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Basic Formal Education Quality, Information Technology and Inclusive Human Development in Sub-Saharan Africa[1]

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Abstract

This study assesses the relevance of basic formal education in information technology for inclusive human development in 49 countries in sub-Saharan Africa for the period 2000-2012. The question it aims to answer is the following: what is the relevance of basic formal education in the effect of mobile phone penetration on inclusive human development in sub-Saharan Africa when initial levels of inclusive human development are taken into account? The empirical evidence is based on instrumental quantile regressions. Poor primary education dampens the positive effect of mobile phone penetration on inclusive human development. This main finding should be understood in the perspective that, the education quality indicator represents a policy syndrome because of the way it is computed, notably: the ratio of pupils to teachers. Hence, an increasing ratio indicates decreasing quality of education. It follows that decreasing quality of education dampens the positive effect of mobile phone on inclusive development. This tendency is consistent throughout the conditional distribution of inclusive human development. Policy implications for sustainable development are discussed.

JEL Classification: G20; I10; I32; O40; O55
Keywords: Quality education; Mobile phones; Inclusive human development; Sustainable Development; Africa

1. Introduction

During the past two decades, the liberalization of the information and communication technology (ICT) sector in Africa has been followed by a plethora of positive development externalities (Bongomin, Ntayi, Munene & Malinga, 2018; Gosavi, 2018; Murphy & Carmody, 2015; Asongu, le Roux, Nwachukwu & Pyke, 2019). One of the development outcomes has been inclusive development partly because associated benefits from mobile banking offer opportunities that are more rewarding to the poor factions of the population (Asongu & Asongu, 2018). Moreover, beyond the perspective that ICT offers opportunities to underserved segments of the population, it reduces informational rents previously enjoyed by rich and privileged factions of the population at the expense of poorer elements of society (Tchamyou & Asongu, 2017; Asongu, Batuo, Nwachukwu & Tchamyou, 2018; Efobi, Tanankem & Asongu, 2018; Uduji & Okolo-Obasi, 2018).

Three main tendencies from scholarly and policy circles motivate the positioning of this study on the assessment of linkages between information technology, education quality and inclusive human development. First, the recent economic development in sub-Saharan Africa (SSA) has been characterized by exclusive growth (Kuada, 2015; Asongu & Kodila-Tedika, 2017). This is essentially because since the mid 1990s, the number of people living in extreme poverty in the sub-region has been consistently rising (Tchamyou, 2018a; Asongu & le Roux, 2018). This is surprising, in spite of more than two decades of growth resurgence in the sub-region (Tchamyou, 2018b). According to the narrative, close to half of countries in the sub-region did not achieve the extreme poverty target of the Millennium Development Goals (MDGs). Moreover, in the light of the relevance of inclusive development in the sustainable development goals (SDGs) agenda, addressing the policy syndrome of exclusive development is relevant for the achievement of inequality-related SDGs[2].

Second, the literature is consistent on the position that the potential for ICT penetration in SSA is high compared to other regions of the globe experiencing saturation levels (Tchamyou, Erreygers, & Cassimon, 2018; Penard, Poussing, Yebe & Ella., 2012). This has led to a growing stream of literature on the relevance of mobile technologies in

[2] In line with recent literature (Asongu, le Roux & Biekpe, 2017), in this study, the conception, definition and measurement of 'inequality adjusted human development' employed as the outcome indicator is in line with at least six of the seventeen SDGs, namely: Goal 1('end poverty in all its forms everywhere'), Goal 2 ('end hunger, achieve food security and improved nutrition and promote sustainable agriculture'); Goal 3 ('ensure healthy lives and promote well-being for all ages'); Goal 4 ('ensure inclusive and equitable quality education and promote lifelong learning opportunities for all'); Goal 8 ('promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all') and Goal 10 (reduce inequality within and among countries). The interested reader can refer to Michel (2016) for a full list of SDGs.

