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Enhancing ICT for Quality Education in Sub-Saharan Africa[1]

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Enhancing ICT for Quality Education in Sub-Saharan Africa

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Abstract

This research assesses the relevance of information and communication technology (ICT) in primary education quality in a panel of 49 Sub-Saharan African countries for the period 2000-2012. The empirical evidence is based on Two Stage Least Squares (2SLS) and Instrumental Quantile regressions (IQR). From the 2SLS: (i) mobile phone and internet penetration rates reduce poor quality education and enhancing internet penetration has a net negative effect of greater magnitude. From the IQR: (i) with the exception of the highest quantile for mobile phone penetration and top quantiles for internet penetration, ICT consistently has a negative effect on poor education quality with a non-monotonic pattern. (ii) Net negative effects are exclusively apparent in the median and top quantiles of internet-related regressions. It follows that enhancing internet penetration will benefit countries with above-median levels of poor education quality while enhancing internet penetration is not immediately relevant to reducing poor education quality in countries with below-median levels of poor education quality.

JEL Classification: F24; F63; L96 O30; O55
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1. Introduction

There are three main factors in policy and scholarly circles that motivate the positioning of this study on enhancing information and communication technology (ICT) for quality education in sub-Saharan Africa (SSA), notably: the policy syndrome of poor education in the development of the sub-region[2]; the importance of ICT in promoting development outcomes and gaps in the attendant literature. The factors are expatiated in the same order of chronology.

First, education in SSA is sub-standard when compared with other regions of the world where students are benefiting from better education facilities and infrastructure. This fact is consistent with the policy literature pertaining to the education of young people (Antoninis, 2017) as well as the scholarly literature on the low productive value of doctoral dissertations (Amavilah, 2009), especially in terms of scientific publications (Asongu & Nwachukwu, 2016a). Concerning lower levels of education, Antoninis (2017) maintains that many teachers are not well prepared and equipped. According to the author, the teaching activity is characterized by over-crowded classrooms, lack of proper teaching equipments and crumbling infrastructure. Moreover, the author further articulates that about a quarter of the young population in the sub-region cannot read properly and 90% of children do not have good reading skills. In a nutshell, standards of education are diminishing in SSA and this policy syndrome represents a challenge to the achievement of Sustainable Development Goal (SDG) 4 of global quality education. Many policy instruments have been documented as instrumental in the achievement of SDGs in the post-2015 development agenda. Among these instruments is the potential of ICT.

Second, ICT can be leveraged by SSA to address policy syndromes and achieve development outcomes because, compared to other regions of the world where, the ICT market has reached levels of saturations, there is a high potential for its penetration in SSA (Penard *et al.*, 2012; Afutu-Kotey *et al.*, 2017; Asongu & Boateng, 2018; Gosavi, 2018; Humbani & Wiese, 2018). The policy relevance of leveraging on the ICT penetration potential to achieve positive development outcomes has motivated a recent stream of the literature on the nexus between ICT and economic development (Tchamyou, 2017; Abor *et al.*, 2018; Minkoua Nzie *et al.*, 2018; Asongu & Nwachukwu, 2016b, 2016c; Issahaku *et al.*,

[2] In the light of Fosu (2013), policy syndromes are characteristics that are detrimental to economic development, *inter alia*: "administered redistribution", "state breakdown", "state controls", and "suboptimal inter temporal resource allocation". According to Asongu (2017), a policy syndrome is a gap in knowledge economy between two countries whereas Asongu and Nwachukwu (2017) conceive and define it as economic growth that is not pro-poor. Tchamyou *et al.* (2019) and Tchamyou (2019a) consider it as inequality. Within the context of this study, policy syndrome is poor educational quality.

2018; Muthinja & Chipeta, 2018; Gosavi, 2018; Uduji & Okolo-Obasi, 2018a, 2018b; Bongomin *et al.*, 2018 ; Asongu *et al.*, 2019). The present research extends this strand of literature by assessing how ICT can influence education quality in SSA. Education quality is understood in this study in terms of the pupil-teacher ratio and hence it is not a direct measure of academic performance in basic formal education.

Third, the positioning on the relevance of ICT in education is also motivated by an apparent gap in the extant literature. On the one hand, contemporary studies on promoting education in SSA have focused on *inter alia*: the importance of education interventions programs (Conn, 2017); PhD by Publication as an argument for scientific publications in Africa in order to boost the lagging position of the continent in relation to other regions of the world (Asongu & Nwachukwu, 2018a), critical analysis of country-specific issues in education (Mosha, 2018) and the importance of governance in promoting the quality of higher education (Abugre, 2018).

