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Abstract

A recent World Bank report reveals that poverty has been decreasing in all regions of the world with the exception of sub-Saharan Africa (SSA) as more than 45% of countries in the sub-region are off-track from achieving the Millennium Development Goal (MDG) extreme poverty target. This paper investigates the effects of mobile phone technology, knowledge creation and diffusion on inclusive human development in 49 SSA countries for the period 2000-2012 using Tobit model. The study finds that mobile phone penetration in SSA is pivotal to sustainable and inclusive human development irrespective of the country's level of income, legal origins, religious orientation and the state of the nation. However, the pupil-teacher ratio exerts a negative influence on inclusive human development. The net effects of interactions between the mobile phone and knowledge diffusion variables are positive.

JEL Classification: G20; I10; I32; O40; O55
Keywords: Mobile phones; inclusive human development; Africa

1. Introduction

Over the past three decades, there has been a significant shift in the widely held position by most economists that differences in development levels across countries are explained by the amount of accumulated capital per worker (Solow, 1956; Fagerberg and Srholec, 2008). Increasingly, a number of scholars have documented the importance of technology as a driving force for economic and human development under the so-called "new growth theory" (see Lucas, 1988; Romer, 1990; Aghion and Hewitt, 1992; Fagerberg and Srholec, 2008; Boor, Oliveira and Veloso, 2014). It is therefore, not surprising that systematic research evidence in the context of developed countries (where most innovations originate) have documented a positive relationship between technological innovation and economic/ human development (Kwan and Chiu, 2015). One assumption which underpins most of the past studies in developed countries is that no innovation occurs in developing countries (see Flam and Helpman, 1987; Grossman and Helpman, 1991; Coe et al., 1997). However, with increasing globalisation and integration of the world economy over the past 25 years, the notion that developing countries are only users of innovations has evaporated. Innovation which is defined as the implementation of a new and significantly improved product, process, or method in marketing, management, or external relation (OECD, 2010) leads to newly created product or service outside its site of origin (Dakhi and de Clercq, 2007). Defined in this way, recent studies such as Boor et al. (2014); Baldwin and Hippel (2011); Oliveira and Hippel (2011) have demonstrated that users in developing countries of global technologies such as mobile phones are important service innovators. A growing number of examples of service innovations in developing countries range from mobile banking and money services such as M-Pesa in Kenya to the hand-held electrocardiogram in India were developed outside the realm of industrialised countries (Keller, 2002; Acemoglu et al., 2006; Alexander, 2010; IMF, 2011; Fu et al., 2011; Govindarajan et al., 2012). Research evidence has demonstrated

that innovations[1] originating from developing countries are low-cost but the resulting services provided often add enormous value to a given technology (Boor et al., 2014) and constitutes an important means of growth for developing countries and organisations (Kwan and Chiu, 2015; Gupta et al., 2003).

While developing countries are increasingly engaged in innovative activities, we know relatively little regarding the effects of mobile phone technology and its interactions with the knowledge creation and diffusion variables on inclusive human development in developing countries. In this paper, we examine the role played by mobile telephony as a source of knowledge creation and diffusion for inclusive human development in SSA countries. Innovation output, which includes 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). It is therefore imperative that we investigate the relationship between mobile phone technology and the extent to which they affect human development. 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 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.

[1] Sometimes called frugal or grass-root innovation (Bound and Thornton, 2012; Gupta et al., 2003)

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 (Ondiege, 2010; Mishra and Bisht, 2013; Al Surikhi, 2012; Asongu, 2014a); elimination of wastes in 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, 2015d; Asongu, 2013a). In addition, Ureta (2008, p. 83) conveys that "mobile phones are used to overcome problems related to physical distance and mobility of people". Arguably, mobile phone technology as a basic necessity in Africa has introduced novel opportunities to the 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 (2015c) suggests that while high-end markets in Asia, Europe and North America are characterised with stabilization in the growth of mobile phones[2], 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 African context. We do so by employing Tobit model to test a sample of 49 SSA over the period 2000-2012.

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

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

to establish the positive correlation between mobile phones and development outcomes (see Asongu, 2013a, 2014a), this study extends the positive correlations to causality. This extension is important because sound policy implications 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 relationship that often arises 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 interaction 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.

The rest of the study is structured as follows. Section 2 reviews the literature relating to technology, economic growth and the role of mobile phone penetration and inclusive 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. Theoretical Background

2.1 Innovation and Growth

The link between innovation, knowledge and economic growth has long been acknowledged in economics and management literature. From the pioneering work of Marshall (1890) through to Kuznets (1971), these studies recognize directly and indirectly that knowledge changes economic activity and economic activity changes knowledge in constant rounds of change. Unlike the early neo-classical approach which views knowledge and technology as