development outcomes (Asongu, 2013; Tchamyou, 2017; Abor, Amidu, & Issahaku, 2018; Afutu-Kotey, Gough & Owusu, 2017; Hubani & Wiese, 2018; Asongu & Boateng, 2018; Muthinja & Chipeta, 2018). Unfortunately, the extant literature has failed to assess if poor education quality can decrease the relevance of information technology on inclusive development. The importance of quality education is consistent with challenges of knowledge economy in development in the 21st century. Accordingly, as evident from recent literature, contemporary development is contingent on how nations have made the transition from product-based economies to knowledge-based economies (Asongu, 2018a; Tchamyou, 2017).

Third, in the light of the engaged literature, the study closest to the present inquiry is Asongu and Nwachukwu (2018) which has assessed education quality thresholds in the diffusion of knowledge with mobile phones for inclusive human development in sub-Saharan Africa. Using simultaneity-robust fixed effects regressions, the study concludes that between 10 to 27 pupils per teacher in primary education are required for inclusive human development to increase as a result of mobile phone penetration. Moreover, from a comparative standpoint, the findings are decomposed to articulate the relevance of income levels, legal origins, political stability, resource-wealth, religious-domination and openness to sea.

The positioning of this study departs from Asongu and Nwachukwu (2018) on two fronts. (i) In terms of problem statement, it assesses how poor education quality can dampen the established positive effect of mobile phones on inclusive human development (Issahaku, Abu & Nkegbe, 2018; Minkoua Nzie, Bidogeza & Ngum, 2017; Asongu & le Roux, 2017; Tony, & Kwan, 2015). (ii) From a methodological front, the study employs simultaneity-robust quantile regressions instead of fixed effects regressions. The importance of quantile regressions is motivated by the fact that the investigated linkages are assessed throughout the conditional distribution of inclusive human development. The policy interest of such a conditional assessment is motivated by the fact that the investigated effects may be contingent on initial levels of inclusive human development such that the impacts vary across countries with low, intermediate and high levels of inclusive human development. Hence, with the quantile regression approach, estimating parameters at multiple points of the conditional distribution of inclusive human development is relevant for policy makers because blanket policy implications based on mean effects may be ineffective unless they are contingent on initial levels of inclusive human development and tailored differently across countries with low, intermediate and high initial levels of inclusive human development. In the light of the

above, the research question this study aims to answer is the following: what is the relevance of basic formal education in the effect of mobile phone penetration on inclusive human development in sub-Saharan Africa when initial levels of inclusive human development are taken into account?

The positioning of the study departs from recent sustainable development literaure which has largely focused on environmental sustianability, notably: nexuses between conflicts, economic developemnt and environmental sustainability (Fisher & Rucki, 2017); the importance of normative beliefs in environmental attitudes (Wang & Lin, 2017); comparative literature on the sustainability of the environment (Asongu, 2018b) and planning for enhanced sustainable development (Saifulina & Carballo-Penela, 2017). It is also relevant emphasize that the concept of inclusive human development used in this research is consistent with sustainable development in the perspective that, for inclusive development to be sustainable, it is supposed to be sustained while for sustained development to be sustainable, it should be inclusive (Amavilah, Asongu & Andrés, 2017; Asongu & Odhiambo, 2018a).

The rest of the study is structured as follows. Section 2 discusses theoretical underpinnings while the data and methodology are covered in section 3. The empirical results are disclosed and discussed in section 4 whereas section 5 concludes with implications and future research directions.

2. Intuition and theoretical underpinnings

According to neoclassical models of economic development, both knowledge and technology are important in the provision of public commodities needed for economic development. On the other hand, new economic development models are founded on two perspectives of economic development, namely, the: endogenous view and neo-Schumpeterian perspective (Howells, 2005). With regard to the new models of economic prosperity, technological improvement is the result of engagements by citizens through considerable mobilisation of relevant resources related to human capital (Romer, 1990).