In the sparse literature on "ICT for education", the study closest to this paper is Joyce-Gibbons (2018) which, has assessed the role of mobile phones in secondary schools in Tanzania. The study concludes that: (i) while most students have access to mobile phones, they are not permitted to go to school with them; (ii) few teachers see the relevance of the technology in the curriculum of students; (iii) it is an urgent policy concern that mobile technologies should be considered as a pedagogical resource subject to frank discussions between teachers, students and the wider community on the opportunities and challenges of these technologies.

The present study departs from Joyce-Gibbons (2018) by focusing on SSA and complementing mobile phone penetration with internet penetration in order to assess the importance of ICT in education quality at the primary level of schooling. We argue that if ICT is relevant in primary education, it is very likely to also be important in higher levels of education. Moreover, the focus on primary education is also motivated by the fact that this level of education has been documented to be associated with more socio-economic outcomes when economies are at initial levels of industrialization (Asiedu, 2014). Hence, the research question this study aims to answer is the following: does enhancing ICT improve basic formal education in terms of the pupil-teacher ratio in SSA?

We further argue in this study that applied econometrics should not exclusively be motivated by the need to either accept or reject existing theories. This is essentially because applied econometrics may also be positioned on extending extant empirical literature, as apparent in the motivation of this study in the light of Joyce-Gibbons (2018). Moreover, the

intuition for the connection between ICT and education is logical because the former is a contemporary determinant of the latter, especially in the light of the relevance of knowledge economy in 21st century development (Tchamyou, 2017). In summary, we are consistent with a recent stream of empirical literature in further arguing that applied econometrics, even in the absence of a formal theoretical model, is a useful scientific activity that can lead to theory-building (Costantini & Lupi, 2005; Narayan *et al*., 2011; Asongu & Nwachukwu, 2016d).

The rest of the study is structured as follows. Section 2 focuses on the data and methodology while Section 3 presents and discusses the empirical results. Section 4 concludes with implications and future research directions.

2. Data and methodology

2.1 Data

This paper focuses on 49 countries in SSA for the period 2000-2012. The data are from World Governance Indicators and World Development Indictors of the World Bank. The temporal and geographical scopes are due to data availability constraints at the time of the study. The outcome variable is poor quality of education at the primary school proxied by the "pupil-teacher ratio". This is a negative economic signal because a higher ratio denotes poor education quality while a lower ratio reflects higher education quality. This is essentially because a lower ratio is consistent with fewer teachers for the same number of pupils, *ceteris paribus*.

Apart from the justification provided in the introduction for focusing on primary education, there are concerns about degrees of freedom in indicators of education quality in secondary and tertiary schools. Hence, higher education levels are not engaged because of data availability constraints. This measure of education quality has been used in recent education literature in Africa for the same justifications provided in this study, notably: (i) issues of degree of freedom in proxies for higher education quality and (ii) the relative importance of primary education in socio-economic outcomes when countries are at tender stages of industrialization (Asiedu, 2014; Asongu & Nwachukwu, 2018b; Tchamyou, 2019b; Asongu & Odhiambo, 2018).

Two ICT indicators are also used in the light of recent information technology literature, namely: mobile phone penetration and internet penetration (Efobi *et al*., 2018; Tchamyou *et al*., 2019). Seven control variables are adopted by the study in order to account for variable omission bias. They include: four non-dummy (corruption-control, foreign direct investment, trade openness and population growth) and three dummy (low income, English

common law and conflict-affected countries) variables (Gyimah-Brempong & Asiedu, 2015; Sun & He, 2014; Asongu & Tchamyou, 2017; Chapman & Lindner, 2016; Tchamyou, 2017).

Concerning the non-dummy variables, with the exception of population growth which has an ambiguous sign, the other variables are expected to reduce poor education quality. Corruption has been established to reduce the quality of education (Chapman & Lindner, 2016). Hence, corruption-control is anticipated to have the opposite effect. Foreign direct investment (FDI) has also been documented to promote human capital (Sun & He, 2014). Asongu and Tchamyou (2017) have used trade openness to control for the effects of foreign aid on all levels of education, including lifelong learning. As for population growth, a negative effect is anticipated because the higher the population, the more teachers are needed to instruct those enrolled in schools for learning. If the population is increasing faster than the capacity of government to recruit more teaching staff in schools, population growth is likely to increase the pupil-teacher ratio. Corruption-control is from World Governance Indicators of the World Bank whereas the other three variables are from World Development Indicators of the same bank.

