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The Effects of Mobile Phone Technology, Knowledge Creation and Diffusion on Inclusive Human Development in Sub-Saharan Africa [1]

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Abstract

This paper examines the joint effects of mobile phone technology, knowledge creation and diffusion on inclusive human development in 49 sub-Saharan African (SSA) countries. The empirical evidence is based on Tobit regressions for the period 2000-2012. The net effects of interactions between the mobile phone, knowledge creation and diffusion variables are positive indicating that the combined effects of these variables improve inclusive human development in SSA countries. Further analysis dividing the dataset into a number of fundamental characteristics based on economic, legal, religion and political stability associated with African economies show that mobile phone penetration and associated innovation in SSA improve inclusive human development irrespective of the country's level of income, legal origins, religious orientation and the state of the nation. The pupil-teacher ratio exerts a negative influence on the outcome variable which is favourable for inclusive human development because higher ratios denote lower education quality since more pupils are accommodated by fewer teachers. The study contributes to innovation diffusion theory and economic development literature.

1. Introduction

The forces of globalisation and increasing integration of the world economy over the past 25 years have dispelled the notion that developing countries are only users of innovations. Recent studies have demonstrated that users of global disruptive technologies such as mobile phones are important service innovators in developing countries (Boor et al., 2014; Oliveira and Hippel, 2011; Efobi et al., 2018; Tchamyou et al., 2019a, 2019b; Asongu and Acha-Anyi, 2020; Karakara and Osabuohien, 2019; Asongu and Kuada, 2020; Ejemeyovwi and Osabuohien, 2018; Asongu and Tchamyou, 2019a, 2020). Aker and Mbiti (2010) echo similar views and point out that mobile telephony has shifted the development paradigm from simple communication device to one that transform lives through innovative application and services in developing countries. It is therefore not surprising that recent literature has paid a notable attention on the impact of information and communication technology (ICT) on economic and human well-being in recent years (Donner, 2008; Sen, 2010; Smith and Seward, 2009; Ureta, 2008; Kwan and Chiu, 2015; Amankwah-Amoah & Sarpong, 2016; Asongu and le Roux, 2017; Asongu and Nwachukwu, 2017; Amankwah-Amoah, 2019; Tchamyou, 2019a, 2020; Uduji & Okolo-Obasi, 2018; Uduji et al, 2019a, 2019b,2019c, 2020). These studies have reported that technological innovations[2] originating from developing countries are low-cost but the resulting services provided often add enormous value to a given technology and constitutes an important means of economic growth for developing countries and organisations (Kwan and Chiu, 2015; Boor et al., 2014; Gupta et al., 2003).

While studies in developing country context have widely documented the benefits of ICT on human and economic development, there are still observable gaps in the literature regarding the impact of mobile phones on inclusive human development (Asongu and Le Roux,

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[2] Sometimes called frugal or grass-root innovation (Gupta et al., 2003)

2017). Thus prior studies suffer from one crucial limitation in that they ignore the combined effects of mobile phone technology, knowledge creation and diffusion variables on human development[3]. Yet the interaction of mobile phone technology and factors such as quality and level of education, internet access are important in developing a better understanding of the impact of mobile phone technology on human and economic development. Innovation dynamics, which include human capital, knowledge creation and diffusion, drives economic and human development (Kwan and Chiu, 2015) and has been identified as one of the causes of poverty in SSA (Boateng and Glaister, 1999). Indeed, the quality and level of education are a basis for generating innovation dynamics and their diffusion. In this paper, we examine the interactive effects of mobile telephony and knowledge creation and diffusion variables on inclusive human development based on a sample of 49 SSA countries over the period 2000-2012. Consequently, we ask the following research question: i) to what extent do mobile phone innovations foster and interact with knowledge creation and diffusion variables to improve the inclusive human development in SSA? We address this question by investigating the penetration of mobile phones in SSA and the extent to which knowledge diffusion, human

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[3] It is important to note that a dataset can consists of more than 100 variables and used for several studies. Hence, the same periodicity can be used for different problem statements. Prior studies that have used the same dataset and based on varying methodologies (i.e. Generalised Methods of Moments, Ordinary Least Squares, Tobit, Fixed Effects, Quantile regressions, *inter alia*), data structures (panel versus cross-sectional) and samples (developing countries versus sub-Saharan Africa), have focused on: thresholds of educational quality in knowledge diffusion for inclusive development (Asongu and Nwachukwu, 2018); the importance of mobile phones in governance for inclusive development (Asongu and Nwachukwu, 2016a); the mobile phone in knowledge diffusion for institutional quality (Asongu and Nwachukwu, 2016b); conditional drivers of mobile phone penetration based on cross sectional data owing to data availability constraints in mobile banking data (Asongu, 2018); mobile phones in knowledge diffusion and persistence in inclusive development (Asongu and Nwachukwu, 2017); determinants of mobile phone penetration based on panel data (Asongu et al., 2018a); nexuses between mobile phones, institutional quality and entrepreneurship (Asongu et al., 2018b); the role of mobile phones in governance-driven technology exports (Asongu and Asongu, 2019); human development thresholds for inclusive mobile banking in developing countries (Asongu and Odhiambo, 2018) and the mobile phone as an argument for good governance (Asongu et al., 2019a). Moreover, the study is consistent with what constitutes a contribution to knowledge in the light using the same dataset for another problem statement, notably, that the motivation, findings and implications should be different (Horbach and Halffman, 2019).

capital, knowledge creation impact on human development after controlling for factors such as access to credit, foreign direct investment (FDI), gross domestic product (GDP) and remittances.

The choice of SSA as an empirical setting is motivated by the following. First, SSA countries have high levels of poverty compared to other regions around the world (World Bank, 2015). Despite the low income levels, Penard et al. (2012) reported that mobile phone and internet penetrations rates in SSA stood at 41% and 9.6% respectively as of 2010. Moreover, a growing stream of development literature has documented a plethora of inclusive benefits from mobile phones such as improving opportunities of doing business and household management efficiency (Aker and Mbiti, 2010; Mishra and Bisht, 2013; Al Surikhi, 2012; Asongu and Odhiambo, 2019a); elimination of wastes in supply chains of the agricultural sector via reductions of demand-supply mismatches as well as demand- and supply-side constraints (Muto and Yamano, 2009; Aker and Fafchamps, 2010). Others further point out that these technologies promote financial inclusion of the rural poor (Singh, 2012; Kirui et al. 2013); bridge the gap between rural and urban areas (Qiang et al., 2011; Chan & Jia, 2011); empower women (Maurer, 2008; Ojo et al., 2012); promote the informal economic sector and reduce income-inequality (Asongu, 2013). In addition, Ureta (2008, p. 83) contends that "mobile phones are used to overcome problems related to physical distance and mobility of people". Arguably, mobile phone technology has introduced novel opportunities to facilitate the delivery of financial, agricultural, health and educational services in SSA. Given the benefits accruing to SSA countries from mobile phone technology, it is timely to ask whether access to mobile phone technologies in SSA would serve as an important catalyst for economic and human development. Second, Asongu (2017a, 2017b) suggests that while high-end markets in Asia,

Europe and North America are characterised with stabilization in the growth of mobile phones[4], developing African markets still project substantial business opportunities centred on mobile penetration. He also points out that the prospects of mobile phone penetration in Africa are promising and encouraging and these considerations motivate research in the African context.

