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Abstract

This study assesses if increasing information and communication technology (ICT) enhances inclusive human development in a sample of 49 countries in Sub-Saharan Africa for the period 2000-2012. The empirical evidence present in this study, is based on instrumental variable Tobit regressions, in order to account for simultaneity and the limited range in the dependent variable. In the interest of increasing room for policy implications and controlling for the unobserved heterogeneity, the analysis is decomposed into the fundamental characteristics that human development based on: income levels, legal origins, religious dominations, political stability, landlockedness and resource-wealth. Our findings show that policies designed to boost ICT (mobile phone, internet, telephone) penetration will increase inclusive development in the post-2015 sustainable development agenda. The degree of positive responsiveness of inclusive development to ICT varies across fundamental characteristics of human development and ICT dynamics. The study has substantial policy relevance because the adoption and/or penetration rate of ICT can be influenced by policy to achieve inclusive development outcomes. Further policy implications are also discussed.

JEL Classification: G20; I10; I32; O40; O55
Keywords: ICT; Inclusive human development; Africa

1. Introduction

This study investigates whether increasing information and communication technology (ICT) adoption affects inclusive human development in Sub-Saharan Africa (SSA). The academic and policy importance of the study is fourfold: the relevance of the knowledge economy for economic development in the 21st century and Africa's lagging position as a knowledge economy; the comparatively high potential for ICT penetration in Africa; growing exclusive development in SSA and the increasing relevance of ICT in inclusive development.

There is a strong consensus in the existing literature that the knowledge economy is central to economic and human developments in the 21st century (see Tchamyou, 2015; Kuada, 2015). According to the narrative, knowledge–based societies are more likely to successfully confront the challenges that globalisation poses to development. Globalisation has become an ineluctable phenomenon, which if neglected can endanger the prosperity of nations at both the macro and micro levels. Among the four components of the World Bank's knowledge economy index, ICT is most likely to exert the highest effects on economic and human development landscapes because of its potential for penetration[1].

Recent literature has shown that compared to other regions of the world where the penetration of ICT has reached saturation levels, there is still great room for its accommodation in Africa (see Penard et al., 2012; Asongu, 2015a). While some emerging economies (e.g. in Asia and Latin America) and developed nations are currently witnessing stability in ICT penetration, Africa still has great potential for its adoption. The policy relevance of this fact becomes clear when one considers that on the one hand, the SSA region has been experiencing increasing levels of non-inclusive development, while elsewhere, ICT has been documented to play a substantial role in non-exclusive development (Alkemade & Surrs, 2012; Ojo et al., 2012; Mishra & Bisht, 2013). Extreme poverty has been decreasing in all regions of the world, however, within SSA, there has been growing exclusive development and increasing poverty.

This has recently been further substantiated by a 2015 World Bank report on Millennium Development Goals (MDGs), which has revealed that extreme poverty has been progressing in Africa (see World Bank, 2015). The worrisome statistics showed that almost half of the countries in SSA were considerably off-track from achieving the MDG extreme poverty target, and this was apparent during an époque when the sub-region enjoyed a growth

[1]The other three components of the knowledge economy index are: (i) economic incentives and institutional regime, (ii) innovation and (iii) education. While the first-two are progressing at a slower rate than ICT, the third is already reaching the maximum limit or a saturation point of 100% academic enrolment.

resurgence that began in the mid-1990s. It logically follows that the fruits of economic prosperity have not been trickling down to the poorest stratas of the population.

An interesting strand of literature documents the inclusive development outcomes of ICT, notably, in terms of: gender empowerment (Maurer, 2008; Ojo et al., 2012); access to health care from the population in the low socio-economic strata (see Kliner et al., 2013); boosting of financial inclusion (Kirui et al., 2013; Singh, 2012); mitigation of the development divide between urban and rural areas (Qiang et al., 2011; Chan &Jia, 2011); purging of agricultural wastes as well as demand- and supply-side constraints/mismatches (see Muto & Yamano, 2009; Aker & Fafchamps, 2010); efficiency in the management of households (Al Surikhi, 2012) and enhancement of business avenues, especially for small and medium sized corporations (Asongu, 2015b; Ondiege, 2010; Mishra &Bisht, 2013). In essence, besides easing business operations (Kuoa &Yub, 2006; Jin& von von Zedtwitz, 2008; Kumar &Zahn, 2003; Lee et al., 2010), the ICT revolution has also substantially contributed to promoting non-exclusive development.

This study incorporates the four strands discussed above, by assessing how an increase in ICT levels would affect inclusive human development. The connection of the inquiry to the four underlying strands can be summarised in a single sentence: due to the increasing relevance of knowledge economy in 21st century development, the established role of ICT in inclusive development, the comparatively high potential for ICT penetration in SSA and evidence of exclusive development in the sub-region, this study investigates how increasing ICT adoption/penetration affects inclusive human development in SSA. The study has substantial policy relevance because the adoption and/or penetration rate of ICT can be influenced by policy to achieve inclusive development outcomes.

In order to increase the set-space for policy implications, the analysis is further classified by the fundamental characteristics of human development, based on: legal origins (French civil law versus (vs.) English common law); income levels (low income vs. middle income); religious domination (Islam-oriented vs. Christian-dominated); openness to sea (un-landlocked vs. landlocked); conflicts (political stability vs. political instability) and resource-wealth (non-petroleum vs. petroleum exporting) countries.

The rest of the study is structured as follows. The theoretical and empirical underpinnings are engaged in Section 2, while the data and methodology are covered in Section 3. Section 4 presents and discusses the findings whereas Section 5 concludes with future research directions.