A fundamental component of innovation is the ability of individuals and corporations to leverage on existing ICT to boost economic and human developments. Coleman (1998) posits that a critical factor in the diffusion of knowledge for economic development is human capital. Within the framework of this study, the mobile phone is a knowledge diffusion variable whereas quality of education represents human capital. According to the Coleman (1998), human capital can be understood as a person's ability, knowledge, skills and expertise

which contribute towards economic development. In accordance with Rosenberg (1972), human capital is fundamental in the adoption and usage of technology. Therefore members of a society can be continuously trained on how to adapt to new technological channels (Dakhi & de Clereq, 2007; Kwan & Chiu, 2015; Asongu & Tchamyou, 2017; Chavula, 2010; Anyanwu, 2012). The duration of training depends on a number of factors, notably: on how complex the new technology is as well as the education status of the person adopting the technology (Asongu & Nwachukwu, 2018). Within the specific context of SSA in which a low literacy rate is apparent, quality education is important in the understanding of how information technology affects development outcomes.

In the light of the above, mobile phones are adopted by users because of, *inter alia*, two main reasons. On the one hand, the adopting user has the required education and knowledge essential for the use of the underlying technology. On the other hand, the user adopting the technology expects human development advantages which may be related to per capita income, health advantages and education. These three advantages are constituents of the human development index used in the study as the outcome variable. Moreover, an individual may also adopt the mobile phone because he/she is educated on its perceived level of reducing inequality or increasing the social income status of the individual if he/she is in the low income strata. The two underlying motivations surrounding the adoption of mobile phones are consistent with the technology acceptance models, which are expanded below.

Consistent with recent information technology literature (Yousafzai, Foxall & Pallister, 2010; Nikiforova, 2013; Lee & Lowry, 2015; Cusick, 2014; Asongu, Nwachukwu & Aziz, 2018), three principal theories can be used to theoretically justify the motivation for the choice of a mobile technology by an individual with some basic threshold of education, namely: the theory of reasoned action (TRA), theory of planned behavior (TPB) and technology acceptance model (TAM). With regard to the TRA, individuals are inherently rational in the acknowledgement of actions they take (Fishbein & Ajzen, 1975; Bagozzi, 1982; Ajzen & Fishbein, 1980). It is important to note that the TPB extends the TRA. According to Ajzen (1991), the TPB puts emphasis on the unavailability of differences between individuals who manifest conscious influence related to their actions and individuals who do not manifest such influence. With respect to the TAM, the hypothesis underlying the individual's desire to adopt a particular mode of technology can be explained by the voluntary decision of the individual to accept a given technology (Davis, 1989). In accordance with the underpinning literature, a striking denominator pertaining to the three theories is twofold,

notably: the individual's belief formation and (ii) composite elements such as psychological, personal, utilitarian and behavioral characteristics.

The highlighted characteristics (i.e. from the three attendant theories) of individuals (i.e. with a certain level of education) who are adopting a mobile phone can be contextualized in the following perspectives. (i) With regard to the utilitarian dimension, an individual adopts a mobile phone because he/she has been educated on the usefulness of such a mobile telephony device in the improvement of his/her living standard and wellbeing. (ii) From the behavioral angle, some individuals can also adopt the mobile phone because they have been educated that many people are adopting the mobile technology to improve their wellbeing. Hence, even without a direct motivation, an individual can adopt the mobile phone because he/she wants to remain part of the social norm. (iii) Psychological and personal motivations are also relevant in the decision to adopt a mobile technology if an individual, through education has more information (that is not driven by common societal tendencies) on the potential gains of the technology. (iv) The importance of an individual's belief formation is founded on the fact that through basic education, it is generally an accepted norm in society that the adoption of a mobile phone increases human wellbeing.

In the light of the above, the decision by an individual to adopt a mobile phone may build on both idiosyncratic and systemic motivations on the potential advantages of such an adoption in the enhancement of human development. The quest to know how the quality of education affects the relationship between mobile phone and the human development outcome is part of the motivation of this study.