With regards to the dummy variables: (i) countries with low income levels are expected to be associated with low quality primary education because poor countries are expected to have less financial resources with which to finance the needs of primary education. (ii) Compared to French civil law countries, English common law countries should be associated with more quality in human development (Asongu & Nwachukwu, 2018c) and education (Agbor, 2015). (iii) From intuition, conflict and political strife decrease enabling conditions for the provision of public commodities, including education.

The categorisation of countries in terms of legal origins is motivated by La Porta *et al.* (2008, p. 289) while the segmentation is countries by levels of income is consistent with the stratification of income groups by the World Bank[3]. In line with Asongu *et al.* (2019), conflict-affected countries reflect those that have experienced political instability/strife and violence for at least half of the sampled periodicity.

The definitions and sources of the variables are provided in Appendix 1 whereas the summary statistics is disclosed in Appendix 2. The correlation matrix is provided in Appendix 3.

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

2.2 Methodology

Ordinary Least Squares (OLS) and Quantile regressions (QR) are used to assess the influence of ICT on education quality. The OLS and QR approaches are also tailored to control for: (i) the unobserved heterogeneity in terms of dummy variables and (ii) simultaneity or reverse causality by means of internal instruments. The employment of these estimation approaches in order to provide robust results is in accordance with recent information technology literature (Asongu *et al*., 2018). The purpose of the OLS approach is to provide baseline regressions estimates on the relationship between education quality and ICT, while the objective of QR approach is to consider initial levels of poor education quality. Accordingly, with the QR, countries are distinguished in terms of those with intermediate poor, least poor and most poor education quality. Hence, in the QR, initial levels of poor education quality are considered in the relationship between ICT and education quality.

2.2.1 Two Stage Least Squares (2SLS)regressions

Consistent with recent information technology and education literature (Asongu & Nwachukwu, 2018b), the concern of simultaneity in endogeneity is tackled by employing an instrumental variable estimation strategy. Simultaneity or reverse causality is a concern because while the study is investigating the effect of ICT on education quality, it is also logical that a reverse effect is possible. In other words, the quality of education can also affect ICT. A method of controlling the issue of reverse causality is to use instruments on the ICT variables in this study. In the research, lagged values of ICT variables are used as internal instruments for the ICT independent variables of interest. The procedure of instrumentation for internet penetration and mobile phone penetration are respectively in Eq. (1) and Eq. (2) below.

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

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

It is relevant to emphasise that the process of instrumentation in Eq. (1) consists of regressing internet penetration 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) to Eq. (7). The specifications are Heteroscedasticity and Autocorrelation Consistent (HAC) in standard errors.

The 2SLS specification with HAC standard errors is presented as follows:

$$Ed_{i,t} = \alpha + \sum_{j=1}^{8} \delta_j W_{j,i,t} + \varepsilon_{i,t} \qquad (3)$$

where $Ed_{i,t}$ is the education quality of country i in period t; α is a constant, W is the vector of determinants which includes instrumented ICT (i.e. mobile phone penetration and internet subscriptions) and the seven control variables (corruption-control, FDI inflows, trade openness, population growth, low income, English common law and conflict-affected countries) and $\varepsilon_{i,t}$ the error term .

2.2.2 Instrumental Quantile regressions

The 2SLS regressions approach discussed in the previous section is based on mean or average values of the poor education quality. Whereas mean values are relevant, there is an associated shortcoming when sampled countries differ in terms of initial levels of education quality. Hence, by adopting a complementary QR approach, the study can distinguish countries in terms of poor education quality. With the QR technique, the relevance of ICT in poor education quality is investigated throughout the conditional distribution of education quality or the outcome variable (Okada & Samreth, 2012; Asongu, 2013; Koenker & Bassett, 1978; Tchamyou & Asongu, 2018). The conditional distribution of education quality consists of countries with intermediate, least poor and most poor levels of education quality. Moreover, as documented by Koenker (2005), Hao and Naiman (2007) and Asongu and Odhiambo (2018a), the 2SLS estimation strategy is distinct from QR from various perspectives, namely, it is: based on conditional mean (versus conditional quantiles); also relevant on small data (against sufficient data); founded on the assumption of normality (versus an agnostic distribution); computationally less intensive (against a characteristics of computational intensiveness) and not to outliers (accounts for outliers).