2. Theory and empirical evidence

The importance of knowledge in general and ICT in particular in economic development have substantially been documented in the literature on economic and management sciences (Asongu et al., 2016). There exists a consensus on a two-way causality flow between knowledge and economic development. As opposed to neo-classical models of economic development that consider knowledge and technology as public commodities that are completely exogenous to the economic system, new economic development is founded on both endogenous interpretations and neo-Schumpeterian perspectives of economic development (Howells, 2005). In line with new growth models, advancement in technology is the outcome of direct engagement/investment by citizens through the mobilization of critical resources that are linked with human capital (see Romer, 1990).

In the light of above, the new theory of growth conceives technology within the perspective of private goods (i.e., as an excludable commodity). Moreover, the generation of knowledge which is potentially associated with creating new intellectual property as well as other forms of rewards for technology can also be considered a private good (Solow, 1994). While the private features of technology (e.g. patents and monopolistic power) have been articulated in some models of economic development, there are some scholarly positions substantiating the thesis that rents resulting from monopoly are for the most part, temporary (Uzawa, 1965). According to Romer (1990), progress in technology can both be simultaneously exogenous and endogenous, in that certain technological characteristics predispose the technology to become a public good and/or service with the passage of time. Romer (1990) further substantiates that due to cross-country technology spillovers, the benefits from technology enjoyed by countries are heterogeneous. It follows that technological development could lead to disequilibrium in economic and human development processes that elicit cross-country differences in economic development (see Verspagen, 1997). Rosenberg (1972) subscribed to the view that the propensity of employing novel technologies for productive purposes is critical to explaining economic development. It thereby follows that output from technology can be leveraged for inclusive development purposes.

Outputs from ICT denote important determinants of sustainable and inclusive development, both from national and business perspectives. This is essentially because they are affected by a multitude of characteristics which entail among others, further advances in ICT. Accordingly, an essential factor for ICT advancement is human capital which Coleman (1998) defines as an individual's knowledge, expertise and abilities that lead to economic

development. This economic development could be inclusive or non-inclusive, which is fundamentally the purpose of the present study.

By engaging in this inquiry, we also contribute to clarifying cautious positions in the literature suggesting that ICT should not be considered as a silver bullet of economic development unless the nexus is substantiated by empirical studies (Mpogole et al., 2008, p. 71). In contributing to the macroeconomic literature on technology management for inclusive development outcomes, the study deviates from mainstream corporate and microeconomic technological innovation literature on technology management for business purposes. Accordingly, some of the recent themes have included: opportunity creation and discovery within the framework of disruptive innovation (Wan et al., 2015; Hang et al., 2015); opportunity identification by scientific entrepreneurs (Maine et al., 2015); growing ecosystems (see Overholm, 2015); engagement of entrepreneurial innovators that leverage on evolving financial skills and resources (Best, 2015); business opportunities from an ageing population (Kohlbacher et al., 2015) and technological innovation for novel avenues as a consequence of road-mapping in patents (Jeong & Yoon, 2015).

Our study complements an evolving strand of literature on distribution externalities (see Cozzens, 2011). Under this canopy, our study is closest to a growing stream of literature on the importance of ICT for development outcomes and social change (Islama & Meadeb, 2012; Brouwer & Brito, 2012; Mira & Dangersfield, 2012). While the existing literature concentrates on both developed (see Thakar, 2012) and developing (Sonne, 2012: Gupta & Jain, 2012) countries, the policy syndrome of non-inclusive development is more striking in developing nations like those in the SSA: a sub-region that has increasingly been experiencing extreme poverty, despite having enjoyed more than two decades of resurgence in economic growth (Fosu, 2015a, p. 44).

3. Data and methodology

3.1 Data

The study examines a panel of 49 Sub-Saharan African (SSA) countries with data from the African Development Indicators (ADI) of the World Bank and the United Nations Development Program (UNDP) for the period 2000-2012. The adopted periodicity is based on constraints in data availability. In accordance with the recent inclusive development literature on Africa (Asongu et al., 2015), inequality adjusted human development index (IHDI) is used as a proxy for inclusive human development. 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.

Following recent African literature on ICT (Asongu & Nwachukwu, 2016a) and the knowledge economy (Tchamyou, 2015), we use three ICT indicators, namely: the mobile phone penetration rate (per 100 people); the internet penetration rate (per 100 people) and the telephone penetration rate (per 100 people).

We adopt six control variables in order to account for omitted variable bias, namely: development assistance, private domestic credit, remittances, foreign direct investment (FDI), GDP per capita growth and primary school enrolment. With the exception of foreign aid, we anticipate the six variables in the conditioning information set to have a positive effect on inclusive human development. Primary school enrolment is expected to impact the dependent variable positively, because compared to other levels of education, social returns from primary education are higher when economies are at a tender stage of industrialisation (see Asiedu, 2014; Petrakis & Stamakis, 2002). More generally, the positive linkage between education and inclusive development in developing countries is consistent with a broad stream of literature on the subject (see Dakhi & de Clereq, 2007; Dunlap-Hinkler et al., 2010). Furthermore, education is a constituent of the IHDI. GDP per capita growth is also expected to have a positive influence on the IHDI, because it is one of the constituent elements of IHDI.

