/2014/nov/24/energy-infrastructure-clean-cookstoves-africa (Accessed: 08/09/2015).

Apergis, N. & J. Payne, J. E., (2009). "CO2 emissions, energy usage, and output in Central America", *Energy Policy*, 37(8), pp. 3282-3286.

Ashraf, Q., & Galor, O., (2013). "The Out of Africa Hypothesis, Human Genetic Diversity, and Comparative Economic Development". *American Economic Review*, 103(1), pp. 1-46.

Asiedu, E., (2014). "Does Foreign Aid in Education Promote Economic Growth? Evidence From Sub-Saharan Africa", *Journal of African Development*, 16(1), pp. 37-59.

Asongu, S. A., (2013). "How has mobile phone penetration stimulated financial development in Africa?", *Journal of African Business*, 14(1), pp. 7-18.

Asongu, S. A., (2014). "The Questionable Economics of Development Assistance in Africa: Hot-Fresh Evidence, 1996–2010", *The Review of Black Political Economy*, 41(4), pp. 455-480.

Asongu, S. A, & De Moor, L., (2017). "Financial Globalisation Dynamic Thresholds for Financial Development: Evidence from Africa", *European Journal of Development Research*, 29(1), pp. 192-212.

Asongu, S. A., Efobi, U., & Beecroft, I., (2015). "Inclusive Human Development in Pre-Crisis Times of Globalisation-Driven Debts", *African Development Review*, 27(4), pp. 428-442.

Asongu, S. A., El Montasser, G., & Toumi, H., (2016). "Testing the relationships between energy consumption, CO2 emissions, and economic growth in 24 African countries: a panel ARDL approach", *Environmental Science and Pollution Research*, 23(7), pp. 6563–6573.

Asongu, S. A., & Le Roux, S., (2017). "Enhancing ICT for inclusive human development in Sub-Saharan Africa", *Technological Forecasting and Social Change*, 118(May), pp. 44–54.

Asongu, S. A, & Nwachukwu, J. C., (2016a). "The Mobile Phone in the Diffusion of Knowledge for Institutional Quality in Sub Saharan Africa", *World Development*, 86(October), pp. 133-147.

Asongu, S. A., & Nwachukwu, J. C., (2016b). "The Role of Governance in Mobile Phones for Inclusive Human Development in Sub-Saharan Africa", *Technovation*, 55-56 (September-October), pp. 1-13.

Asongu, S. A., Nwachukwu, J., & Tchamyou, S. V., (2016a). "Information Asymmetry and Financial Development Dynamics in Africa", *Review of Development Finance*, 6(2), pp. 126–138.

Babatunde, M. A., (2011). "Keeping the Lights on in Nigeria: Is Power Sector Reform Sufficient?", *Journal of African Business*, 12(1), pp. 368-386.

Baltagi, B. H., (2008). "Forecasting with panel data", *Journal of Forecasting*, 27(2), pp. 153-173.

Batuo, M. E., (2015). "The role of telecommunications infrastructure in the regional economic growth of Africa", *Journal of Development Areas*, 49(1), pp. 313-330.

Beck, T., Demirgüç-Kunt, A., & Levine, R., (2003), "Law and finance: why does legal origin matter?", *Journal of Comparative Economics*, 31(4), pp. 653-675.

Begum, R. A., Sohag, K., Abdullah S. M. S., & Jaafar, M., (2015). "CO2 emissions, energy consumption, economic and population growth in Malaysia", *Renewal and Sustainable Energy Reviews*, 41(January), pp. 594-601.

Blundell, R., & Bond, S., (1998). “Initial conditions and moment restrictions in dynamic panel data models” *Journal of Econometrics*, 87(1), pp. 115-143.

Bölük, G., & Mehmet, M., (2015). “The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach”, *Renewal and Sustainable Energy Reviews*, 52(December), pp. 587-595.

Bond, S., Hoeffler, A., & Tample, J. (2001) “GMM Estimation of Empirical Growth Models”, University of Oxford.

Bradley, A., (2016). “China and South Africa: Emerging Powers in an Uncomfortable Embrace”, *Journal of Contemporary China*, 25(102), pp. 881-892.

Byrne, E., Nicholson, B., & Salem, F., (2011). “Information communication technologies and the millennium development goals”, *Information Technology for Development*, 17(1), pp. 1-3.

Carmody, P., (2013). “A knowledge economy or an information society in Africa? Thintegration and the mobile phone revolution”, *Information Technology for Development*, 19(1), pp. 24-39.

Chavula, H. K., (2013). “Telecommunications development and economic growth in Africa”, *Information Technology for Development*, 19(1), pp. 5-23.

Chen, J., Cheng, C., & Song, M., (2017). “Decomposing inequality in energy-related CO2 emissions by source and source increment: The roles of production and residential consumption”, *Energy Policy*, 107 (August), pp. 698-710.

Cummins, J. (2000). Language, power and pedagogy: Bilingual children in the crossfire. Clevedon, England: Multilingual Matters.