The θ^{th} quantile estimator of education quality is obtained by solving for the following optimization problem, which is presented without subscripts in Eq. (4) for the purpose of simplicity and readability.

$$\min_{\beta \in R^k} \left[\sum_{i \in \{i: y_i \geq x_i'\beta\}} \theta \left| y_i - x_i'\beta \right| + \sum_{i \in \{i: y_i < x_i'\beta\}} (1-\theta) \left| y_i - x_i'\beta \right| \right], \quad (4)$$

where $\theta \in (0,1)$. As opposed to 2SLS which is based on the minimization of sum of squared residuals, with QR, it is the weighted sum of absolute deviations that is minimized. For example, the 25th or 75th quantiles (with θ=0.25 or 0.75, respectively) are estimated by approximately weighing the residuals. The conditional quantile of education quality or y_i given x_i is:

$$Q_y(\theta / x_i) = x_i'\beta_\theta \quad , \quad (5)$$

where unique slope parameters are estimated for each θ^{th} specific quantile. This formulation is analogous to $E(y / x) = x_i'\beta$ in the 2SLS slope where parameters are examined only at the mean of the conditional distribution of education quality. For Eq. (5), the dependent variable y_i is education quality whereas x_i contains: a constant term, instrumented ICT, corruption-control, FDI inflows, trade openness, population growth, low income, English common law and conflict-affected countries.

In the light of the above, the regression equations for the QR and 2SLS for the research question being investigated are as follows.

$$Ed_{i,t} = \sigma_0 + \sigma_1 X_{i,t} + \varepsilon_{i,t} \quad (6)$$

$$Ed_{i,t} = \sigma_0^{(p)} + \sigma_1^{(p)} \sigma_1 X_{i,t} + \varepsilon_{i,t}^{(p)} \quad (7)$$

The 2SLS and QR respectively in Equation (6) and Equation (7) above focus on the role of ICT on education quality, where, $Ed_{i,t}$ is education quality of country i in period t, σ_0 is a constant, X entails instrumented ICT and other control variables (corruption-control, FDI inflows, trade openness, population growth, low income, English common law and conflict-affected countries), and $\varepsilon_{i,t}$ is the error term.

3. Empirical results

In this section, while 2SLS findings are disclosed in Table 1, Table 2 provides corresponding results from QR. The information criteria used for the validity of the step-wise 2SLS is the Fisher statistics and coefficient of determination (i.e. R^2) while the information criterion used for the Quantile regressions is the Pseudo R^2. While Fisher statistics reflect the combined significance of estimated coefficients in the models, the R^2 shows the explanatory power of the estimated model. Based on these criteria the step-wise 2SLS regressions are overwhelmingly valid and QR models have important explanatory powers. The left-hand side of Table 1 focuses on "mobile phone"-oriented regressions whereas the right-hand side presents the corresponding internet-related findings. Each ICT specification in Table 1 has two main characteristics: (i) estimation with and without fixed dummy effects and (ii) quadratic and non-quadratic specifications. The non-quadratic estimations articulate the effect of ICT on education quality whereas the quadratic estimations are used to assess the relevance of enhancing ICT on education quality.

Hence, net or overall effects are computed to examine the total effect of ICT from the unconditional and marginal effects of ICT. For instance in the seventh column of Table 1, the net impact from instrumented internet penetration is -1.097 (2×[0.017× 4.395] + [-1.247]). In the computation, the mean value of instrumented internet penetration is 4.395, the unconditional effect of instrumented internet penetration -1.247 while the conditional or marginal effect from enhancing instrumented internet penetration is 0.017. In the same vein, in the last column of Table 1, the net impact from increasing instrumented internet penetration is -0.979 (2×[0.017× 4.395] + [-1.129]). In the computation, the mean value of instrumented internet penetration is 4.395, the unconditional effect of instrumented internet penetration -1.129 while the conditional or marginal effect from enhancing instrumented internet penetration is 0.017.

When interpreting the negative net effects, it is important to note that since the outcome variable is a negative economic signal, a negative effect on the outcome variable should be understood as a reduction in poor education quality. Hence, a diminishing magnitude in the outcome variable reflects an increasing ability of teachers to allocate more time for the education of pupils.