Existing literature has concluded that foreign aid decreases the IHDI in Africa (See Asongu (2014a)). Private domestic credit, remittances and FDI have been documented by a bulk of inclusive growth/development literature to have a positive effect on non-exclusive development. This is because for the most part, they create conditions for social mobility and unemployment reduction (see Mishra et al., 2011; Anand et al., 2012; Seneviratne & Sun, 2013; Mlachila et al., 2014; Asongu & Nwachukwu, 2016b). While credit facilities and FDI have been documented by Mlachila et al. (2014) to positively affect inclusive growth, Ssozi and Asongu (2015) argue that remittances are very likely to positively impact human development as they are used for consumption purposes.

Further details on the definitions of variables and sources can be found in Appendix 1. Appendix 2 provides the summary statistics. The correlation matrix is presented in Appendix3.

3.2 Methodology

In order to control for the limited range in the dependent variable, we adopt a Tobit model to support our analysis. Accordingly, since the IHDI is theoretically between the interval of zero and one, estimating by Ordinary Least Squares (OLS) is not appropriate. Therefore, we implement a double-censored Tobit estimation approach since it accounts for the limited range in the dependent variable (see Kumbhakar & Lovell, 2000; Koetter et al., 2008; Ariss, 2010; Coccorese & Pellecchia, 2010). In cases when there are no observations with the values of zero or one, estimating with a double-censored Tobit model is similar to estimating with a linear model because the likelihood functions coincide (this is consistent with the approach followed by McDonald (2009) and Coccorese and Pellechia (2010)). This method of estimation is also consistent with the behaviour of our data, because the IHDI for SSA ranges from 0.129 to 0.768.

The standard Tobit model (Tobin, 1958; Carsun & Sun, 2007) is as follows in Eq. (1):

$$y_{i,t}^{*} = \alpha_0 + \beta X_{i,t} + \varepsilon_{i,t}, \qquad (1)$$

where, $y_{i,t}^{*}$ is a latent response variable, α_0 is a constant, $X_{i,t}$ is an observed $(1\times k)$ vector of explanatory variables and $\varepsilon_{i,t} \approx$ i.i.d. N(0, σ^2) and is independent variables in $X_{i,t}$.

Instead of observing $y_{i,t}^{*}$, we observe $y_{i,t}$ in Eq. (2):

$$y_{i,t} = \begin{cases} y_{i,t,}^{*} \; if \; y_{i,t}^{*} > \gamma \\ 0, \; if \; y_{i,t}^{*} \le \gamma, \end{cases} \qquad (2)$$

where, γ is a non-stochastic constant. In other words, the value of $y_{i,t}^{*}$ is missing when it is less than or equal to γ.

We address the concern of endogeneity by controlling for both simultaneity and the unobserved heterogeneity. The issue of simultaneity is handled in baseline regressions with an instrumental variable (IV) Tobit approach; while concerns about the unobserved heterogeneity and simultaneity are addressed with an IV Tobit approach, which further controls for fundamental characteristics of human development in Africa, notably: income levels, legal origins, religious dominations, political stability, resource-wealth and access to sea.

In the light of the above, the instrumentation procedure for mobile phone penetration, internet penetration and telephone penetration are respectively displayed in Eq. (3), Eq. (4) and Eq. (5) below.

$$Mob_{i,t} = \alpha + \delta_j \left(Mob_{i,t-1}\right) + \varepsilon_{i,t}, \qquad (3)$$

where: $Mob_{i,t}$, is the mobile phone penetration indicator of country i at period t, α is a constant, $Mob_{i,t-1}$, represents the mobile phone penetration in country i at period $t-1$, and $\varepsilon_{i,t}$ is the error term.

$$Inter_{i,t} = \alpha + \delta_j\left(Inter_{i,t-1}\right) + \varepsilon_{i,t}, \qquad (4)$$

where: $Inter_{i,t}$, is the internet penetration indicator of country i at period t, α is a constant, $Inter_{i,t-1}$, represents the internet penetration indicator of country i at period $t-1$, and $\varepsilon_{i,t}$ is the error term.

$$Tel_{i,t} = \alpha + \delta_j\left(Tel_{i,t-1}\right) + \varepsilon_{i,t}, \qquad (5)$$

where: $Tel_{i,t}$, is the telephone penetration indicator of country i at period t, α is a constant, $Inter_{i,t-1}$, represents telephone penetration indicator of country i at period $t-1$, and $\varepsilon_{i,t}$ is the error term.

The instrumentation processes in Equations (3)-(5) consist of regressing the variable ICT on its first lag and then saving the corresponding fitted value. The fitted value is used as the independent variable of interest in the Tobit estimation. The specifications for instrumentation are Heteroscedasticity and Autocorrelation Consistent (HAC) in standard errors.

Given that the estimation approach is based on interactive regressions, it is relevant to briefly discuss some of the pitfalls of interactive specifications which we avoid in the computation of net effects. Consistent with Brambor et al. (2006), all constitutive variables are entered into the specifications. Moreover, in order for the estimated parameters to have economic meaning, the estimates from interactions are interpreted as marginal or conditional effects, whereas corresponding net effects are computed from the marginal and unconditional impacts of the ICT indicators.

4. Empirical results

4.1 Baseline of results

The baseline findings for the effect of mobile phone penetration, internet penetration and telephone penetration are presented in the three main columns in Table 1. Each column has two sub-columns, one based on non-interactive regressions and the other based on interactive regressions. In order to investigate if enhancing ICT has a positive effect on the outcome indicator, the incidence of ICT in the non-interactive framework is compared with the net effect of ICT within the interactive framework. If the net effect is higher than the

corresponding independent impact, we conclude that increasing ICT boosts inclusive human development.