Diao, X. D., Zeng, S. X., Tam, C. M. & Tam, V. W .Y., (2009). "EKC Analysis for Studying Economic Growth and Environmental Quality: A Case Study in China", *Journal of Cleaner Production*, 17(5), pp. 541-548.

Dunlap-Hinkler, D., Kotabe, M., & Mudambi, R., (2010)."A story of breakthorough versus incremental innovation: Corporate entrepreneurship in the global pharmaceutical industry", *Strategic Entrepreneurship Journal*, 4(2),pp. 106-127.

Esselaar, B., Gilwald, A., & Stork, C., (2007). "Towards an Africa e-index: Telecommunications sector performance in 16 African countries". Research ICT Africa, www.researchICTafrica.net

Esso, L.J. (2010). "Threshold cointegration and causality relationship between energy use and growth in seven African countries", *Energy Economics*, 32(6), pp. 1383-1391.

Fosu, A. K. (2015). "Growth, Inequality and Poverty in Sub-Saharan Africa: Recent Progress in a Global Context", *Oxford Development Studies*, 43(1), pp. 44-59.

Gille, L., Noumba Um, P, Rudel, C., & Simon, L., (eds) (2002) "A model for calculating interconnection costs in telecommunications". The World Bank. http://www.ppiaf.org/sites/ppiaf.org/files/publication/WB%20-

%20Model%20Calculating%20Interconnection%20Costs%20Telecoms%202004.pdf (Accessed: 27/11/2014).

Gilwald, A., & Stork, C., (2008). "Towards evidence-based ICT policy and regulation: ICT access and usage in Africa", Volume 1 policy Paper Two, Research ICT Africa, www.researchICTafrica.net .

Gutierrez, L. H., Lee, S., & Virto, L. R., (2009). "Market concentration and performance in mobile markets in Africa and Latin America". OECD Development Center (mimeo).

He, J., & Richard, P., (2010). "Environmental Kuznets Curve for Co2 in Canada", *Ecological Economics*, 69(5), pp. 1083-1093.

Hertwich, E. G., & Peters, G. P., (2009). "Carbon Footprint of Nations: A Global, Trade-Linked Analysis", *Environmental Science & Technology*, 42, pp 6414-6420

Huxster, J. K., Uribe-Zarain, X. & Kempton, W., (2015). "Undergraduate Understanding of Climate Change: The Influences of College Major and Environmental Group Membership on Survey Knowledge Scores", *The Journal of Environmental Education*, 46(3), pp. 149-165.

Jumbe, C. B., (2004). "Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi", *Energy Economics*, 26(1), pp. 61-68.

Kifle, T. (2008). "Africa hit hardest by Global Warming despite its low Greenhouse Gas Emissions", *Institute for World Economics and International Management Working Paper* No. 108, http://www.iwim.uni-bremen.de/publikationen/pdf/b108.pdf (Accessed: 08/09/2015).

Kamel, S., (2005). “The use of information technology to transform the banking sector in developing nations”, *Information Technology for Development*, 11(4), pp. 305-312.

Kivuneki, F. N., Ekenberg, L., Danielson, M., & Tusubira. F.F., (2011). “Perceptions of the role of ICT on quality of life in rural communities in Uganda”, *Information Technology for Development*, 21(1), pp. 61-80.

Levendis, J., & Lee, S. H., (2013). “On the endogeneity of telecommunications and economic growth: evidence from Asia”, *Information Technology for Development*, 19(1), pp. 62-85.

Love, I., & Zicchino, L., (2006). “Financial Development and Dynamic Investment Behaviour: Evidence from Panel VAR” .*The Quarterly Review of Economics and Finance*, 46(2), pp. 190-210.

Marcantonini, C., & Valero, V., (2017). “Renewable energy and CO2 abatement in Italy”, *Energy Policy*, 106(July), pp. 600-613.

Martinez, J., Marti-Herrero, J., Villacis, S., Riofrio, A. J., & Vaca, D., (2017). “Analysis of energy, CO2 emissions and economy of the technological migration for clean cooking in Ecuador”, *Energy Policy*, 107(August), pp. 182-187

Mehrara, M., (2007). “Energy consumption and economic growth: The case of oil exporting countries”, *Energy Policy*, 35(5), pp. 2939-2945.

Menyah, K., & Wolde-Rufael, Y., (2010). "Energy consumption, pollutant emissions and economic growth in South Africa", *Energy Economics*, 32(6), pp. 1374-1382.

Mishra, S., Gable, S. L., &Anand, R., (2011), "Service Export Sophsitication and Economic Growth," *World Bank Policy Working Paper* No. 5606, Washington.

Mlachila, M., Tapsoba, R., &Tapsoba, S. J. A., (2014). "A Quality of Growth Index for Developing Countries: A Proposal", *IMF Working Paper* No. 14/172, Washington.