3. Data and methodology

3.1 Data

The study is based on a panel of 49 African countries with data for the period 2000-2012 from a multitude of sources, namely: (i) the United Nations Development Program (UNDP) and African Development Indicators (ADI) of the World Bank. The adopted periodicity and sampled countries are based on data availability constraints at the time of the study. Accordingly, of the 54 existing African countries, 49 are in Sub-Saharan Africa and 5 are in North Africa, namely: Egypt, Tunisia, Libya, Morocco and Algeria. In accordance with recent exclusive development literature on Africa and the motivation of the study, the dependent variable is the inequality adjusted human development index (IHDI) from the UNDP (Asongu, Efobi & Beecroft, 2015). The human development index (HDI) denotes a

national average of achievements in three categories, namely: (i) knowledge; (ii) decent standards of living and (iii) long life and health. Conversely, the IHDI extends the HDI by controlling for inequality in the distribution of achievements in the three categories. Consistent with recent information technology (Asongu & Nwachukwu, 2016a) and knowledge economy (Tchamyou, 2017) literature, the mobile phone is proxied by the mobile phone penetration rate (per 100 people).

The quality of education is measured with the "pupil-teacher ratio" in primary education (Asongu & Nwachukwu, 2016b). It is important to note that education quality is computed as a policy syndrome, such that, increasing levels represent decreasing education quality. This is essentially because an increasing number of "pupils per teacher" reflects a diminishing ability of teachers to allocate more time for imparting knowledge to their pupils.

Three main factors motivate the choice of this indicator. (i) There are limited degrees of freedom in quality of education indicators at the secondary and tertiary levels of schooling. (ii) In accordance with the literature, primary education has greater socio-economic benefits, compared to higher levels of education when countries are at an initial stage of industrialisation (Asiedu, 2014). This is the case with the sampled countries in SSA. It is argued in the narrative that primary education generates more social returns. (iii) The basic knowledge required for the use of the mobile phone can be hypothetically acquired exclusively in the primary school.

Borrowing from recent inclusive human development literature, four main control variables are adopted in the study, namely: remittances, foreign direct investment (FDI), private domestic credit and GDP per capita (Mlachila, Tapsoba & Tapsoba 2017; Seneviratne & Sun, 2013; Anand, Mishra & Spatafora, 2012; Mishra, Gable & Anand, 2011; Asongu & Nwachukwu, 2016c; Meniago & Asongu, 2018). With the exception of FDI which is expected to have a negative effect of the outcome variable, the other variables in the conditioning information set are positively associated with inequality adjusted human development. This is essentially because FDI in most African countries is resource-driven and from the motivation of the study, over the past two decades, the resource-driven economic prosperity has not been equitably distributed across the population. Credit access has been recently established to improve inclusive human development in Africa (Tchamyou, 2018b; Tchamyou et al., 2018). GDP per capita is an inherent component in the composition of the outcome variable, hence, the expected positive nexus. Remittances are largely used in Africa for consumption-related expenses (see Ssozi & Asongu, 2016). The consumption-related expenses are naturally

consistent with components of the human development outcome variable employed in this study. It is also worthwhile to articulate that the effects of various indicators may vary throughout the conditional distribution of the outcome variable. For instance the relevance of remittances may be less in countries at the top quantile of human development because of less migration from wealthier countries.

The definition of variables and corresponding sources are provided in Appendix 1, the summary statistics is disclosed in Appendix 2, while the correlation matrix is presented in Appendix 3.