The following findings can be established: Enhancing mobile penetration has a "synergy effect", while increasing telephone penetration has a positive net effect on IHDI. While internet penetration boosts inclusive human development, the incremental benefit of increasing internet access is not significantly apparent. A synergy effect is established when both the unconditional and marginal effects of ICT are positive. For example the net effect in the last column of Table 1 corresponding to mobile phone penetration is:

$$0.028([-0.0006 \times 3.090] + 0.030]),$$

where, -0.0006 and 0.030 are respectively the estimated conditional and unconditional effects of telephone penetration, whereas 3.090 is the instrumented mean value of mobile phone penetration[2]. Most of the control variables are significant with the expected signs.

Table 1: ICT and Inclusive Human Development (IV Tobit)

	Dependent Variable: Inequality Adjusted Human Development					
	Mobile Phone Penetration		**Internet Penetration**		**Telephone Penetration**	
Constant	**0.297*** (0.000)**	**0.301*** (0.000)**	**0.302*** (0.000)**	**0.302*** (0.000)**	**0.299*** (0.000)**	**0.290*** (0.000)**
Mobile (IV)	**0.001*** (0.000)**	**0.0007** (0.046)**	---	---	---	---
Mobile(IV)*Mobile(IV)	---	**0.000006* (0.070)**	---	---	---	---
Internet(IV)	---	---	**0.006*** (0.000)**	**0.006*** (0.000)**	---	---
Internet(IV)*Internet(IV)	---	---	---	-0.00001 (0.703)	---	---
Telephone(IV)	---	---	---	---	**0.013*** (0.000)**	**0.030*** (0.000)**
Telephone(IV)*Telephone(IV)	---	---	---	---	---	**-0.0006*** (0.000)**
Foreign Aid	**-0.002*** (0.000)**	**-0.002*** (0.000)**	**-0.002*** (0.000)**	**-0.002*** (0.000)**	**-0.002*** (0.000)**	**-0.001*** (0.000)**
Private Domestic Credit	**0.0007** (0.023)**	**0.0007** (0.018)**	**0.0008*** (0.004)**	**0.0008*** (0.006)**	0.0004 (0.105)	-0.0002 (0.296)
Remittances	-0.0003 (0.408)	-0.0003 (0.433)	-0.0004 (0.328)	-0.0004 (0.318)	-0.0003 (0.374)	-0.0005 (0.136)
Foreign Direct Investment	**0.001** (0.034)**	**0.001** (0.014)**	**0.001** (0.010)**	**0.001** (0.012)**	**0.001*** (0.000)**	**0.001*** (0.005)**
GDP per capita growth	0.001 (0.314)	0.0008 (0.397)	-0.00006 (0.948)	-0.00004 (0.960)	-0.0001 (0.867)	0.0003 (0.663)
PSE	**0.001*** (0.000)**	**0.001*** (0.000)**	**0.001*** (0.000)**	**0.001*** (0.000)**	**0.001*** (0.000)**	**0.001*** (0.000)**
Net effects	na	Synergy	na	na	Na	0.028
LR Chi-Square	**210.23***	**213.53***	**215.90***	**216.05***	**287.25***	**327.25***
Log Likelihood	358.360	360.011	361.115	361.188	394.932	414.930
Observations	266	266	261	261	264	264

***,**,*: significance levels at 1%, 5% and 10% respectively. IV: Instrumental Variable. GDP: Gross Domestic Product. PSE: Primary School Enrolment. ICT: Information Communication Technology.

[2]The mean values for instrumented internet penetration and instrumented telephone penetration are respectively 4.395 and 3.090.

4.2 Extensions based on fundamental characteristics

In order to account for the unobserved heterogeneity and further provide space for policy options, the dataset is decomposed into the fundamental characteristics of human development based on: legal origins, income levels, resource-wealth, access to the sea, religious domination and political stability. These characteristics have been documented in recent inclusive growth/development literature, in order to explain cross-country differences in development outcomes (see Mlachila et al., 2014; Asongu, 2015c). Mlachila et al. (2014, p. 13) have also substantiated the relevance to connecting inclusive development to the following characteristics: income levels, regional proximity, state fragility and resource-wealth.

With respect to income levels, it is logical that countries endowed with higher average incomes are more likely to be associated with better institutions, which enable a more equitable distribution of national wealth resulting from economic growth. Two principal justifications can be provided to substantiate this position. Wealthier countries are linked with more avenues for social mobility and unemployment reduction. Recent African institutional literature has documented that institutions in higher income nations generate better rewards, and in turn contribute more effectively to the equitable distribution of wealth accruing from economic growth (Fosu, 2015bc).

Nations that enjoy comparatively more political stability are also more likely to be rewarded with improved conditions for the equitable distribution of wealth accruing from national economic prosperity[3].

In accordance with the narrative on the wealth of nations (or income levels), inclusive human development should be expected to be more apparent in resource-rich countries. However, this nexus should be treated with caution because nations that have acknowledged scarcity in natural resource-wealth, have focused more on human capability development and knowledge-driven economies, as means of achieving economic prosperity and inclusive human development (see America, 2013; Fosu, 2013; Amavilah, 2015). The stance on the development of human capabilities is broadly in accordance with Kuada (2015), who has

[3] While nations like the USA and UK have been experiencing growing inequality despite enjoying comparatively high levels of political stability, ceteris paribus, inequality in the UK and USA may have been much higher had the countries been politically unstable. But the rationale for political stability (vis-à-vis political instability) goes beyond income inequality to incorporating social services like health and education (which are components of the human development index). Hence, the delivery of social services is more unevenly affected in politically unstable countries compared to their politically stable counterparts.

proposed a paradigm shift to soft economics or human capability development, as a means of understanding non-inclusive growth in Africa.