The following findings can be established from Table 1. First, while mobile phone penetration reduces poor quality education, net effects from enhancing mobile phone penetration cannot be established because at least one estimated coefficient needed for the computations is not significant. Second, internet penetration reduces poor education quality

and enhancing internet penetration has a net negative effect on poor education quality. Moreover, the negative effect from enhancing internet penetration is higher than the negative effect of internet penetration. For instances: (i) the effect of internet penetration in the 6th column of Table 1 which is -0.662, is lower in magnitude than the corresponding net effect from enhancing internet penetration in the 7th column of the same table which is -1.097. (ii) The impact of internet penetration in the 8th column of Table 1 which is -0.569, is lower than the corresponding net impact from enhancing internet penetration in the 9th column of the same table which is -0.979. Third, the significant control variables have the expected signs.

Table 1: Two Stage Least Squares Regressions

	Dependent variable: Poor Education Quality (Pupil teacher ratio in primary education)							
	Mobile phone penetration				**Internet penetration**			
	Without fixed effects		With fixed effects		Without fixed effects		With fixed effects	
Constant	**46.349*** (0.000)**	**46.537*** (0.000)**	**38.598*** (0.000)**	**38.793*** (0.000)**	**47.769*** (0.000)**	**50.590*** (0.000)**	**40.479*** (0.000)**	**43.260*** (0.000)**
Mobile phone (IV)	**-0.145*** (0.000)**	**-0.172*** (0.002)**	**-0.132*** (0.000)**	**-0.162*** (0.002)**	---	---	---	---
Internet (IV)	---	---	---	---	**-0.662*** (0.000)**	**-1.247*** (0.000)**	**-0.569*** (0.000)**	**-1.129*** (0.000)**
Mobile phone(IV) × Mobile phone(IV)	---	0.0002 (0.503)	---	0.0003 (0.468)	---	---	---	---
Internet(IV) × Internet(IV)	---	---	---	---	---	**0.017*** (0.000)**	---	**0.017*** (0.000)**
Corruption-Control	**-5.990*** (0.000)**	**-5.964*** (0.000)**	**-4.674*** (0.000)**	**-4.657*** (0.000)**	**-5.772*** (0.000)**	**-5.213*** (0.000)**	**-4.738*** (0.000)**	**-4.237*** (0.000)**
FDI Inflows	-0.136 (0.148)	-0.132 (0.166)	-0.131 (0.104)	-0.126 (0.119)	-0.107 (0.305)	-0.088 (0.401)	-0.107 (0.223)	-0.088 (0.321)
Trade Openness	**-0.081*** (0.002)**	**-0.081*** (0.003)**	**-0.062*** (0.007)**	**-0.062*** (0.007)**	**-0.089*** (0.002)**	**-0.093*** (0.001)**	**-0.072*** (0.003)**	**-0.077*** (0.002)**
Population growth	**2.264* (0.057)**	**2.303* (0.053)**	**2.743*** (0.008)**	**2.782*** (0.007)**	1.615 (0.196)	1.297 (0.312)	**2.251** (0.041)**	**1.921* (0.090)**
Low Income	---	---	**5.397*** (0.000)**	**5.422*** (0.000)**	---	---	**4.674*** (0.000)**	**4.803*** (0.000)**
English	---	---	1.780 (0.144)	1.826 (0.134)	---	---	1.147 (0.371)	1.188 (0.357)
Conflicts	---	---	**6.078*** (0.001)**	**6.037*** (0.000)**	---	---	**5.362*** (0.005)**	**5.021*** (0.008)**
Net Effects	---	na	---	na	---	-1.097	---	-0.979
R^2	0.349	0.350	0.406	0.406	0.356	0.369	0.398	0.410
Fisher	**71.93***	**74.59***	**62.59***	**62.38***	**63.09***	**75.51***	**50.05***	**63.56***
Observations	356	356	356	356	349	349	349	349

*, **, ***: significance levels of 10%, 5% and 1%, respectively. OLS: Ordinary Least Squares. R^2: coefficient of adjustment. FDI: Foreign Direct investment. na: not applicable because at least one of the estimated coefficients needed for the computation is net effects is not significant. The mean value of instrumented mobile phone penetration is 25.313 while the mean value of instrumented internet penetration is 4.395. Low income: Low income countries. English: English common law countries. Conflict: Conflict-affected countries.

In Table 2, Panel A shows results for mobile phone penetration while Panel B discloses findings pertaining to internet penetration. For both panels, non-quadratic specifications are apparent on the left-hand side while quadratic specifications are found on the-right hand side.