3.2 Methodology

Consistent with recent literature on the conditional determinants of outcome variables, a quantile regression estimation strategy is adopted (Ajide & Osode, 2017; Alia, Diagne, Adegbola & Kinkingninhoun, 2017; Tchamyou & Asongu, 2018; Aosngu & Odhiambo, 2017, 2018b). Hence, in order to investigate how initial levels of human development play-out when education quality modulates the effect of mobile phone penetration on inclusive human development, we use quantile regressions (QR). QR assesses the determinants of inclusive human development throughout the conditional distributions of inclusive human development (Keonker & Hallock, 2001). It is important to articulate that this estimation technique departs from previous studies within the same framework. Accordingly, prior exposition (addressing different problem statements from the one being addressed in this study) on the diffusion of knowledge through ICT, has reported estimated parameters at the conditional mean of inclusive human development, notably by using fixed effects regressions (Asongu & Nwachukwu, 2018).

Whereas mean impacts coud be relevant, it is also important to assess relationships with QR in order to distinguish countries on the basis of initial levels in the outcome variable: countries with low, intermediate and high initial levels of inclusive human development. Hence, with this estimation approach, emphasis is placed on worst-, intermediate- and best-performing countries in terms of inclusive human development.

Consistent with Asongu and Nwachukwu (2018), the concern about endogeneity (i.e. simultaneity) is addressed by adopting an instrumental variable estimation approach.

The procedure of instrumentation for education quality and mobile phone penetration are respectively in Eq (1) and Eq (2) below.

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

where $Edu_{i,t}$, denotes the educational indicator of country i at period t, α is a constant, $Edu_{i,t-1}$, represents the educational indicator of country i at period $t-1$, η_i is the country-specific effect, and $\varepsilon_{i,t}$ the error term.

$$Mob_{i,t} = \alpha + \delta_j \left(Mob_{i,t-1}\right) + \eta_i + \varepsilon_{i,t}, \qquad (2)$$

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

It important to note that, the instrumentation process in Eq. (1) consists of regressing education quality on its first lag and country-specific effects. The corresponding fitted values are saved and then used as the independent variable of interest in Eq. (3). The specifications are Heteroscedasticity and Autocorrelation Consistent (HAC) in standard errors.

The θth quantile estimator of inclusive human development is obtained by solving for the following optimization problem, which is presented without subscripts in Eq. (3) for the purpose of simplicity and ease of presentation.

$$\min_{\beta \in R^k} \left[\sum_{i \in \{i: y_i \geq x_{i'}\beta\}} \theta \left| y_i - x_{i'}\beta \right| + \sum_{i \in \{i: y_i < x_{i'}\beta\}} (1-\theta) \left| y_i - x_{i'}\beta \right| \right], \qquad (3)$$

where $\theta \in (0,1)$. Contrary to ordinary least squares (OLS) which is based on the minimization of the sum of squared residuals, with QR, the weighted sum of absolute deviations are minimised. For example the 10th and 90th quantiles (with θ=0.10 or 0.90 respectively) is estimated by weighing the residuals approximately. The conditional quantile of inclusive human development or y_i given x_i is:

$$Q_y(\theta / x_i) = x_{i'}\beta_\theta \qquad (4)$$

where unique slope parameters are modelled for each θth specific quantile. This formulation is analogous to $E(y / x) = x_{i'}\beta$ in the OLS slope where parameters are examined only at the mean of the conditional distribution of inclusive human development. For the model in Eq. (4) the dependent variable y_i is the inequality adjusted human development index while x_i contains a *constant term, education quality, mobile phone penetration, the interaction*

between education quality and mobile phone penetration, *foreign direct investment, private domestic credit, GDP per capita* and *remittances.*

It is important to note that in the specification, primary education is assumed to be a basic condition for mobile phone literacy. Hence, the effectiveness of the relevance of mobile phone penetration in affecting inclusive human development is contingent on the quality of primary education. This therefore provides the basis for an interactive specification which is designed to assess how the quality of primary education modulates the effect of mobile phone penetration on the outcome variable.

4. Empirical results

The empirical results are presented in this section. While Panel A of Table 1 discloses findings not based on instrumental variables, Panel B shows simultaneity-robust instrumental QR. In order to assess the role of education quality in modulating the effect of mobile phone penetration on inclusive human development, net effects are computed. The net effects are then compared with the corresponding unconditional effect of mobile phone on inclusive human development. If the computed net effect is lower in terms of magnitude compared to the corresponding unconditional effect of mobile phone penetration, we conclude that the policy syndrome or poor education quality dampens the effect of mobile phone penetration on inclusive human development.