The basis for legal origins in comparative economic development has been substantially documented in the literature (see La Porta et al., 1998, 1999). The relevance of legal origins in contemporary African economic development has been confirmed by Agbor (2015). Beck et al. (2003) have theorised and empirically justified the perspective that English Common law countries differ from their French Civil law counterparts because of political and adaptability channels. From a political perspective, English Common law lays emphasis on private property rights while the French Civil law focuses on the power of the state. With respect to the adaptability channel, the authors show that English Common law countries adjust more quickly to changing and evolving socio-economic conditions. It follows that English Common law countries are more likely to provide enabling conditions that reduce unemployment and enhance social mobility, compared to their French Civil law counterparts. In a nutshell, the institutional web of formal norms, informal rules and enforcements features resulting from legal origins, influence cross-country differences in social mobility and economic vulnerability, which affect inclusive human development.

The basis of religious domination is solidified by the perspective that inclusive development is logically influenced by solidarity. Both social and national solidity systems are affected by the two dominant religions in African nations, namely: Christianity and Islam.

There is an institutional cost to being closed-off from the sea (see Arvis et al., 2007). Moreover, such institutional shortcomings from landlockedness could be linked to less economic governance, which ultimately decreases effectiveness of the formulation and implementation of policies that deliver public goods and services for inclusive human development. It is important to note that education and health (which are components of the IHDI), substantially depend on the effectiveness of economic governance.

The categorisation of nations by legal origins is provided by La Porta et al. (2008, p. 339) while income-levels stratification is in line with Asongu (2014c, p. 364)[4] from the World Bank classification. Resource-wealth is based exclusively on petroleum exports. A country is considered as a petroleum exporter if its oil-dominant exports represent a significant part of its GDP, for a substantial part of the sampled periodicity. While landlocked nations can directly be observed from an African map, the stratification of religious domination is

[4] There are four main World Bank income groups: (i) high income, $12,276 or more; (ii)upper middle income,$3,976-$12,275; (iii) lower middle income, $1,006-$3,975 and (iv) low income, $1,005 or less.

borrowed from the Central Intelligence Agency (CIA) World Fact Book (CIA, 2011). Politically-unstable countries are those that have witnessed political instability/violence for at least half of the sampled periodicity.

Table 2 presents the extension of the baseline regressions presented in Table 1. Panel A, Panel B and Panel C present findings pertaining to mobile phone penetration, internet penetration and telephone penetration, respectively. Each panel is further sub-divided into two sub-panels: one on non-interactive regressions and the other on interactive regressions. In the second sub-panel, net effects from increasing ICT for inclusive human development are calculated using the same computation framework as in the baseline findings. In the interest of brevity, estimated coefficients corresponding to the control variables are omitted, since Table 1 has already established that they display the expected signs.

In order to assess whether enhancing a given ICT variable positively affects inclusive human development, we compare the effect of the ICT in the first sub-panel (with non-interactive regressions) with the net effect of increasing the ICT in the second sub-panel (with interactive regressions). If the net effect in the second sub-panel is higher than the corresponding effect in the first sub-panel, we conclude that increasing ICT enhances inclusive human development.

The following findings can be established: Firstly, with regard to mobile phone oriented estimations, by analysing the non-interactive regressions we find that, the effect of mobile phone penetration on inclusive human development is higher in: (i) middle income countries compared to low income countries; (ii) English Common law nations vis-à-vis French Civil law nations; (iii) Christian-oriented countries relative to their Islam-dominated counterparts; (iv) countries that have access to the sea compared to landlocked countries; (v) petroleum-exporting nations versus non-petroleum exporting nations and (vi) politically-unstable countries vis-à-vis politically-stable countries. When we analyse the interactive regressions, we find that enhancing mobile phone penetration increases inclusive human development in non-petroleum exporting and politically-unstable countries.

Secondly, we consider the effects of internet penetration. When we analyse the non-interactive estimations, we note that the impact of internet penetration on inclusive human development is higher in: (i) low income countries compared to their middle income counterparts; (ii) French Civil law countries relative to English Common law countries; (iii) Christian-oriented nations vis-à-vis Islam-dominated nations; (iv) unlandlocked countries compared to those that have no access to the sea; (v) non-petroleum exporting countries compared to petroleum exporting countries and (vi) politically-unstable nations compared to

their relatively politically stable counterparts. Moreover, from the interactive regressions, we can conclude that increasing internet penetration would enhance inclusive human development in: French Civil law, Islam-oriented, landlocked, petroleum exporting and politically-unstable countries.

Thirdly, we move our focus to the effects of telephone penetration. When we analyse the non-interactive estimations, the impact of telephone penetration on inclusive human development is higher in: (i) low income (versus(vs.) middle income countries; (ii) French Civil law vs. English Common law countries; (iii) Islam-oriented vs. Christian-dominated countries; (iv) landlocked vs. unlandlocked nations; (v) Petroleum-poor vs. petroleum-rich countries and (vi) politically-unstable vs. politically-stable countries. The estimates from the interactive regressions show that, enhancing telephone penetration would increase inclusive human development in: low income, English Common law, French Civil law, Christian-dominated, Islam-oriented, unlandlocked, petroleum-poor, politically-stable and politically-unstable countries.