The study contributes to the literature in several ways. First, while a number of recent studies have examined the role of mobile phone, most of these studies have used cross-sectional data to establish the positive correlation between mobile phones and development outcomes (see Asongu, 2013). This study extends the positive correlations to causality by exploring the interaction between mobile phone, knowledge creation and diffusion variables which have been neglected in the past empirical efforts. This extension is important because sound policy formulation should be based on established causalities, not correlations. Second, orchestration of inclusive human development relies heavily on connectivity of individuals and organisations, that is, individual-based personal relationships that often arise within communities of practice, inter- and intra- organisation networks (Lorenzen and Mudambi, 2013) and more importantly communication within and between locations. By analysing the role of how globally significant innovation, like mobile phone and its interactions with key knowledge creation and diffusion variables affect inclusive human development in an environment where poverty, high illiteracy rate, low ICT and mobile phone connectivity are predominant, we contribute to economic development literature and innovation diffusion theory. It is worthwhile to emphasize that learning within the context of the study is broadly considered, notably, it entails the process within an educational system as well as organizational learning in an evolutionary relationship based on interactive learning in companies.

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[4] The terms, 'mobile phone penetration', 'mobile', 'mobile phones' and 'mobile telephony' are used interchangeably throughout the paper.

The rest of the study is structured as follows. Section 2 reviews the literature relating to innovation and the role of mobile phone penetration and inclusive human development. The data and methodology are discussed in Section 3. Section 4 presents the empirical results, discussion and implications of the study while Section 5 summarises conclusion.

2. Literature Review

2.1 Innovation and Inclusive Development

Innovation dynamics which are key determinants of sustainable growth for countries and firms are influenced by a number of factors including human capital, knowledge creation and diffusion. Human capital which is defined as individual's knowledge, skills, expertise, and abilities that allow for changes in action and economic growth (Coleman, 1988; Fonseca et al., 2019) is a critical ingredient for innovation to occur. Rosenberg (1972) noted that human capital is an essential prerequisite for the use and effective exploitation of innovative technology (Asongu and Nwachukwu, 2018). Through formal and continuous education, individuals update and renew their capabilities to do well in the society (Dakhi and de Clereq, 2007; Kwan and Chiu, 2015; Asongu, 2015). At country level, OECD (2013) reported that, in the European Union and the USA, business investment in talent management contributes to 20 percent and 34 percent of average productivity growth. For instance, a study of 1258 executives in Asia supports the link between human capital and innovation (PwC, 2012). The length of learning period depends on many factors including the complexity of the new technology but the level of education is crucial. Consequently, different regions offer different levels of qualified human capital. However, in the context of SSA where the literacy rate is very low, education becomes critical for diffusion of technology and shape subsequent incremental innovation.

Another important dimension of innovation dynamics is knowledge diffusion and creation (Kwan and Chiu, 2015; Alshanty and Emeagwali, 2019). Neo-classical models of economic

growth suggest that technology transfer is an important source of innovation in poor countries (Abramowitz, 1986; Bernard and Jones, 1996). Kwan and Chiu (2015) observe that knowledge diffusion provides a direct measure of innovation dynamics. Arguably, knowledge diffusion and creation variables include foreign direct investment (FDI), communication, computers, information services and technical journal articles published in a particular country (see World Bank Knowledge Economy Index; Global Innovation Index, 2013)[5]. Nonaka (1994) ascertains that ideas are formed in the minds of individuals, however, interactions (i.e. connectivity) between individuals typically plays a critical role in developing these ideas. Simply put, interactions between individuals contribute to the amplification and development of new knowledge (Kent and Rechavi, 2020). Feder and Savastano (2006) have rendered support to this line of thinking indicating that communications and information relating to new knowledge are embedded within the general fabric of social interactions among individuals. Overall, the capacity to innovate and improve the economic and social well-being of a country depends on a broad set of factors and interactions of these factors with human capital (Badinger and Tondi, 2005; Amankwah-Amoah, 2019).

2.2 Mobile phones penetration and Inclusive Human Development

In the increasingly competitive and changing world, immobility means being left behind with its negative consequences of social exclusion and human under-development (Bauman, 1998; Ureta, 2008). Numerous authors point out that mobile phone technology reduces the need to move physically and this is especially important in enhancing the individual's capabilities of acting-at-a-distance without the need to be physically present at where the action takes place (Ureta, 2008; Smith et al., 2008; Shaikh and Karjaluoto, 2015; Uduji and Okolo-Obasi, 2018;

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[5] Global Innovation Index is co-published annually by INSEAD, Cornell University and the World Intellectual Property Organisation

Uduji et al., 2018). Brown et al. (2001), Katz (2003), Ling and Pedersen (2005) and Aker and Mbiti (2010) show also that, mobile phones are used to overcome problems related to physical distance and mobility of people, allowing them to enlarge their area of practices and maintain connections outside the immediate space of their homes, work, and other local areas.

Another important role of mobile phone technology is that it increases access to timely and relevant information. Information is a key input in many developmental activities (Mchombu, 2003; Aker and Mbiti, 2010; Asongu et al., 2019a). Smith et al. (2011) document that mobile phones increase the users' ability to exchange relevant information cheaply and in timely manner thereby altering individuals' access to developmental input and reducing one of the barriers to expanded capabilities. Information is seen as commodity capable of yielding knowledge as it carries signals which we can learn from. In the context of developing countries, Asongu and De Moor (2015) argue that the underlying benefits of mobile phones are linked with almost all fabrics of African society through enhanced corporate and household management. Specifically, these authors point out that the benefits are mostly economic and inclusive human development in nature including (i) consolidation of household-to-business, business-to-business and household-to-household networks; (ii) improvements in payment facilities for small and medium- sized enterprises (SMEs) and (iii) bridging the gap of the rural-urban divide. Asongu (2015) documented that one of the key benefits of mobiles is gender inclusiveness. This view is supported by Maurer (2008) and Ojo et al. (2012) who pointed out that mobile phones lead to the empowerment of women through financial inclusion channels as mobile phones provide a better channel for coordination in household management and female-managed SMEs. In addition to the benefits derived from multi-tasking, education and cost reduction (Jonathan and Camilo, 2008; Ondiege, 2010; Al Surikhi, 2012), others have documented that mobile phones facilitate health service provision as mobile telephony is used to improve health-service delivery to large segment of population living in rural areas in

developing countries. West (2013) has rendered some support for this view and indicate that, facilities from the mobile phone devices are important in the provision of affordable medical services that may otherwise be unavailable to geographically distanced poor population in many African countries. In particular, mobile phones facilitate access to reference material, assessment of medical records and efficiency in laboratory tests, better tailored feedback because of enhanced self-monitoring; improved observation and treatment of patients with tuberculosis, remind those affected by HIV and AIDS to take their medicines on schedule and more efficient management of clinical appointments (Bauer et al., 2010; Hoffman et al., 2010; De Costa et al., 2010; Aker and Mbiti, 2010). According to Kliner et al. (2013), rural communities are those that benefit most from the development externalities of health-tailored mobile phone applications.