It is relevant to substantiate the narrative above with an example from Table 1. Taking the first column of Panel A of the table as an example, the net effect is 0.0002([-0.00004 × 43.601] + [0.002]). Accordingly, 0.002 is the unconditional effect of mobile phone penetration on inclusive human development, -0.00004 is the corresponding conditional effect from the interaction between mobile phone penetration and the indicator for primary education quality, while 43.601 is the mean value of education quality as apparent in the summary statistics (see Appendix 2).

Two more points are worth emphasising. On the one hand, difference between OLS estimates (in the second column of panels) and quantile estimates (in the other column of panels) partly justify the need for the quantile regression approach. This is essentially because OLS produce results with blanket policies since the estimates are at the conditional mean of the inclusive human development distribution. On the other hand, inclusive human development increases from the left hand side to the right hand side of both panels (i.e. from Q.10 to Q.90).

Table 1: Mobile phone penetration, education quality and inclusive development

Panel A: Baseline regressions

	OLS	Q.10	Q.20	Q.30	Q.40	Q.50	Q.60	Q.70	Q.80	Q.90
Constant	**0.466*** (0.000)**	**0.273*** (0.000)**	**0.373*** (0.000)**	**0.482*** (0.000)**	**0.486*** (0.000)**	**0.472*** (0.000)**	**0.466*** (0.000)**	**0.453*** (0.000)**	**0.494*** (0.000)**	**0.521*** (0.000)**
Mobile phones (Mob)	**0.002*** (0.000)**	**0.003*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**	**0.003*** (0.000)**	**0.002*** (0.000)**	**0.003*** (0.000)**	**0.002*** (0.000)**	**0.002** (0.010)**
Education	**-0.001*** (0.003)**	0.00007 (0.869)	**-0.001*** (0.005)**	**-0.002*** (0.000)**	**-0.002*** (0.000)**	**-0.001*** (0.002)**	**-0.001*** (0.005)**	-0.0006 (0.275)	-0.001 (0.143)	-0.001 (0.268)
Education.Mob	**-0.00004*** (0.000)**	**-0.00003*** (0.002)**	**-0.00003*** (0.005)**	**-0.00004*** (0.009)**	**-0.00004*** (0.000)**	**-0.00006*** (0.000)**	**-0.00005*** (0.000)**	**-0.00006*** (0.000)**	**-0.00004*** (0.001)**	**-0.00004* (0.068)**
GDP per capita growth	0.0003 (0.719)	**0.003*** (0.003)**	0.002 (0.120)	-0.0008 (0.598)	0.0004 (0.600)	0.0001 (0.912)	0.0001 (0.826)	0.0002 (0.865)	0.0002 (0.891)	0.0002 (0.906)
Private Credit	**0.001*** (0.002)**	**0.001** (0.024)**	**0.001** (0.028)**	**0.001*** (0.004)**	**0.001*** (0.000)**	**0.001*** (0.000)**	**0.001*** (0.000)**	**0.001*** (0.000)**	**0.002*** (0.000)**	**0.003*** (0.000)**
Remittances	0.00004 (0.877)	**0.002*** 0.001*** (0.000)**		0.0008 (0.128)	0.0004 (0.194)	0.0002 (0.610)	0.00007 (0.841)	-0.00003 (0.951)	-0.0003 (0.697)	-0.001 (0.381)
FDI	**-0.001* (0.083)**	**-0.001** (0.011)**	**-0.002*** (0.002)**	**-0.001** (0.036)**	**-0.001*** (0.000)**	**-0.001*** (0.000)**	**-0.001*** (0.003)**	**-0.001** (0.030)**	**-0.002*** (0.005)**	**-0.003*** (0.000)**
Net effect of mobile	0.0002	0.0016	0.0007	0.0002	0.0002	0.0004	0.0002	0.0004	0.0002	0.0002
Adjusted R^2	0.544									
Fisher	**62.37*** **									
Pseudo R^2		0.302	0.257	0.254	0.268	0.281	0.307	0.345	0.402	0.476
Observations	278	278	278	278	278	278	278	278	278	278