Table 2: Instrumental Quantile regressions for mobile phone and internet penetrations

Dependent variable: Poor Education Quality (Pupil teacher ratio in primary education)

Panel A: Mobile phone penetration

	Non Quadratic					Quadratic				
	Q.10	Q.25	Q.50	Q.75	Q.90	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	**27.197*** **	**25.078*** **	**29.426*** **	**0.254*** **	**58.547*** **	**26.681*** **	**25.229*** **	**29.416*** **	**43.898*** **	**54.857*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Mobile phone(IV)	**-0.061***	**-0.053***	**-0.099*** **	**-0.098** **	-0.143	-0.023	-0.058	**-0.154*** **	**-0.186***	-0.318
	(0.099)	**(0.036)**	**(0.000)**	**(0.024)**	(0.109)	(0.782)	(0.341)	**(0.008)**	**(0.093)**	(0.123)
Mobile phone(IV) × Mobile phone(IV)	---	---	---	---	---	-0.0003	0.00003	0.0006	0.0007	0.001
						(0.643)	(0.956)	(0.244)	(0.440)	(0.414)
Corruption-Control	0.912	-1.947	**-4.727*** **	**-8.706*** **	**-12.609*** **	0.624	-1.999	**-5.252*** **	**-8.807*** **	**-10.642** **
	(0.612)	(0.119)	**(0.000)**	**(0.000)**	**(0.004)**	(0.720)	(0.111)	**(0.000)**	**(0.000)**	**(0.012)**
FDI Inflows	-0.149	**-0.229*** **	**-0.296*** **	0.176	0.352	-0.147	**-0.224** **	**-0.303*** **	0.172	0.368
	(0.231)	**(0.008)**	**(0.000)**	(0.231)	(0.244)	(0.224)	**(0.010)**	**(0.000)**	(0.278)	(0.219)
Trade Openness	-0.076	**-0.040***	-0.010	**-0.085** **	**-0.163** **	**-0.079*** **	**-0.040** **	-0.010	**-0.093** **	**-0.140** **
	(0.010)	**(0.050)**	(0.598)	**(0.015)**	**(0.023)**	**(0.005)**	**(0.049)**	(0.589)	**(0.013)**	**(0.043)**
Population growth	**4.770*** **	**5.033*** **	**4.456*** **	**2.564***	1.388	**4.852*** **	**4.977*** **	**4.496*** **	2.316	3.063
	(0.000)	**(0.000)**	**(0.000)**	**(0.091)**	(0.655)	**(0.000)**	**(0.000)**	**(0.000)**	(0.155)	(0.309)
Low Income	**3.936** **	**4.307*** **	**3.484*** **	2.536	2.973	**3.895** **	**4.358*** **	**3.765*** **	2.539	3.213
	(0.033)	**(0.001)**	**(0.004)**	(0.243)	(0.504)	**(0.028)**	**(0.001)**	**(0.002)**	(0.274)	(0.455)
English	-1.077	1.869	**3.378*** **	**4.425** **	2.902	-0.995	1.963	**3.753*** **	**4.656** **	3.848
	(0.223)	(0.137)	**(0.005)**	**(0.040)**	(0.510)	(0.571)	(0.120)	**(0.002)**	**(0.044)**	(0.367)
Conflicts	3.418	**2.903***	**3.129** **	**9.460*** **	**12.557** **	3.062	**2.798***	**3.132** **	**9.199*** **	**15.107*** **
	(0.129)	**(0.062)**	**(0.033)**	**(0.000)**	**(0.022)**	(0.158)	**(0.073)**	**(0.035)**	**(0.001)**	**(0.004)**
Net Effects	---	---	---	---	---	na	na	na	na	na
R^2	0.326	0.314	0.307	0.254	0.222	0.327	0.314	0.309	0.258	0.231
Observations	356	356	356	356	356	356	356	356	356	356