Prior literature also points to the importance of mobile phones in banking services. Chan and Jia (2011) suggest that the use of mobile phones to access to finance represents an ideal choice for meeting the rural financial needs as evidenced in the phenomenal growth rates for money transfers through mobile phones at commercial banks. An important example is M-Pesa – a mobile money service is used by more than 70% of Kenyan adults and a vast majority of poor rural population (IMF, 2011; Alexander, 2010). Warren (2007), Donner (2008) and Rangaswamy and Nair (2010) indicate that the benefits of mobile phones might be proportionately greater in resource-constrained setting such as the poor rural populations. This is probably because it substantially reduces information asymmetry and alleviates constraints to information acquisition and purchase of commodities (Asognu and Biekpe, 2017; Tchamyou and Asongu, 2017a, 2017b; Tchamyou et al., 2018). In India for example, Singh (2012) has shown that mobile phones are increasing financial inclusion in rural areas. The narratives in this section are broadly consistent with contemporary literature on technology spillovers for development outcomes (Del Giudice et al., 2019; Stephan et al., 2019; Zhang et al., 2020 ; Cai

et al., 2020 ; Miremadi et al., 2019) and mobile technologies for inclusive development (Afutu-Kotey et al., 2017; Asongu & Boateng, 2018; Bongomin et al., 2018 ; Gosavi, 2018; Isszhaku et al., 2018; Minkoua Nzie et al., 2018; Humbani & Wiese, 2018; Muthinja & Chipeta, 2018; Abor et al., 2018).

3. Data and Methodology
3.1 Data

We investigate a panel of 49 SSA African countries with data from African Development Indicators of the World Bank for the period 2000-2012. Following Asongu and Nwachukwu (2016a), Asongu and Le Roux (2017), the dependent variable is measured by the inequality adjusted human development index (IHDI). The human development index (HDI) represents a national average of achievements in three principal dimensions: (i) decent living standards, (ii) health and long life, and (iii) knowledge. The IHDI does not only account for average achievements in terms of income, education and health, but it also controls for the distribution of underlying attainments among the population by discounting the mean value of each dimension with respect to its inequality level.

Consistent with the studies of (Tchamyou, 2017) and Asongu (2015), the mobile telephony variable is proxied with the mobile phone penetration rate (per 100 people).

Three knowledge creation and diffusion variables representing three of the four pillars of the World Bank's Knowledge Economy Index are employed: education, information and communication technology (ICT) and innovation. First, education is proxied with 'pupil-teacher ratio' in primary education. Data availability constraints and the documented relative importance of primary education have motivated the choice of this variable. In essence: (i) we observe issues in degrees of freedom on the other educational quality variables (e.g. 'pupil-teacher ratio' in secondary education) and (ii) compared to other levels of education, primary education has been documented to engender comparatively higher positive development

externalities at the initial stage of industrialisation. According to Petrakis and Stamatakis (2002) and Asiedu (2014), primary schooling is associated with higher social returns compared to other levels of education in undeveloped/developing economies. Second, the number Scientific and Technical Journal Articles (STJA) published annually is used to proxy for innovation because of data availability constraints in other proxies (e.g. trademark and patent applications). This same justification has been provided by Tchamyou (2017). Third, in line with the narrative of the introduction (see Penard et al., 2012), internet penetration is used as the complementary ICT variable because its market has a high potential for development in SSA, given the low penetration of internet in the sub-region compared to other regions of the World.

Four control variables are adopted, namely: remittances, foreign direct investment (FDI), private domestic credit and GDP per capita. In accordance with the inclusive growth/development literature, we expect a positive relationship between selected covariates and the dependent variable (see Mishra et al., 2011; Seneviratne & Sun, 2013; Mlachila et al., 2017). According to Mlachila et al. (2017), remittances are expected to increase inclusive human development because they are used for consumption purposes for the most part. Mlachila et al. (2017) have used FDI, credit facilities and GDP per capita as determinants of economic growth quality. Definitions and sources of variables are reported in Table 1

Table 1: Definitions and sources of variables

Variables		Measurements	Sources
Inclusive development	IHDI	Inequality Adjusted Human Development Index	UNDP
Mobile Phone	Mobile	Mobile phone subscriptions (per 100 people)	WDI
Educational Quality	Educ	Pupil teacher ratio in Primary Education	WDI
Innovation (KC)	STJA	Scientific and Technical Journal Articles	WDI
Internet	Internet	Internet penetration (per 100 people)	WDI
GDP per capita	GDP	GDP per Capita growth rate	
Private Credit	Credit	Private credit by deposit banks and other financial institutions (% of GDP)	WDI
Remittances	Remit	Remittance inflows (% of GDP)	WDI
Foreign investment	FDI	Foreign Direct Investment net inflows (% of GDP)	WDI

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

3.2 Methodology

The methodology adopted in this study is in accordance with data behaviour (Kou et al., 2012, 2014, 2016, 2019a, 2019b; Li et al., 2014, 2016; Zhang et al., 2019). We adopt the standard Tobit model to examine the relationship between the mobile phone penetration and inclusive human development. Since the IHDI theoretically falls between 0 and 1, estimation by Ordinary Least Squares (OLS) is not appropriate (Asongu et al., 2019b). A double-censored Tobit model is employed to control for the limited range in the dependent indicator (Kumbhakar & Lovell, 2000; Koetter et al., 2008; Coccorese & Pellecchia, 2010; Ariss, 2010; Asongu & Odhiambo, 2019, 2020; Ajide et al., 2019). Consistent with McDonald (2009) and Coccorese and Pellecchia (2010), in the absence of observations taking the values of either 0 or 1, estimation by double-censored Tobit is the same as estimation by a linear model because the two likelihood functions coincide. This is the case with IHDI because it has minimum and maximum values of 0.129 and 0.768 respectively.

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

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

where $y_{i,t}^*$ is a latent response variable, $X_{i,t}$ is an observed $1 \times k$ vector of explanatory variables and $\varepsilon_{i,t} \approx$ i.i.d. N(0, σ2) and is independent variable of $X_{i,t}$. Instead of observing $y_{i,t}^*$, we observe $y_{i,t}$:

$$y_{i,t} = \begin{cases} y_{i,t}^*, & if \ y_{i,t}^* > \gamma \\ 0, & if \ y_{i,t}^* \leq \gamma, \end{cases} \quad (2)$$

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.

Given that our estimation strategy deals with interactive regressions, it is important to briefly discuss some pitfalls linked to interactive specifications. Consistent with Brambor et al. (2006), all constitutive variables should be involved in the specifications. Furthermore, for the estimated parameters to make economic sense, they should be interpreted as conditional

marginal effects. Thresholds from which the modifying policy variables of knowledge diffusion can change an underlying mobile phone penetration sign also have to be within the range of the knowledge variables provided by the summary statistics.

4. Results & Discussion

4.1 Summary Statistics

The summary statistics of the sample variables are presented in Table 2. The mean scores for mobile phone and internet penetration are about 23% and 4% respectively suggesting that internet access is still low in SSA countries. Comparatively, mobile phone access appears relatively high. The mean for pupil-teacher ratio is about 43 per teacher indicating a high ratio which may be detrimental to the quality of education in SSA countries.

Table 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
Educational Quality	43.601	14.529	12.466	100.236	444
Innovation (STJA)	91.231	360.522	0.000	2915.5	480
Internet Penetration	4.152	6.450	0.005	43.605	566
GDP per Capita growth	2.198	5.987	-49.761	58.363	608
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

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

Table 3 presents the correlation matrix of the variables in our model. We observe that most of the correlations among the independent variables are low with the exception of internet and innovation variables having coefficient of 0.746 and 0.779. We therefore carried out variable inflation factor (VIF) test and our results are well below 10 suggesting that multicollinearity is not an issue in this study (Neter, Wasserman and Kutner, 1985). In addition, it is important to note that since we employ interactive regressions, issues of multicollinearity do not take

precedence over the inclusion of all constitutive terms because corresponding interaction terms are interpreted essentially as marginal effects (see Brambor et al., 2006).