Panel B: Extensions with Instrumental Quantile regressions

	OLS	Q.10	Q.20	Q.30	Q.40	Q.50	Q.60	Q.70	Q.80	Q.90
Constant	**0.470*** (0.000)**	**0.247*** (0.000)**	**0.433*** (0.000)**	**0.496*** (0.000)**	**0.482*** (0.000)**	**0.477*** (0.000)**	**0.463*** (0.000)**	**0.471*** (0.000)**	**0.502*** (0.000)**	**0.534*** (0.000)**
Mobile phones (IVMob)	**0.002*** (0.000)**	**0.003*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**	**0.003*** (0.000)**	**0.003*** (0.000)**	**0.003*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**
Education(IV)	**-0.001*** (0.003)**	**0.0007* (0.082)**	**-0.002*** (0.000)**	**-0.002*** (0.000)**	**-0.001*** (0.000)**	**-0.001*** (0.000)**	**-0.0008* (0.052)**	-0.0005 (0.353)	-0.001 (0.161)	-0.001 (0.282)
Education(IV).IVMob	**-0.00004*** (0.000)**	-0.00003 (0.024)	**-0.00002* (0.066)**	**-0.00004*** (0.004)**	**-0.00004*** (0.000)**	**-0.00004*** (0.000)**	**-0.00007*** (0.000)**	**-0.00006*** (0.000)**	**-0.00004*** (0.002)**	**-0.00006*** (0.006)**
GDP per capita growth	-0.001 (0.395)	0.001 (0.390)	0.0002 (0.907)	0.002 (0.146)	**-0.002* (0.075)**	-0.001 (0.439)	-0.0008 (0.517)	-0.0004 (0.770)	-0.001 (0.317)	-0.001 (0.690)
Private Credit	**0.001*** (0.001)**	**0.0007*** (0.000)**	**0.001*** (0.004)**	**0.001*** (0.002)**	**0.001*** (0.000)**	**0.001*** (0.005)**	**0.001*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**	**0.002*** (0.000)**
Remittances	0.00009 (0.715)	**0.002*** (0.000)**	**0.001** (0.013)**	0.0008 (0.103)	0.0005 (0.125)	0.0002 (0.501)	0.00005 (0.889)	-0.0001 (0.833)	-0.0004 (0.592)	-0.0009 (0.439)
FDI	0.0003 (0.749)	-0.0005 (0.664)	0.001 (0.434)	0.00004 (0.972)	-0.0003 (0.719)	-0.001 (0.201)	-0.0007 (0.372)	0.0001 (0.890)	-0.0004 (0.749)	**0.002* (0.070)**
Net effect of mobile	0.0002	na	0.0011	0.0002	0.0002	0.0002	0.0001	0.0004	0.0002	0.0004
Adjusted R^2	0.595									
Fisher	**53.82*** **									
Pseudo R^2		0.296	0.274	0.285	0.290	0.304	0.338	0.381	0.451	0.538
Observations	233	233	233	233	233	233	233	233	233	233

*, **, ***: significance levels of 10%, 5% and 1% respectively. OLS: Ordinary Least Squares. R^2 for OLS and Pseudo R^2 for quantile regression. Lower quantiles (e.g., Q 0.1) signify nations where Inclusive Human Development is least. The mean value of education is 43.601 whereas the instrumented education is 43.673. IVMob is instrumented mobile banking while Education(IV) is instrumented education quality.