Panel B: Internet penetration

	Non Quadratic					Quadratic				
	Q.10	Q.25	Q.50	Q.75	Q.90	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	**30.612*** **	**31.317*** **	**29.939*** **	**37.325*** **	**56.052*** **	**33.000*** **	**35.214*** **	**31.420*** **	**41.982*** **	**57.333*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Internet (IV)	**-0.332** **	**-0.367*** **	**-0.410*** **	-0.245	-0.284	**-0.722** **	**-0.675*** **	**-0.771*** **	**-1.265*** **	**-2.318*** **
	(0.037)	**(0.000)**	**(0.000)**	(0.211)	(0.505)	**(0.025)**	**(0.000)**	**(0.001)**	**(0.007)**	**(0.001)**
Internet (IV) × Internet (IV)	---	---	---	---	---	0.008	0.008	**0.012** **	**0.028** **	**0.054*** **
						(0.313)	(0.199)	**(0.034)**	**(0.024)**	**(0.004)**
Corruption-Control	-0.026	**-3.197*** **	**-4.700*** **	**-8.858*** **	**-16.113*** **	-0.320	**-3.450*** **	**-5.140*** **	**-7.419*** **	-4.931
	(0.988)	**(0.008)**	**(0.000)**	**(0.000)**	**(0.005)**	(0.854)	**(0.006)**	**(0.000)**	**(0.004)**	(0.193)
FDI Inflows	-0.115	**-0.173** **	**-0.263*** **	0.178	-0.060	-0.029	-0.129	**-0.254*** **	0.152	0.285
	(0.356)	**(0.034)**	**(0.001)**	(0.247)	(0.857)	(0.801)	(0.124)	**(0.002)**	(0.372)	(0.265)
Trade Openness	**-0.072** **	**-0.061*** **	-0.025	**-0.076** **	**-0.156***	**-0.071** **	**-0.075*** **	-0.025	**-0.070***	**-0.143** **
	(0.016)	**(0.002)**	(0.187)	**(0.038)**	**(0.051)**	**(0.011)**	**(0.000)**	(0.195)	**(0.087)**	**(0.020)**
Population growth	**3.290** **	**3.396*** **	**4.256*** **	**3.332** **	3.333	**2.075***	**2.570*** **	**4.144*** **	2.639	2.347
	(0.014)	**(0.000)**	**(0.000)**	**(0.043)**	(0.351)	**(0.099)**	**(0.005)**	**(0.000)**	(0.149)	(0.392)
Low Income	**3.277***	**3.382*** **	**3.483*** **	2.221	0.434	**4.296** **	**3.687*** **	**2.730** **	3.453	**6.407***
	(0.079)	**(0.005)**	**(0.004)**	(0.333)	(0.930)	**(0.014)**	**(0.003)**	**(0.025)**	(0.172)	**(0.092)**
English	-1.079	0.958	**3.441*** **	**5.343** **	1.370	-1.003	0.758	**3.742*** **	**4.428***	**8.490** **
	(0.556)	(0.422)	**(0.004)**	**(0.019)**	(0.780)	(0.558)	(0.538)	**(0.002)**	**(0.076)**	**(0.024)**
Conflicts	2.054	1.463	**2.862** **	**9.487*** **	**10.8530***	1.988	1.162	2.362	**8.214*** **	**16.379*** **
	(0.363)	(0.319)	**(0.048)**	**(0.001)**	**(0.073)**	(0347)	(0.444)	(0.109)	**(0.008)**	**(0.000)**
Net Effects	---	---	---	---	---	na	na	-0.665	-1.018	-1.843
Pseudo R^2	0.329	2.054	0.306	0.235	0.203	0.334	0.328	0.314	0.250	0.240
Observations	349	349	349	349	349	349	349	349	349	349

*, **, ***: significance levels of 10%, 5% and 1%, respectively. FDI: Foreign Direct Investment. Lower quantiles (e.g., Q 0.1) signify nations where poor education quality is least. na: not applicable because at least one of the estimated coefficients needed for the computation is net effects is not significant. The mean value of instrumented mobile phone penetration is 25.313 while the mean value of instrumented internet penetration is 4.395. Low income: Low income countries. English: English common law countries. Conflict: Conflict-affected countries.

The following findings can be established. First, in non-quadratic specifications, with the exception of the highest quantile of mobile phone penetration and top quantiles of internet penetration, ICT (i.e. mobile phone penetration and internet penetration) consistently has a

negative effect on poor education quality with a non-monotonic pattern. Second, in quadratic specifications, whereas net effects are not apparent from regressions related to the mobile phone, net negative effects are exclusively apparent in the median and top quantiles of internet-related regressions. Third, the significant control variables have the expected signs.