Table 3: Correlation Matrix (Uniform sample size : 233)

| Diffusion of Knowledge | | | Control Varaibles | | | | Ind. Vble | Dep. Vble | |
Edu	STJA	Internet	GDPpcg	Credit	Remit	FDI	Mobile	IHDI	
1.000	-0.127	-0.484	0.029	-0.369	-0.073	-0.118	-0.461	-0.096	Edu
	1.000	-0.124	0.036	**0.779**	-0.083	-0.062	0.221	**0.701**	STJA
		1.000	0.043	0.479	-0.039	0.060	**0.746**	0.088	Internet
			1.000	0.014	0.035	0.131	-0.003	-0.023	GDPpcg
				1.000	-0.096	-0.117	0.471	0.599	Credit
					1.000	0.078	-0.058	-0.050	Remit
						1.000	0.114	-0.026	FDI
							1.000	0.049	Mobile
								1.000	IHDI

Edu : Educational quality. STJA: Scientific & Technical Journal Articles. Internet: Internet Penetration. GDPpcg : GDP per capita growth rate. Credit: Private domestic credit. Remit: Remittances. FDI: Foreign Direct Investment. Mobile: Mobile Phone Penetration. IHDI: Inequality Adjusted Human Development Index. Ind. Vble: Independent Variable. Dep. Vble: Dependent Variable.

4.2 Regression Results

Given that the IHDI varies between 0 and 1, we employ a double censored Tobit model and our baseline regression results are reported in Tables 4. We document that the coefficients for mobile phone and internet penetration variables are positive and significant suggesting that mobile phones improve inclusive human development. The results are positive for all of the knowledge creation and diffusion variables, namely education, innovation and internet. The results that mobile phones exert a positive and significant influence on human development support the widely held view that mobile phones are a key input to many developmental activities (Mchombu, 2003; Benkler, 2006). The results are also consistent with the findings of Asongu and De Moor (2015) who pointed out that the underlying benefits of mobile phones are linked with almost all fabrics of African society through enhanced corporate and household management. However, while the coefficients for innovation variable have positive signs, their effects on human development appear insignificant. Regarding the effects of education on human development, we document that the pupil-teacher ratio has a negative and significant on human development. The findings that education as measured by pupil-teacher ratio exerts a

negative impact on human development is not surprising because higher ratios denote lower education quality since more pupils are accommodated by fewer teachers. It follows that lower quality education is associated with lower levels of inclusive human development, which is consistent with the findings of Dakhi and de Clereq (2007); Kwan and Chiu (2015); OECD (2013); PwC (2012) which find support for the link between education and human development.

Further analysis includes interactions of mobile phone and education, innovation and internet variables as independent variables in our models. Brambor et al. (2006) point out the importance of interpreting marginal effects for interaction models, consequently, we compute the marginal effects of these interactions. We find the net effect of the interaction term to be positive and significant suggesting that the joint effect of mobile phones and the level of education and innovation improve inclusive human development. For instance, the net effect (i.e. 0.0012) of the second column of Table 4 is computed as 0.0012 ([-0.00004×43.601] + [0.003]). In this calculation, the mean value of education as disclosed in the summary statistics is 43.601, the interactive effect between mobile phone penetration and education is -0.00004 whereas the unconditional impact of mobile phone penetration is 0.003. Our results remain the same after controlling for GDP, private credit, remittances and foreign direct investment which have been identified as factors affecting human development (Mishra et al., 2011; Seneviratne and Sun, 2013; Mlachila et al., 2017).

Table 4: Inclusive development and mobile phones (Tobit regression)

	Dependent Variable: Inequality Adjusted Human Development (IHDI)								
	Education (Quality of education)			Innovation (STJA)			Internet		
Constant	0.470*** (0.000)	0.453*** (0.000)	0.465*** (0.000)	0.376*** (0.000)	0.353*** (0.000)	0.346*** (0.000)	0.385*** (0.000)	0.370*** (0.000)	0.378*** (0.000)
Mobile phones (Mob)	0.003*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.003*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Education	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.001)	---	---	---	---	---	---
Innovation (STJA)	---	---	---	0.00008 (0.282)	0.00002 (0.708)	0.0001 (0.114)	---	---	---
Internet	---	---	---	---	---	---	0.003** (0.031)	0.006*** (0.000)	0.008*** (0.000)
Education.Mob	-0.00004*** (0.000)	-0.00003*** (0.000)	-0.00004*** (0.000)	---	---	---	---	---	---
STJA.Mob	---	---	---	-0.000 (0.197)	-0.000001* (0.063)	-0.000002*** (0.001)	---	---	---
Internet.Mob	---	---	---	---	---	---	-0.000 (0.762)	-0.00002 (0.154)	-0.00003** (0.032)
GDP per capita	---	0.0003 (0.696)	0.0003 (0.782)	---	0.003*** (0.001)	-0.0004 (0.695)	---	0.002*** (0.001)	0.0003 (0.740)
Private Credit	---	0.001*** (0.000)	0.001*** (0.000)	---	0.002*** (0.000)	0.003*** (0.000)	---	0.0009*** (0.001)	0.001*** (0.000)
Remittances	---	---	0.00004 (0.925)	---	---	0.0004 (0.370)	---	---	0.0001 (0.709)
FDI	---	---	-0.001* (0.056)	---	---	0.0008 (0.324)	---	---	-0.0007 (0.193)
Thresholds	-75	-66.66	-50	Na	-20000	-10000	na	na	-33.33
Net Effects	0.0012	0.0006	0.0002	Na	0.0019	0.0018	na	na	0.0008
LR Chi-Square	232.09***	252.55***	218.6***	139.10***	177.6***	192.30***	186.5***	228.6***	234.9***
Log Likelihood	398.346	386.817	331.802	319.801	332.661	318.135	400.744	406.009	378.296
Observations	342	323	278	346	330	271	428	400	328

*, **, ***: significance levels of 10%, 5% and 1% respectively. STJA: Scientific and Technical Journal Articles. GDP: Gross Domestic Product. FDI: Foreign Direct Investment. na: thresholds and/or net effects cannot be computed because of insignificant marginal effects. 43.601 is the mean value of education. 91.231 is the mean value of Scientific and Technical Journal Articles. 4.152 is the mean of internet penetration.

4.3 Extensions based on Fundamental Characteristics

To shed more lights on our baseline regression results, we decompose the dataset into fundamental characteristics based on legal origins, income-levels, resource wealth, openness to sea, religious domination and political stability. Previous literature indicates that these factors have some bearing on human development (Mlachila et al., 2017; Asongu, 2017a).

Mlachila et al. (2017) have provided an interesting literature on the linkages between inclusive development and the following fundamental characteristics: income levels, regional proximity, state fragility and resource-wealth. According to the authors, inclusive development increases

with income levels, political stability and resource-poor countries. First, high income countries are more likely to be associated with better institutions that enable equitable distribution of wealth from economic prosperity. Two main reasons motivate this positive association. On the one hand, higher income offers more opportunities of social mobility and employment. On the other hand, institutions have recently been documented to positively affect quality of growth in Africa (Fosu, 2015b).