In particular, with the exception of politically-unstable countries (vis-à-vis their politically-stable counterparts), no specific sub-sample consistently performs better than the other, within the same fundamental characteristic across ICT specifications. We note that the main objective of this study is not to conjecture over which sub-sample performs better than the other. The main purpose of disaggregating into fundamental characteristics of human development is to increase room for policy implications and account for the unobserved heterogeneity, in order to increase control for endogeneity.

Overall, what matters is the evidence that cross-country differences in the fundamental features can explain cross-country variations in the nexus between ICT and inclusive development. With this clarification in mind, it is important to elucidate the consistent performance of politically-unstable countries vis-à-vis their politically-stable counterparts. A possible reason may be that politically-stable countries rely for the most part on ICT infrastructure, since travelling and transactions through other traditional transport mechanisms become limited with political strife and conflicts. An eloquent testimony to elucidate this point is a recent World Bank study, which has found politically-unstable Somalia to be a global frontrunner in the use of ICT for mobile banking services (see Mosheni-Cheraghlou, 2013).

Table 2: Comparative economics with Instrumental Variable Tobit regressions

Panel A: Mobile Phone Penetration

Panel A1: Non-interactive regressions (Mobile Phones)

	Income levels		Legal origins		Religion		Openness to sea		Oil exports		Political stability	
	LI	MI	Eng.	Frch.	Christ.	Islam	Open	Closed	Oil	Nonoil	Stable	Unstable
Constant	**0.290*** **	**0.273*** **	**0.436*** **	**0.272*** **	**0.383*** **	**0.370*** **	**0.373*** **	**0.273*** **	**0.381*** **	**0.279*** **	**0.303*** **	**0.400*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Mobile(IV)	**0.0008*** **	**0.001*** **	**0.001*** **	**0.0003**	**0.001*** **	**0.0006*** **	**0.001*** **	**0.0005** **	**0.002*** **	**0.001*** **	**0.001*** **	**0.002*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.227)**	**(0.000)**	**(0.009)**	**(0.000)**	**(0.049)**	**(0.009)**	**(0.000)**	**(0.000)**	**(0.002)**
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR Chi-Square	**156.38*** **	**115.04*** **	**105.47*** **	**138.19*** **	**142.32*** **	**106.26*** **	**98.26*** **	**196.54*** **	**27.03*** **	**203.41*** **	**247.59*** **	**20.19*** **
Log Likelihood	259.163	145.024	174.577	217.791	244.238	152.209	209.861	198.000	55.216	316.640	336.431	44.894
Observations	172	94	119	147	185	81	154	112	39	227	222	44

Panel A2: Interactive regressions (Mobile Phones)

Constant	**0.290*** **	**0.278*** **	**0.444*** **	**0.271*** **	**0.383*** **	**0.367*** **	**0.375*** **	**0.279*** **	**0.383*** **	**0.283*** **	**0.310*** **	**0.397*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Mobile(IV)	0.0006	0.0002	**0.0009***	0.0005	**0.001*** **	-0.00004	0.00009	-0.0005	0.002	**0.0006***	-0.00004	**0.006*** **
	(0.337)	(0.541)	**(0.050)**	(0.488)	**(0.001)**	(0.951)	(0.829)	(0.459)	(0.275)	**(0.081)**	(0.910)	**(0.001)**
Mobile(IV)*Mobile(IV)	0.000002	**0.000007 ** **	0.000005	-0.000002	0.000001	0.0000007	**0.00001 *** **	**0.00001***	-0.00001	**0.000007 ** **	**0.00001*** **	**-0.00005 ** **
	(0.709)	**(0.040)**	(0.110)	(0.791)	(0.689)	(0.302)	**(0.005)**	**(0.080)**	(0.787)	**(0.031)**	**(0.000)**	**(0.030)**
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	na	Na	na	na	na	Na	Na	na	na	Synergy (0.077)	na	0.004
LR Chi-Square	**98.57*** **	**119.27*** **	**108.04*** **	**138.26*** **	**142.48*** **	**107.33*** **	**106.22*** **	**199.66*** **	**27.11*** **	**208.07*** **	**261.59*** **	**25.03*** **
Log Likelihood	259.232	147.139	175.863	217.826	244.319	152.747	213.841	199.561	55.253	318.970	343.436	47.314
Observations	172	94	119	147	185	81	154	112	39	227	222	44

Panel B: Internet Penetration

Panel B1: Non-interactive regressions (Internet)

	LI	MI	Eng.	Frch.	Christ.	Islam	Open	Closed	Oil	Nonoil	Stable	Unstable
Constant	**0.294*** **	**0.003*** **	**0.425*** **	**0.308*** **	**0.401*** **	**0.329*** **	**0.375*** **	**0.270*** **	**0.352*** **	**0.291*** **	**0.315*** **	**0.403*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Internet (IV)	**0.008*** **	**-0.006*** **	**0.004*** **	**0.007*** **	**0.007*** **	0.0004	**0.005*** **	0.002	0.005	**0.007*** **	**0.005*** **	**0.008***
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	(0.691)	**(0.000)**	(0.219)	(0.107)	**(0.000)**	**(0.000)**	**(0.062)**
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR Chi-Square	**114.84*** **	**112.96*** **	**123.32*** **	**160.74*** **	**136.77*** **	**97.61*** **	**118.19*** **	**194.14*** **	**21.27*** **	**225.81*** **	**275.35*** **	**12.05***
Log Likelihood	264.503	143.756	184.248	229.066	244.754	143.961	220.641	196.803	49.108	330.838	355.134	36.051
Observations	170	91	114	147	183	78	149	112	37	224	221	40

Panel B2: Interactive regressions (Internet)