4. Concluding implications and future research directions

This research has assessed the relevance of ICT in education quality in a panel of 49 Sub-Saharan African countries for the period 2000-2012. The empirical evidence is based on Two Stage Least Squares (2SLS) and Instrumental Quantile regressions (IQR). From the 2SLS: (i) mobile phone penetration reduces poor quality education and (ii) internet penetration reduces poor education and enhancing internet penetration has a net negative effect of greater magnitude. From the IQR results: (i) with the exception of the highest (top) quantile(s), mobile phone (internet penetration) consistently has a negative effect on poor education quality with a non-monotonic pattern. (ii) Net negative effects are exclusively apparent in the median and top quantiles of internet-related regressions. It follows that while internet penetration does not significantly affect poor education quality in top quantiles of the education quality distribution, when internet penetration is enhanced; net negative effects are established in top quantiles of poor education quality. Given that top quantiles reflect countries with above-median levels of poor education quality, it follows that enhancing internet penetration will benefit countries with above-median levels of poor education quality while enhancing internet penetration is not relevant in countries with below-median levels of poor education quality, in order to achieve a reduction in poor education quality.

While the findings in this study cannot be directly compared with those of Joyce-Gibbons (2018): a research which has assessed the role of mobile phone in secondary schools in Tanzania and partially motivated the present study; it is nonetheless worthwhile to articulate that, contrary to the findings of Joyce-Gibbons (2018), ICT improves education quality in SSA and teachers should start considering its relevance in the curriculum of pupils and students.

Future studies can focus on other ICT mechanisms by which education quality can be improved in Africa. Moreover, considering higher levels of education in the light of challenges to knowledge-based economies and lifelong learning in Africa is also worthwhile. A caveat of this study is related to reliability and use of the applied data and methodology. Accordingly, the research could not complement the macroeconomic data used with within-

country observations from which districts with poor quality education and corresponding levels of ICT use can be clearly articulated. To address this concern future research will need to build on primary data collection and set up a study in which all other variables are controlled for and ICT is used as a treatment.

Appendices

Appendix 1: Definitions and sources of variables

Variables	Signs	Definitions	Sources
Educational Quality	Educ	Pupil teacher ratio in primary education	WDI
Mobile phone	Mobile	Mobile phone subscriptions (per 100 people)	WDI
Mobile phone (Instrumented)	MobileIV	Instrumental Mobile phone subscriptions (per 100 people)	Author's calculation
Internet penetration	Internet	Internet subscriptions (per 100 people)	WDI
Internet penetration (Instrumented)	InternetIV	Instrumental Internet subscriptions (per 100 people)	Author's calculation
Corruption-Control	CC	"Control of corruption (estimate): captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests"	WGI
Foreign Investment	FDI	Foreign Direct Investment Inflows (% of GDP)	WDI
Trade Openness	Trade	Imports + Exports of Commodities (% of GDP)	WDI
Population growth	Popg	Net Official Development Assistance (% of GDP)	WDI

WDI: World Development Indicators. WGI: World Governance Indicators. GDP: Gross Domestic Product.

Appendix 2: Summary statistics

	Mean	SD	Min	Max	Obs
Educational Quality	43.601	14.529	12.466	100.236	444
Mobile phone	23.379	28.004	0.000	147.202	572
Mobile phone (Instrumented)	25.313	28.144	2.705	156.082	522
Internet penetration	4.152	6.450	0.005	43.605	566
Internet penetration (Instrumented)	4.395	6.299	0.322	47.577	513
Corruption-Control	-0.642	0.591	-1.924	1.249	579
Net Foreign Direct Investment Inflows	5.332	8.737	-6.043	91.007	603
Trade Openness	78.177	36.138	20.964	209.874	597
Population growth	2.361	0.948	-1.081	6.576	588

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

Appendix 3: Correlation Matrix (Uniform sample size: 347)

Education	MobileIV	InternetIV	CC	FDI	Trade	Popg	
1.000	-0.445	-0.489	-0.401	-0.112	-0.350	0.416	Education
	1.000	0.724	0.365	0.098	0.270	-0.402	Mobile
		1.000	0.444	0.041	0.199	-0.475	Internet
			1.000	-0.093	0.061	-0.405	CC
				1.000	0.336	0.078	FDI
					1.000	-0.439	Trade
						1.000	Popg

Education: Educational quality. MobileIV: Instrumented Mobile phone penetration. InternetIV: Instrumented Internet penetration. CC: Corruption-Control. FDI: Foreign Direct Investment. Trade: Trade Openness. Popg: Population growth.

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