Second, nations with more political stability are intuitively more likely to create conducive conditions for the juice of economic prosperity to trickle down to the poorer factions of the population. Third, in the light of the first point on income-levels, while the prospect that inclusive development is comparatively higher in resource-rich countries may be counter-intuitive; there are also strong reasons to suggest that nations that have acknowledged scarcity in natural resources focused more on human capability development to achieve growth and inclusive development (America, 2013; Fosu, 2013; Amavilah, 2015). This narrative is consistent with the Kuada (2015) paradigm on 'soft economics' to understanding Africa's poverty tragedy.

Fourth, legal origins are fundamental in contemporary comparative economic development (La Porta et al., 1998, 1999). This assertion has been recently confirmed in African countries (see Agbor, 2015). The literature is broadly consistent with the view that because of better political and adaptability channels (see Beck et al., 2003), French Civil law countries compared with English Common law traditions provide better conditions for the improvement of social mobility and reduction of economic vulnerability. In essence, French civil law places more emphasis on the power of the State while English Common law is more aligned to the consolidation of private property rights. Hence, the institutional web of formal norms, informal rules and enforcement characteristics intuitively affect social mobility and economic vulnerability within a nation.

Fifth, the basis for religious dominations builds on the intuition that solidarity affects inclusiveness. Christianity and Islam are two dominant models of such solidarity. Sixth, there is an institutional cost of being landlocked (Arvis et al., 2007). Such an institutional setback could be linked to less economic governance: the formulation and implementation of effective policies that deliver public commodities for inclusive development. To account for the above factors, this study carried out further analysis to shed more lights on the effects of mobile phones on inclusive human development.

Table 5 reports the findings using Tobit regression model[6]. For brevity, we report only the independent variables of interest, since most of the control variables are significant with expected signs. The table consists of three panels as follows: education (Panel A), innovation (Panel B) and ICT (Panel C) specifications. Panel A of the table indicates that mobile phones improve inclusive human development irrespective of the level of income, legal origins, religious orientation, openness to sea, country's oil resources and the level of the country stability. We also document that education (i.e. pupil-teacher ratio) negatively affects inclusive human development in respect of the fundamental characteristics of the country. Regarding the interaction of mobile phones and education, we find that the net effect of the interactive variable improves inclusive human development in respect of the following fundamental characteristics, low and lower-middle income countries, countries with French legal origins, non-oil and -landlocked countries; the state of stability in the country.

Panel B of table 5 reports the impact of mobile phones on human development. We document a positive and significant impact of mobile phones and innovation (using scientific and technical Journal articles as proxy) on inclusive human development. Regarding the interaction of mobile phones and innovation, with the exception of Upper Middle Income countries

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[6] We also used fixed effect model to control for the unobserved heterogeneity and the results are more or less similar.

(UMIC), the complementarity of knowledge diffusion of mobile phones for inclusive development is consistently apparent in Low Income Countries (LIC). On the effects of interactions in respect of legal origins, we also document positive and significant coefficients for both countries with English and French legal origins. However, the effect of countries with English Common law tradition is consistently higher their French counterparts. The differences between oil and non-oil producing countries appear not be significant issue in the use of mobile phone technology for the inclusive human development. The net effects for our interactions are all positive for oil and non-oil countries. Islamic countries and landlocked have higher coefficients over their Christian-dominated and 'Not landlocked' counterparts respectively. We also find that politically-unstable countries appear to have positive net effect of our interactive terms.

It is important to note that Mlachila et al. (2017) have also found resource-poor countries to be associated with higher levels of inclusive development, compared to their resource-rich counterparts. Moreover, politically unstable countries may use the mobile phone more effectively for inclusive development than politically stable countries. For example in a recent global study on the use of mobile phones for banking purposes, Somalia which has experienced more than two decades of political instability has been found to be leading in the use of mobile phones for inclusive development (Mosheni-Cheraghlou, 2013; Asongu, 2018).

The results reported in Panel C of Table 5 document the positive and significant effect of mobile phones and internet on inclusive human development. We also note the positive net effect of the interaction between the internet and mobile phones on inclusive human development. All in all, we find mobile phones, internet penetration and innovation to be important vehicles for inclusive human development. Another important finding of this study is the overwhelming evidence of net effects of the interaction education, innovation and internet access conditional on on the level of mobile phone penetration. From our findings, we can

conclude that: (i) mobile phones constitute as important vehicle for the knowledge creation and diffusion and consequently inclusive human development in developing countries; (ii) the crucial role played by mobile phones is more apparent with a disaggregated sample which indicates that the effects of mobile phone penetration are positive irrespective of important country factors such as legal origins, level of income and the level of political stability. However, the low levels of education in SSA countries exert a negative influence on inclusive human development.

Table 5: Decomposition Results: Tobit regressions

Dependent Variable: Inequality Adjusted Human Development (IHDI)

Panel A: Education (Quality of Education)

	Income Levels				Legal Origins		Religious Domination		Openness to Sea		Resource-Wealth		Conflict	
	UM. Income	M. Income	LM Income	L Income	English	French	Christian	Islam	Landlocked	Not Landlocked	Oil	Non-Oil	Conflict	Non Conflict
Constant	0.420***	0.518***	0.500***	0.425***	0.500***	0.366***	0.447***	0.614***	0.735***	0.415***	0.459***	0.491***	0.573***	0.433***
	(0.000)	(0.000)	(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 phones (Mob)	0.003*	0.001**	0.002***	0.003***	0.002**	0.002***	0.002***	0.002***	0.003***	0.003***	-0.005*	0.002***	0.012**	0.002***
	(0.053)	(0.017)	(0.000)	(0.000)	(0.013)	(0.000)	(0.006)	(0.000)	(0.007)	(0.000)	(0.083)	(0.000)	(0.016)	(0.000)
Education	-0.003***	-0.003***	-0.001*	-0.0007	-0.002***	0.0002	-0.0008	-0.005***	-0.005***	-0.0003	-0.0004	-0.002***	-0.002	-0.001**
	(0.008)	(0.000)	(0.092)	(0.185)	(0.000)	(0.722)	(0.169)	(0.000)	(0.000)	(0.541)	(0.586)	(0.000)	(0.134)	(0.018)
Education.Mob	-0.00008	-0.00001	-0.00004***	-0.00005***	-0.00002	-0.00004***	-0.00003	-0.00002	-0.00001	-0.00005***	0.0001**	-0.00003***	-0.0002**	-0.00003***
	(0.144)	(0.266)	(0.004)	(0.009)	(0.359)	(0.001)	(0.120)	(0.115)	(0.515)	(0.000)	(0.029)	(0.001)	(0.029)	(0.002)
Thresholds	Na	na	-50	-60	Na	-50	na	na	na	-60	50	-66.66	-60	-66.66
Net Effects	Na	na	0.00025	0.00081	Na	0.00025	na	na	na	0.00081	-0.00063	0.00069	0.00327	0.00069
LR Chi-Square	64.67***	103.65***	69.07***	144.16***	90.09***	153.39***	59.18***	146.47***	98.26***	172.17***	20.85***	245.51***	30.75***	208.46***
Log Likelihood	63.804	127.131	77.983	213.72	167.63	179.80	227.97	113.60	119.92	234.20	57.55	300.498	53.156	286.006
Observations	52	107	55	171	133	145	198	80	86	192	40	238	42	236