Constant	**0.294*** **	**0.280*** **	**0.436*** **	**0.306*** **	**0.405*** **	**0.352*** **	**0.374*** **	**0.265*** **	**0.370*** **	**0.292*** **	**0.315*** **	**0.389*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Internet (IV)	**0.010****	0.001	0.001	**0.015*** **	**0.009*** **	**0.010*** **	**0.004*** **	**0.013*** **	**0.017****	**0.008*** **	**0.005*** **	**0.038*** **
	(0.036)	(0.464)	(0.297)	**(0.001)**	**(0.000)**	**(0.005)**	**(0.006)**	**(0.008)**	**(0.014)**	**(0.000)**	**(0.000)**	**(0.000)**
Internet(IV)*Internet(IV)	-0.0001	0.00006	**0.00008****	**-0.0004***	-0.00006	**-0.0004*** **	0.00003	**-0.0008****	**-0.0005***	-0.00003	0.00001	**-0.001*** **
	(0.635)	(0.156)	**(0.039)**	**(0.061)**	(0.199)	**(0.005)**	(0.424)	**(0.016)**	**(0.053)**	(0.335)	(0.757)	**(0.001)**
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	na	na	na	0.013	na	0.008	Na	0.009	0.014	na	na	0.033
LR Chi-Square	**115.06*** **	**115.00*** **	**127.67*** **	**164.27*** **	**138.41*** **	**105.71*** **	**118.83*** **	**199.97*** **	**25.15*** **	**226.73*** **	**275.44*** **	**23.71*** **
Log Likelihood	264.616	144.776	186.425	230.829	245.575	148.014	220.963	199.716	51.052	331.300	355.183	41.881
Observations	170	91	114	147	183	78	149	112	37	224	221	40

Panel C: Telephone Penetration

Panel C1: Non-interactive regressions (Telephone)

	LI	MI	Eng.	Frch.	Christ.	Islam	Open	Closed	Oil	Nonoil	Stable	Unstable
Constant	**0.264*** **	**0.288*** **	**0.426*** **	**0.297*** **	**0.367*** **	**0.307*** **	**0.360*** **	**0.264*** **	**0.318*** **	**0.287*** **	**0.303*** **	**0.224****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.013)**
Telephone(Tel) (IV)	**0.050*** **	**0.009*** **	**0.011*** **	**0.036*** **	**0.013*** **	**0.034*** **	**0.011*** **	**0.023*** **	0.010	**0.014*** **	**0.012*** **	**0.060****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	(0.449)	**(0.000)**	**(0.000)**	**(0.015)**
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR Chi-Square	**136.76*** **	**156.52*** **	**233.42*** **	**168.23*** **	**181.80*** **	**144.33*** **	**144.88*** **	**288.31*** **	**20.45*** **	**316.17*** **	**355.53*** **	**15.10****
Log Likelihood	275.466	165.764	238.097	232.811	263.386	169.571	231.987	243.886	51.924	370.889	390.404	40.194

Observations	170	94	117	147	184	80	152	112	39	225	222	42
	Panel C2:Interactive regressions (Telephone)											
Constant	**0.235*** (0.000)**	**0.286*** (0.000)**	**0.396*** (0.000)**	**0.269*** (0.000)**	**0.353*** (0.000)**	**0.269*** (0.000)**	**0.350*** (0.000)**	**0.263*** (0.000)**	**0.289*** (0.002)**	**0.279*** (0.000)**	**0.296*** (0.000)**	0.098 (0.292)
Tel(IV)	**0.142*** (0.000)**	**0.013*** (0.000)**	**0.022*** (0.000)**	**0.080*** (0.000)**	**0.028*** (0.000)**	**0.094*** (0.000)**	**0.021*** (0.000)**	**0.024*** (0.000)**	0.048 (0.361)	**0.035*** (0.000)**	**0.027*** (0.000)**	**0.219*** (0.001)**
Tel(IV)*Tel(IV)	**-0.029*** (0.000)**	-0.0001 (0.180)	**-0.0004*** (0.000)**	**-0.010** (0.015)**	**-0.0005*** (0.000)**	**-0.017*** (0.001)**	**-0.0003** (0.020)**	-0.0001 (0.811)	-0.010 (0.457)	**-0.0008*** (0.000)**	**-0.0005*** (0.000)**	**-0.046*** (0.008)**
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	0.052	na	0.020	0.049	0.026	0.041	0.019	na	na	0.030	0.023	0.076
LR Chi-Square	**163.75*** **	**158.32*** **	**265.59*** **	**174.22*** **	**206.21*** **	**156.09*** **	**150.28*** **	**288.37*** **	**21.01*** **	**399.13*** **	**401.35*** **	**22.55*** **
Log Likelihood	288.961	166.667	254.184	235.803	275.593	175.452	234.687	243.915	52.207	412.370	413.311	43.923
Observations	170	94	117	147	184	80	152	112	39	225	222	42

*,**,***: significance levels of 10%, 5% and 1% respectively. IV: Instrumented Variable. Glob: Globalisation.LI: Low Income. MI: Middle Income. Eng. English common law.Frch: French civil law. Christ: Christian-dominated. Islam: Islam-oriented. Open: Unlandlocked. Closed: Landlocked. Oil: petroleum exporting. Nonoil: Non petroleum exporting. Stable: Politically stable. Unstable: Politically unstable.

5. Concluding implications and future research directions

In the transition from Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs), extreme poverty has been decreasing in all regions of the world with the exception of Sub-Saharan Africa (SSA), where close to 50% of countries in the sub-region were substantially off-track from achieving the MDG extreme poverty target.