From the findings in Table 1, it is apparent that education consistently decreases the positive relevance of mobile phone penetration on inclusive human development. This main finding should be understood in the perspective that the education quality indicator represents a policy syndrome because of the way it is computed, notably: the ratio of pupils to teachers. Hence, an increasing ratio indicates decreasing quality of education. It follows that decreasing quality of education dampens the positive effect of mobile phone on inclusive development. This tendency is consistent throughout the conditional distribution of inclusive human development. The findings in Panel B which are based on an instrumental variable estimation approach are consistent with those of Panel A. The significant control variables display the expected signs.

5. Concluding implications and future research directions

This study has assessed the relevance of basic formal education in the effect of mobile phone penetration on inclusive human development in 49 countries in sub-Saharan Africa for the period 2000-2012. The empirical evidence is based on instrumental quantile regressions. Poor primary education quality dampens the positive effect of mobile phone penetration on inclusive human development. This main finding should be understood in the perspective that the education quality indicator represents in policy syndrome because of the way it is computed, notably: the ratio of pupils to teachers. Hence, an increasing ratio indicates decreasing quality of education. It follows that decreasing quality of education dampens the positive effect of mobile phone on inclusive development. This tendency is consistent throughout the conditional distribution of inclusive human development. In what follows, the policy implications are discussed in three main strands, notably: (i) measures by which quality education can be improved in Africa; (ii) how ICT penetration can be enhanced and (iii) the relevance of the findings to sustainable development goals (SDGs). The strands are expanded in chronological order.

First, quality of education can be increased by improving the number of schools and teachers, given that the number of pupils is likely to remain unchanged. Increasing the number of schools and teachers will require an increase in the budget of primary education. Moreover, improving the training of teachers is also worthwhile in order to ensure the transmission of quality knowledge from teachers to students.

Second, given the positive unconditional effect of mobile phone penetration on inclusive development, increasing access to mobile phones will go a long way to improving

human development and reducing inequality in sampled countries. Many citizens in the sampled countries do not still have mobile phones. Hence, complete liberalisation of the ICT sector can enhance competition and by extension, access to mobile phones. In the same vein, universal access schemes through low pricing mechanisms by the governments of sampled countries will go a long way to reducing inequality and improving human development in the post-2015 sustainable development era.

Third, it is important to note that poverty and inequality still represent glaring challenges to achievement of SDGs in most sampled countries. This is essentially because about half of the sampled countries failed to achieve the MDG extreme poverty target. Hence, simultaneously improving the quality of education at the primary level with universal access schemes in mobile phones will go a long ways to curtailing poverty and inequality in Africa. It also relevant to articulate that the outcome variable entails: inequality, health, income and knowledge.

Future research should explore other ICT mechanisms that can be modulated by education to improve human development. Within the alternative framework, considering other education variables is worthwhile.

Appendices

Appendix 1: Definitions and sources of variables

Variables	Signs	Definitions	Sources
Inclusive development	IHDI	Inequality adjusted human development index	UNDP
Mobile Phone	Mobile	Mobile phone subscriptions (per 100 people)	WDI
Mobile Phone (IV)	Mobile (IV)	Instrumented mobile phone subscriptions (per 100 people)	Author's calculation
Education quality	Educ	Pupil teacher ratio in primary education	WDI
Education quality (IV)	Educ(IV)	Instrumented pupil teacher ratio in primary education	Authors' calculation
GDP per capita	GDPpcg	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.

Appendix 2: Summary statistics

	Mean	SD	Min	Max	Obs
Inequality Adj. Human Development	0.721	3.505	0.129	0.768	485
Mobile Phone Penetration	23.379	28.004	0.000	147.202	572
Mobile Phone Penetration(IV)	25.313	28.144	2.705	156.082	522
Education quality	43.601	14.529	12.466	100.236	444
Education quality(IV)	43.673	14.227	12.978	98.512	365
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.

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

Edu	GDPpcg	Credit	Remit	FDI	Mobile	IHDI	
1.000	0.029	-0.369	-0.073	-0.118	-0.461	-0.096	Edu
	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 : Education 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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