Panel B: Innovation (STJA)

	Income Levels				Legal Origins		Religious Domination		Openness to Sea		Resource-Wealth		Conflict	
	UM. Income	M. Income	LM Income	L Income	English	French	Christian	Islam	Landlocked	Not Landlocked	Oil	Non-Oil	Conflict	Non Conflict
Constant	0.234***	0.302***	0.394***	0.338***	0.362***	0.347***	0.363***	0.322***	0.397***	0.353***	0.502***	0.324***	0.400***	0.337***
	(0.000)	(0.000)	(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 phones (Mob)	0.003***	0.003***	0.003***	0.002***	0.003***	0.002***	0.002***	0.002***	0.004***	0.002***	0.003***	0.002***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Innovation (SJTA)	0.003***	0.001***	0.0008**	0.00007	0.0003**	0.0001*	0.0004**	0.00001	0.0002***	0.000008*	0.0004	0.0001*	0.0002	0.0002**
	(0.000)	(0.000)	(0.010)	(0.210)	(0.027)	(0.052)	(0.047)	(0.852)	(0.007)	(0.922)	(0.175)	(0.050)	(0.280)	(0.010)
STJA. Mob	-0.00002	-0.00003***	-0.00004***	-0.000002***	-0.000004***	-0.000007**	-0.000006	-0.000002***	-0.000004	-0.000001*	-0.00003**	-0.000003***	-0.000001	-0.000008***
	(0.290)	(0.005)	(0.001)	(0.001)	(0.008)	(0.010)	(0.498)	(0.005)	(0.298)	(0.087)	(0.015)	(0.000)	(0.339)	(0.004)
Thresholds	na	-100	-75	-1000	-750	-285.71	na	-1000	na	-2000	-100	-666.67	na	-250
Net Effects	na	0.00026	0.00296	0.00163	0.00263	0.00136	na	0.00163	na	0.00190	0.000263	0.00172	na	0.00127

	UM. Income	M. Income	LM Income	L Income	English	French	Christian	Islam	Landlocked	Not Landlocked	Oil	Non-Oil	Conflict	Non Conflict
LR Chi-Square	76.50***	80.05***	53.69***	147.94***	68.36***	131.80***	69.60***	128.79***	59.43***	158.46***	26.55***	211.27***	23.76***	177.90***
Log Likelihood	63.334	114.04	74.642	216.20	143.77	177.07	213.22	112.85	94.15	231.67	56.42	284.99	48.38	269.18
Observations	46	102	56	169	122	149	191	80	82	189	41	230	46	225

	Income Levels				**Legal Origins**		**Panel C: Internet** **Religious Domination**		**Openness to Sea**		**Resource-Wealth**		**Conflict**	
	UM. Income	M. Income	LM Income	L Income	English	French	Christian	Islam	Landlocked	Not Landlocked	Oil	Non-Oil	Conflict	Non Conflict
Constant	0.289***	0.372***	0.417***	0.365***	0.367***	0.377***	0.375***	0.382***	0.394***	0.385***	0.473***	0.363***	0.378***	0.361***
	(0.000)	(0.000)	(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 phones (Mob)	0.004***	0.001***	0.00004	0.0004	0.002***	0.0009***	0.001***	-0.0007	0.003***	0.0002	0.002***	0.001***	0.001*	0.001***
	(0.000)	(0.001)	(0.936)	(0.104)	(0.000)	(0.003)	(0.000)	(0.167)	(0.000)	(0.342)	(0.005)	(0.000)	(0.061)	(0.000)
Internet	0.037***	0.010***	0.010***	0.010***	0.009***	0.006***	0.013***	0.011***	0.012***	0.013***	0.009	0.008***	0.016***	0.004**
	(0.000)	(0.004)	(0.001)	(0.000)	(0.003)	(0.004)	(0.000)	(0.000)	(0.001)	(0.000)	(0.120)	(0.000)	(0.003)	(0.011)
Internet. Mob	-0.0006***	-0.00005*	-0.00002	-0.00006**	-0.0001**	-0.00001	-0.0001***	-0.00001	-0.0001**	-0.00005***	-0.0002*	-0.00003**	-0.0001*	-0.00001
	(0.000)	(0.063)	(0.217)	(0.030)	(0.017)	(0.288)	(0.002)	(0.347)	(0.010)	(0.003)	(0.089)	(0.020)	(0.093)	(0.483)
Thresholds	-6.66	-20	na	-6.66	-20	-90	-10	na	-30	-4	-10	-33.33	-10	na
Net Effects	0.00150	0.00079	na	0.00015	0.00158	0.00085	0.00058	na	0.00258	-0.0000076	0.00116	0.00087	0.00058	na
LR Chi-Square	72.40***	91.02***	70.36***	177.19***	93.84***	165.48***	97.69***	127.39***	66.28***	207.92***	22.07***	248.54***	38.55***	218.99***
Log Likelihood	67.98	128.25	85.28	262.01	173.49	216.41	266.53	117.42	113.33	279.77	57.52	338.68	56.74	327.23
Observations	56	121	65	207	145	183	233	95	100	228	46	282	53	275

*, **, ***: significance levels of 10%, 5% and 1% respectively. STJA: Scientific and Technical Journal Articles. GDP: Gross Domestic Product. FDI: Foreign Direct Investment. na: thresholds and/or net effects cannot be computed because of insignificant marginal effects. UM Income: Upper Middle Income Countries. M. Income: Middle Income Countries. LM Income: Lower Middle Income Countries. L. Income: Low Income Countries. English: English Common Law Countries. French: French Civil Countries. Christian: Christian Dominated Countries. Islam: Islam Oriented Countries. Landlocked: Landlocked Countries. Not Landlocked: Not Landlocked Countries. Oil: Oil-exporting Countries. Non-Oil: Non-oil exporting Countries. Conflict: Conflict Affected Countries. Non Conflict: Non Conflict Affected Countries.

Robustness Check

To check the robustness of our results, the independent variables of interest are instrumented with their first lags in order to control for simultaneity which is a cause of endogeneity. The instrumented variables (or saved fitted values) are then used as the new independent variables of interest in the main equation. The instrumentation process is Heteroscedascity and Autocorrrelation Consistent (HAC) in standard errors. The results confirm our earlier findings in Tables 4 & 5. The results are reported in Tables 6 and 7 in the appendix A