The current study has assessed whether increasing information and communication technology (ICT) enhances inclusive human development in a sample of 49 countries in SSA countries for the period 2000-2012. The empirical evidence is based on instrumental variable Tobit regressions in order to account for simultaneity and the limited range in the dependent variable. For the purposes of increasing room for policy implications and controlling for the unobserved heterogeneity, the analysis is decomposed into fundamental characteristics of human development based on: income levels, legal origins, religious dominations, political stability, landlockedness and resource-wealth. The findings show that policies designed to boost ICT (mobile phone, internet, telephone) penetration will increase inclusive development in the post-2015 sustainable development agenda. The degree of positive responsiveness of inclusive development to ICT varies across fundamental characteristics and ICT dynamics.

In the light of the motivation of this study, the findings have strong implications for SSA in its quest to reach sustainable development goals. This is because for the most part, the post-2015 development agenda is fundamentally centred on the imperative to consolidate global inclusive development trends and reverse exclusive development tendencies. The apparent exclusive development in SSA falls within the latter framework. The conception, definition and measurement of 'inequality adjusted human development' employed as the

outcome indicator in this study is in line with at least six of the seventeen SDGs, namely: *Goal* 1(‘end poverty in all its forms everywhere’), *Goal* 2 (‘end hunger, achieve food security and improved nutrition and promote sustainable agriculture’); *Goal* 3 (‘ensure healthy lives and promote well-being for all ages’); *Goal* 4 (‘ensure inclusive and equitable quality education and promote lifelong learning opportunities for all’); *Goal* 8 (‘promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all’) and *Goal* 10 (reduce inequality within and among countries)[5].

Currently, the usage of ICT in SSA is lowest in the world whereas the corresponding growth rate of ICT in SSA is the highest. Our findings consolidate the need to promote ICT penetration and/or adoption for more inclusive development. While the findings of this inquiry demonstrate the relevance of ICT for socio-economic benefits, we concede that the affordability and lack of relevant infrastructure constitute substantial barriers to access. The governments of sampled countries should formulate and implement policies that enable universal access mechanisms via low pricing and sharing schemes and increase the infrastructure needed for ICT penetration.

Future studies can improve the existing literature by using alternative measurements of human development and methodologies, to assess whether the established linkages withstand further empirical scrutiny.

[5]The interested reader can refer to Michel (2016), for a full list of SDGs.

Appendices

Appendix 1: Definition and sources of variables

Variables	Signs	Definitions	Sources
Inclusive development	IHDI	Inequality Adjusted Human Development Index	UNDP
Mobile Phone	Mobile	Mobile phone subscriptions (per 100 people)	WDI
Internet	Internet	Internet subscriptions (per 100 people)	WDI
Telephone	Telephone	Telephone subscriptions (per 100 people)	WDI
Foreign Aid	Aid	Total Official Development Assistance (% of GDP)	WDI
Private Credit	Credit	Private credit by deposit banks and other financial institutions (% of GDP)	WDI
Remittance	Remit	Remittance inflows (% of GDP)	WDI
Foreign investment	FDI	Foreign Direct Investment net inflows (% of GDP)	WDI
GDP per capita	GDPpcg	Gross Domestic Product Per Capita Growth Rate (Annual %)	WDI
Education	PSE	Primary School Enrolment (% of Gross)	WDI

UNDP: United Nations Development Program. WDI: World Development Indicators. GDP: Gross Domestic Product.

Appendix 2: Summary statistics

	Mean	SD	Min	Max	Obs
Inequality Adj. Human Development	0.721	3.505	0.129	0.768	485
Mobile Phone Penetration	23.379	28.004	0.000	147.202	572
Internet Penetration	4.152	6.450	0.005	43.605	566
Telephone Penetration	3.039	5.810	0.005	32.455	565
Foreign Aid	11.687	14.193	-0.253	181.187	606
Private Domestic Credit	18.551	22.472	0.550	149.78	507
Remittances	3.977	8.031	0.000	64.100	434
Net Foreign Direct Investment Inflows	5.332	8.737	-6.043	91.007	603
GDP per capita growth	2.198	5.987	-49.761	58.363	608
Education	97.446	25.895	32.199	181.700	470

SD: Standard deviation. Min: Minimum. Max: Maximum. Obs: Observations. Adj: Adjusted.

Appendix 3: Correlation Matrix (Uniform sample size: 285)

Aid	Credit	Remittances	FDI	GDPpcg	PSE	Mobile	Internet	Telephone	IHDI	
1.000	-0.104	-0.068	0.336	0.098	0.074	-0.134	-0.146	-0.201	-0.371	Aid
	1.000	-0.048	-0.019	-0.0000	0.022	0.403	0.310	0.356	0.298	Credit
		1.000	0.116	0.045	0.065	-0.002	0.006	-0.016	0.020	Remittances
			1.000	0.163	0.067	0.174	0.148	0.053	0.072	FDI
				1.000	0.010	0.006	0.091	0.049	0.027	GDPpcg
					1.000	0.233	0.193	0.123	0.431	PSE
						1.000	0.743	0.586	0.576	Mobile
							1.000	0.736	0.581	Internet
								1.000	0.659	Telephone
									1.000	IHDI

Aid: Foreign aid. Credit: Private Domestic Credit. FDI: Foreign Direct Investment. GDPpcg: GDP per capita growth. PSE: Primary School Enrolment. Mobile: Mobile Phone Penetration. Internet: Internet Penetration. Telephone: Telephone Penetration. IHDI: Inequality Adjusted Human Development Index.

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