completely exogenous to the system and a kind of public good, the new growth models are based on endogenous and neo-Schumpeterian interpretation of economic growth (Howells, 2005). The new growth models suggest that technological progress arises out of directed actions and investments by people through allocation of key resources linked to human capital (Romer, 1990; Temple, 1999). The new growth theory therefore recognizes the existence of intellectual property rights over new technologies. Technology is therefore considered as a private good and knowledge generation, yields rewards in the form of returns to the innovators (Temple, 1999; Solow, 1994). The private nature of technology in terms of patents and monopoly power has been supported in Nordhaus' (1969) model. However, other researchers disagree and point out that monopoly rents over technology are incomplete and temporary (Uzawa, 1965, Temple, 1999). Temple (1999) therefore asserts that innovation and technological advances are both exogenous and endogenous to the system. Romer (1990) supports this contention, and argues that technology has characteristics of becoming a public good over time. The author goes on to point out that innovation and technology may spillover to other countries and regions. The above perspective suggests that countries and regions are not equally placed to generate and benefit from technological innovations. Innovation therefore leads to a strong disequilibrium in the process of economic growth and human development, giving rise to the pervasive differentials in growth rates between countries and regions (Verspagen, 1997). Rosenberg (1972) therefore concluded that the rate at which new technologies are adopted and integrated into a productive process is one of the central issues of human development and economic growth. We briefly turn our attention to factors that influence growth and development (i.e. innovation output).

2.2 Innovation Outputs and Inclusive Development

Innovation outputs 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) is critical ingredient for innovation to occur. Rosenberg (1972) noted that human capital is essential prerequisite for the use and effective exploitation of innovative technology. 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). 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 output is knowledge diffusion and creation (Kwan and Chiu, 2015). 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 output. 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)[3]. 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. Feder and Savastano (2005) 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).

2.3 Mobile phones penetration and Inclusive Human Development

Prior literature has given a notable attention on the impact of mobile phones on economic and human well-being in recent years (see Donner, 2008; Sen, 2010; Smith and Seward, 2009; Ureta, 2008; Kwan and Chiu, 2015). This section briefly reviews the impact of mobile phones on 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). Researchers 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). Brown et al. (2001); Katz (2003); Ling and Pedersen (2005); Aker and Mbiti (2010) show 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.

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

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; Benkler, 2006). 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 (2014a) 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. Apart from the benefits derived from multi-tasking, education and cost reduction (Jonathan & Camilo, 2008; Ondiege, 2010, 2013; Al Surikhi, 2012; Asongu, 2015d), 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 and more efficient management of clinical appointments (Bauer et al., 2010; Hoffman et al., 2010; De Costa et al., 2010). In accordance with Kliner et al. (2013), rural communities are those that are most benefiting from the development externalities of health-tailored mobile phone applications.

Another strand of literature 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); Rangaswamy and Nair (2010) suggest 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. In India for example, Singh (2012) has shown that mobile phones are increasing financial inclusion in rural areas.

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. The dependent variable is measured with the inequality adjusted human development index (IHDI), in accordance with recent African inclusive development literature (Asongu et al., 2015; Asongu and Nwachukwu, 2016abc). 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 recent African (KE) knowledge economy (Tchamyou, 2015) and mobile phone (Asongu, 2015c) literatures, 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 (KEI) 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 (2015). 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; Anand et al., 2012; Seneviratne & Sun, 2013; Mlachila et al., 2014). According to Mlachila et al. (2014) and Ssozi and Asongu (2015), remittances are expected to increase inclusive human development because they are used for consumption purposes for the most part. Mlachila et al. (2014) 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

(Insert Table 1)

3.2 Methodology

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. 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). 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.

(Insert Table 2 here please)

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).

(Insert Table 3 here please)

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 appears surprising and contrary to 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. Perhaps, the findings may be explained by the high pupil-teacher ratio leading to low literacy rate in sub-Saharan African countries.

As an additional analysis, we further include interactions of mobile phone and education, innovation and internet variables as independent variables in our models. These interactions allow us to capture the marginal effects of education, innovation and internet on human development conditional on the level of mobile phone penetration. In line with the recommendation by Brambor et al. (2006) on the importance of interpreting marginal effects for interaction models, we compute the marginal effects of these interactions. We find the net effect of the interaction term to be positive and significant suggesting that education and mobile phones play important role in innovation and consequently inclusive human development. For example, Dunlop-Hinkler et al. (2010); Boor et al. (2014) note that individual-specific human capital, particularly, levels of education are important for incremental innovation such as extensions and variations to an existing service or product line. We therefore conclude that the interaction of mobile phones and the level of education and innovation improve inclusive human development. It is important to point out that, our results are robust after controlling for GDP, private credit, remittances and foreign direct investment which have been identified as factors affecting human development (Mishra et al., 2011; Anand et al., 2012; Seneviratne and Sun, 2013; Mlachila et al., 2014; and Ssozi and Asongu, 2015).

(Insert Table 4 here please)

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	-0.001
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.

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., 2014; Asongu, 2015a). Mlachila et al. (2014, p. 13) 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, 2015bc).

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[4]. 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

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

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 (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. Third, 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. Landlocked and Islamic countries 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. (2014) 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, 2015c).

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 with 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*** **
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*** **
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** **
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*** **
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*** **
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** **
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
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

Panel C: Internet

	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	**0.289*** **	**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 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.

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 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 education to be negatively related to inclusive human development contrary to 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). The findings may be due to the high pupil-teacher ratio in primary education in almost all the SSA countries. 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. 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. However, pupil-teacher ratio has a negative effect on inclusive human development. 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., 2014; Asongu, 2015a). 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 1: Definitions and sources of variables

Variables		**Measurement**	**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	Remittances 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.

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: 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.

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