4.4 Policy implications

In this section, we discuss the policy implications of our results. First, the positive effect of mobile phone penetration is broadly consistent with all our analysis thereby providing an unequivocal support for the view that mobile phones improve inclusive human development in SSA countries. The results appear unsurprising and confirm the point that access to mobile phones reduces transaction costs associated with the markets (i.e. savings in time and travel) and help expand market boundaries as pointed out by Aker and Mbiti (2010). Indeed, mobile phones are at the forefront of many innovative activities occurring in SSA. These activities include: promotion of inclusive finance such as M-pesa in Kenya and other African countries (Kirui et al., 2013; Singh, 2012); empowerment of women (Maurer, 2008; Ojo et al., 2012); consolidation of health services (Kliner et al., 2013); household management efficiency (Al Surikhi, 2012); bridging of the rural-urban (Chan & Jia, 2011; Qiang et al., 2011); enhancement of household opportunities for business (Mishra & Bisht, 2013; Ondiege, 2010) and elimination of wastes in agriculture as well as supply- and demand-side obstacles (Aker and Fafchamps, 2010; Muto and Yamano, 2009). From a regional-specific perspective, the findings that mobile phones influence inclusive development imply that African governments should put mobile phones at the heart of policy making in respect of issues such as alleviation of poverty, women

empowerment and bridging the gap between the rural poor and urban rich. We strenuously argue that, access to mobile phones remains an important instrument for pro-poor growth and inclusive human development in SSA. With the knowledge that about 45% of nations within the sub-region have not achieved the MDG extreme poverty target, the mobile telephony can be very instrumental in the post-2015 SDGs agenda if steps such as institutional support and government intervention are taken to ensure cheaper acquisition and access to mobile phones by the rural poor. More specifically, to increase access to mobile phones and internet, SSA governments should establish mobile phone kiosks and information centres equipped with mobile phones and computer network facilities to enable access through group sharing at a low cost. Moreover, SSA governments should also support and incentivise African businesses through tax holidays for firms that come out with innovative products and services to enhance existing inclusive benefits.

Second, we find low quality education to be negatively related to inclusive human development which is consistent with the extant literature that human capital, particularly, education plays a central role in knowledge creation and diffusion and are pivotal to inclusive human development (Dunlap-Hinkler et al., 2010; Dakhi and de Clereq, 2007). This suggests that individual-specific human capital, particularly, individual level of education is important to incremental innovation such as extensions, variations or complements to an existing product line (Dunlap-Hinkler et al., 2010), country's growth and inclusive human development. The implication here is that, to reverse the negative impact of poor quality of education on human development, SSA governments should allocate a large proportion of their budgets to improve education infrastructure at all levels of education. The investment in education would not only improve productivity of factors of production but help SSA countries to escape from the poverty trap and improve inclusive human development. The result that the interaction between education and mobile phones has a net positive effect on human development supports the

contention that education is a key developmental input, and can remove one of the barriers to the diffusion of knowledge and expand capabilities.

Last, although ICT usage is lowest in SSA but the growth rate is highest in SSA countries (Spence, Smith and Rashid, 2011), and our results suggest that innovation and ICT (i.e. proxies for STJA and internet penetration) are significant in complementing mobile phones for inclusive development. The results imply that current inclusive benefits enjoyed by SSA countries can be enhanced with appropriate ICT and innovative policies. While the results of this study show that SSA countries highly value ICT for social, economic, and other benefits, lack of infrastructure and affordability constitute important barriers for access. We reiterate that policy makers should adopt a policy of universal access schemes through low pricing and non-profit activity and usage sharing scheme, provide basic infrastructure, liberalise regulation and increase ICT and research and development spending. At regional level, SSA governments should encourage African universities to do collaborative research in extending the uses of mobile phones and ICT for inclusive human and economic development.

5. Conclusion

A recent World Bank report has revealed that poverty has been decreasing in all regions of the world with the exception of sub-Saharan Africa (SSA) and more than 45% of countries in the sub-region are off-track from achieving the Millennium Development Goal (MDG) extreme poverty target (World Bank, 2015; Asongu & le Roux, 2019; Tchamyou, 2019b). In light of apparent challenges in the post-2015 development agenda on Sustainable Development Goals (SDGs), this study extends the existing literature by investigating the role of knowledge creation and diffusion in the inclusive benefits of mobile penetration in 49 SSA countries. This study is based on data for the period 2000-2012 using a Tobit regression and constitutes one of the first attempts to systematically investigate the role of mobile phone technology and its knowledge creation and diffusion on inclusive human development.

The study finds that mobile phone penetration in SSA is of pivotal importance to sustainable and inclusive human development. We also find that the net effects of the interactions between the mobile phone and knowledge diffusion variables are positive. The pupil-teacher ratio exerts a negative influence on the outcome variable which is favourable for inclusive human development because higher ratios denote lower education quality since more pupils are accommodated by fewer teachers.

To shed further light on our results, we decompose our dataset into fundamental characteristics of income levels, legal origins, religious dominations, 'openness to sea', political stability and resource wealth which the previous literature indicates may have some bearing on human development (Mlachila et al., 2017; Asongu, 2017a). The results confirm that mobile phones have inclusive human development benefits irrespective of the country's income category, legal origins, religious orientation and the state of the nation. Despite the significant contribution of the study, future study appears warranted. We suggest that future studies should focus on decomposing the human development indicator into component factor analysis in order to investigate if established linkages withstand further empirical scrutiny when the three underlying components are examined distinctly.

Table 6: Inclusive development and mobile phones (IV Tobit Regression)

	Dependent Variable: Inequality Adjusted Human Development (IHDI)								
	Education (Quality of education)			Innovation (STJA)			Internet		
Constant	0.483***	0.470***	0.469***	0.368***	0.349***	0.350***	0.382***	0.366***	0.376***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Mobile phones (Mob)IV	0.003***	0.002***	0.002***	0.003***	0.003***	0.002***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EducationIV	-0.001***	-0.001***	-0.001***	---	---	---	---	---	---
	(0.000)	(0.000)	(0.002)						
Innovation (STJA)IV	---	---	---	0.00008	0.00001	0.00004	---	---	---
				(0.188)	(0.800)	(0.330)			
InternetIV	---	---	---	---	---	---	0.003**	0.007***	0.009***
							(0.040)	(0.000)	(0.000)
EducationIV.MobIV	-0.00003 ***	-0.00003 ***	-0.00004 ****	---	---	---	---	---	---
	(0.001)	(0.000)	(0.000)						
STJAIV.MobIV	---	---	---	-0.000001*	-0.000001 **	-0.000002 ***	---	---	---
				(0.087)	(0.041)	(0.001)			
InternetIV.MobIV	---	---	---	---	---	---	0.00005	-0.00003**	-0.00004 ***
							(0.763)	(0.041)	(0.006)
GDP per capita	---	-0.0002	-0.001	---	0.003***	-0.0008	---	0.002***	0.0001
		(0.810)	(0.319)		(0.001)	(0.515)		(0.001)	(0.922)
Private Credit	---	0.001***	0.001***	---	0.001***	0.002***	---	0.0008***	0.001***
		(0.000)	(0.000)		(0.000)	(0.000)		(0.003)	(0.000)
Remittances	---	---	0.00009	---	---	0.0003	---	---	0.00004
			(0.837)			(0.535)			(0.923)
FDI	---	---	0.0003	---	---	0.0007	---	---	-0.0008
			(0.699)			(0.396)			(0.181)
Net Effects	0.0016	0.0006	0.0002	0.0029	0.0029	0.0018	na	0.0008	0.0008
LR Chi-Square	215.50***	235.13***	210.90***	140.89***	172.05***	185.55***	171.76***	212.33***	222.47***
Log Likelihood	345.009	335.678	289.415	297.166	307.462	294.855	369.749	376.562	353.328
Observations	287	270	233	314	300	247	392	367	301

*, **, ***: significance levels of 10%, 5% and 1% respectively. STJA: Scientific and Technical Journal Articles. GDP: Gross Domestic Product. FDI:
Foreign Direct Investment. na: thresholds and/or net effects cannot be computed because of insignificant marginal effects. IV: Instrumental Variable.