Murphy, J. T. & Carmody, P. (2015). *Africa's Information Revolution: Technical Regimes and Production Networks in South Africa and Tanzania*, RGS-IBG Book Series, Chichester, UK: Wiley.

Narayan, P.K., Mishra, S., & Narayan, S., (2011). "Do market capitalization and stocks traded converge? New global evidence". *Journal of Banking and Finance*, 35(10), pp. 2771-2781.

Nigeria Electricity (2017). "Why Nigeria Should Invest in Renewable Energy", Nigeria Electricity http://www.nigeriaelectricityhub.com/2017/02/01/why-nigeria-should-invest-in-renewable-energy/ (Accessed: 17/04/2017).

Odhiambo, N. M., (2009a). "Electricity consumption and economic growth in South Africa: a trivariate causality test". *Energy Economics*, 31(5), pp. 635–640

Odhiambo, N. M., (2009b). "Energy consumption and economic growth nexus in Tanzania: an ARDL bounds testing approach". *Energy Policy*, 37 (2), pp. 617–622.

Olusegun, O. A., (2008). "Consumption and Economic Growth in Nigeria: A bounds testing cointegration approach", *Journal of Economic Theory*, 2(4), pp. 118-123.

Ozturk, I., & Acaravci, A., (2010). "CO2 emissions, energy consumption and economic growth in Turkey", *Renewable and Sustainable Energy Reviews*, 14(9), pp. 3220-3225.

Penard, T., Poussing, N., Yebe, G. Z., & Ella, P. N., (2012). "Comparing the Determinants of Internet and Cell Phone Use in Africa: Evidence from Gabon ", *Communications & Strategies*, 86(2), pp. 65-83.

Peters, G. P., & Hertwich, E. G., (2008). "CO2 Embodied in International Trade with Implications for Global Climate Policy", *Environmental Science & Technology*, 42(5), pp 1401-1407.

Petrakis, P. E., &Stamatakis, D. (2002). "Growth and educational levels: a comparative analysis". *Economics of Education Review*, 21(2), pp. 513-521.

Ponelis, S. R., & Holmner, M. A., (2013a). "ICT in Africa: Enabling a Better Life for All", *Information Technology for Development*, 21(1), pp. 1-11.

Ponelis, S. R., & Holmner, M. A., (2013b). "ICT in Africa: Enabling a Better Life for All", *Information Technology for Development*, 21(1), pp. 163-177.

Qureshi, S., (2013a). "What is the role of mobile phones in bringing about growth?", *Information Technology for Development*, 19(1), pp. 1-4.

Qureshi, S., (2013b). “Networks of change, shifting power from institutions to people: how are innovations in the use of information and communication technology transforming development?” ?”, *Information Technology for Development*, 19(2), pp. 97-99.

Qureshi, S., (2013c). “Information and Communication Technologies in the Midst of Global Change: How do we Know When Development Takes Place?”, *Information Technology for Development*, 19(3), pp. 189-192.

Roller, L-H., & Waverman, L. (2001). “Telecommunications infrastructure and economic development: a simultaneous approach”, *American Economic Review*, 91(4), pp. 909-923.

Roodman, D., (2009a). “A Note on the Theme of Too Many Instruments”, *Oxford Bulletin of Economics and Statistics*, 71(1), pp. 135-158.

Roodman, D., (2009b). “How to do xtabond2: An introduction to difference and system GMM in Stata”, *Stata Journal*, 9(1), pp. 86-136.

Seneviratne, D., & Sun, Y., (2013), “Infrastructure and Income Distribution in ASEAN-5: What are the Links?” *IMF Working Paper* No. 13/41, Washington.

Soumoni, O. C., & Sounmoni, O. Y., (2011). “Promoting West African Ownership of the Power Sector: Alternative Financing for Distributed Generation of Renewable Electricity”, *Journal of African Business*, 12(1), pp. 310-329.

Shurig, S., (2015). “Who will fund the renewable solution to the energy crisis?”, *theguardian*, http://www.theguardian.com/global-development-professionals-network/2014/jun/05/renewable-energy-electricty-africa-policy (Accessed: 08/09/2015).

Tchamyou, V. S., (2016). “The role of knowledge economy in African business”, *Journal of the Knowledge Economy*, DOI: 10.1007/s13132-016-0417-1.

Tchamyou, V. S., & Asongu, S. A., (2017). “Information Sharing and Financial Sector Development in Africa”, *Journal of African Business*, 18(1), pp. 24-49.

Van Heek, J., Arning, K., & Ziefle, M., (2017). “Acceptance of CO2-utilization for plastic products”, *Energy Policy*, 105,(June), pp. 53-66.

Xu, X., Mu, M., & Wang, Q., (2017). “Recalculating CO2 emissions from the perspective of value-added trade: An input-output analysis of China's trade data”, *Energy Policy*, 107 (August), pp. 158-166.

World Bank (2015). “World Development Indicators”, *World Bank Publications*http://www.gopa.de/fr/news/world-bank-release-world-development-indicators-2015 (Accessed: 25/04/2015).