Table 7: Instrumental Variable Tobit Regressions

Dependent Variable: Inequality Adjusted Human Development (IHDI)

Panel A: Education (Quality of Education)

	Income Levels				Legal Origins		Religious Domination		Openness to Sea		Resource-Wealth		Conflict	
	UM. Income	M. Income	LM Income	L Income	English	French	Christian	Islam	Landlocked	Not Landlocked	Oil	Non-Oil	Conflict	Non Conflict
Constant	0.342***	0.529***	0.519***	0.436***	0.515***	0.353**	0.435***	0.668***	0.771***	0.415***	0.434***	0.492***	0.434***	0.439***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.046)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Mobile phones (Mob)(IV)	0.006**	0.001**	0.002***	0.003***	0.002**	0.003***	0.003***	0.001***	0.003***	0.003***	-0.001	0.002***	0.015**	0.002***
	(0.010)	(0.011)	(0.000)	(0.000)	(0.020)	(0.000)	(0.001)	(0.004)	(0.006)	(0.000)	(0.380)	(0.000)	(0.036)	(0.000)
Education(IV)	-0.001	-0.003***	-0.001	-0.0007	-0.002***	0.0005	-0.0006	-0.006***	-0.005***	-0.0001	0.001*	-0.002***	-0.0004	-0.001**
	(0.232)	(0.000)	(0.205)	(0.245)	(0.001)	(0.472)	(0.411)	(0.000)	(0.000)	(0.774)	(0.064)	(0.000)	(0.807)	(0.027)
Education(IV).Mob(IV)	-0.0001**	-0.00002	-0.00006***	-0.00006***	-0.00002	-0.00006***	-0.00006**	-0.00001	-0.00002	-0.00006***	0.00009*	-0.00004***	-0.0003**	-0.00004***
	(0.016)	(0.203)	(0.000)	(0.000)	(0.362)	(0.000)	(0.022)	(0.424)	(0.447)	(0.000)	(0.061)	(0.003)	(0.046)	(0.001)
Net Effects	0.0016	0.0001	-0.0006	0.0003	na	0.0003	0.0003	na	na	0.0003	0.0029	0.0002	0.0018	0.0002
LR Chi-Square	59.91***	93.51***	71.18***	136.29***	77.59***	152.81***	60.78***	135.24***	106.98***	172.46***	49.41***	214.97***	31.28***	198.33***
Log Likelihood	56.434	107.516	69.407	185.659	143.071	159.149	200.144	99.280	109.635	210.175	72.299	252.125	48.136	249.681
Observations	45	88	43	145	113	120	165	68	71	162	33	200	33	200

Panel B: Innovation (STJA)

	Income Levels				Legal Origins		Religious Domination		Openness to Sea		Resource-Wealth		Conflict	
	UM. Income	M. Income	LM Income	L Income	English	French	Christian	Islam	Landlocked	Not Landlocked	Oil	Non-Oil	Conflict	Non Conflict
Constant	0.241***	0.300***	0.398***	0.342***	0.369***	0.344***	0.351***	0.333***	0.380***	0.359***	0.487***	0.330***	0.389***	0.338***
	(0.000)	(0.000)	(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 phones (Mob)(IV)	0.003***	0.003***	0.003***	0.002***	0.003***	0.003***	0.003***	0.002***	0.005***	0.002***	0.003***	0.002***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Innovation (SJTA)(IV)	0.003***	0.001***	0.0009**	0.00002	0.0001	0.0002**	0.0004**	-0.00004	0.0003***	-0.00003	0.0004	0.00004	0.0002	0.0002***
	(0.000)	(0.001)	(0.013)	(0.597)	(0.147)	(0.025)	(0.044)	(0.328)	(0.004)	(0.511)	(0.248)	(0.345)	(0.270)	(0.004)
STJA(IV). Mob(IV)	-0.00001	-0.00003**	-0.00004***	-0.000001***	-0.000001**	-0.000009***	-0.000009	-0.000001**	-0.000006	-0.000001*	-0.00003**	-0.000002***	-0.000001	-0.000009***
	(0.604)	(0.012)	(0.002)	(0.002)	(0.014)	(0.000)	(0.391)	(0.014)	(0.147)	(0.079)	(0.033)	(0.000)	(0.132)	(0.002)
Net Effects	na	0.0002	-0.0006	0.0019	0.0019	0.0021	na	0.0019	na	0.0019	0.0002	0.0018	na	0.0021
LR Chi-Square	72.05***	78.34***	54.97***	139.07***	66.84***	126.20***	70.71***	115.76***	62.01***	151.60***	23.67***	201.69***	23.64***	175.72***
Log Likelihood	59.259	106.438	69.330	198.556	134.344	163.143	199.162	100.937	91.148	212.819	50.287	264.655	43.129	253.224
Observations	42	93	51	154	111	136	175	72	76	171	37	210	42	205

	Income Levels				Legal Origins		Religious Domination		Openness to Sea		Resource-Wealth		Conflict	
						Panel C: Internet								
	UM. Income	M. Income	LM Income	L Income	English	French	Christian	Islam	Landlocked	Not Landlocked	Oil	Non-Oil	Conflict	Non Conflict
Constant	0.277***	0.372***	0.427***	0.369***	0.359***	0.378***	0.365***	0.383***	0.378***	0.385***	0.440***	0.359***	0.366***	0.009***
	(0.000)	(0.000)	(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 phones (Mob)(IV)	0.005***	0.001***	0.0002	0.0004	0.002***	0.0008***	0.002***	-0.0008*	0.003***	0.0001	0.004***	0.001***	0.001**	0.0002***
	(0.000)	(0.004)	(0.710)	(0.156)	(0.000)	(0.009)	(0.000)	(0.086)	(0.000)	(0.551)	(0.002)	(0.000)	(0.037)	(0.000)
Internet(IV)	0.039***	0.013***	0.014***	0.009***	0.011***	0.007***	0.014***	0.013***	0.014***	0.015***	0.008	0.010***	0.019***	0.001***
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.198)	(0.000)	(0.008)	(0.000)
Internet(IV). Mob(IV)	-0.0006***	-0.00007**	-0.00005**	-0.00004	-0.0001**	-0.00002	-0.0001***	-0.00003**	-0.0002***	-0.00006***	-0.0003**	-0.00004***	-0.0001	0.00001
	(0.000)	(0.014)	(0.014)	(0.137)	(0.016)	(0.122)	(0.000)	(0.035)	(0.001)	(0.001)	(0.014)	(0.002)	(0.127)	(0.108)
Net Effects	0.0023	0.0006	na	na	0.0015	na	0.0015	-0.093	0.0021	na	0.0040	0.0008	na	na
LR Chi-Square	71.77***	80.55***	59.71***	172.90***	92.60***	150.47***	94.36***	128.42***	71.57***	198.39***	23.05***	242.67***	33.81***	207.04***
Log Likelihood	65.906	116.684	74.889	246.898	161.977	200.176	249.537	112.749	110.790	261.343	51.931	322.420	48.409	308.719
Observations	52	109	57	192	132	169	216	85	93	208	41	260	48	253

*, **, ***: significance levels of 10%, 5% and 1% respectively. STJA: Scientific and Technical Journal Articles. GDP: Gross Domestic Product. FDI: Foreign Direct Investment. na: thresholds and/or net effects cannot be computed because of insignificant marginal effects. IV: Instrumental Variable.

Compliance with Ethical Standards

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