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The role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa[1]

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The role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa

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Abstract

This study assesses the role of ICT in modulating the impact of education and lifelong learning on income inequality and economic growth. It focuses on a sample of 48 African countries from 2004 to 2014. The empirical evidence is based on the generalised method of moments (GMM). The following findings are established. First, mobile phone and internet each interact with primary school education to decrease income inequality. Second, all ICT indicators interact with secondary school education to exert a negative impact on the Gini index. Third, fixed broadband distinctly interacts with primary school education and lifelong learning to have a positive effect on economic growth. Fourth, ICT indicators do not significantly influence inequality and economic growth through tertiary school education and lifelong learning. These main findings are further substantiated. Policy implications are discussed.

*Keywords:*Education; Lifelong learning; ICT; Inequality; Africa

*JEL Codes***:**I28; I20; I30; L96; O55

1. Introduction

In the development of the 21st century, Information and Communication Technologies (ICT) are expected to enhance the quality of education and the corresponding knowledge acquired; the deepening of knowledge and the creation of knowledge (UNESCO, 2015). Overall, the transformative power of ICT is aligned with the post-2015 Sustainable Development Goals (SDGs) on the education agenda. It follows that ICT can be relevant in modulating education for economic outcomes such as economic growth and inequality. The positioning of this study on the role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth is based on four main trends in scholarly and policy circles: (i) growing interest in knowledge economy, specifically, education for development; (ii) increasing potential of ICT for development; (iii) growingevidence of exclusion in the African continent and (iv) gaps in the literature. We further engage these points chronologically.

First, nowadays, competitiveness is an important factor that each country has to take into account in order to be actively involved in the global economy. In the 21st century, competition is increasingly focusing on the knowledge economy, which has been one of the important themes of the World Bank and the Organization for Economic Co-operation and Development (OECD) (World Bank, 2007; Weber, 2011; Tchamyou, 2017; Asongu, 2017). In this regard, the developed world, especially North America and Europe, is dominating in terms of economic development as it has well understood the relevance of the knowledge economy. Latin America has been facing the challenges of globalisation by emphasizing on policy frameworks which respond to the growing need of knowledge economy (Dahlman, 2007). The Japanese model based on the knowledge economy has also been leveraged by the Newly Industrialized Economies of Asia (Hong Kong, Taiwan, Singapore and South Korea), China and Malaysia (Chandra & Yokoyama, 2011; Asongu, 2017). South Korea is one of the freshly industrialised Asian nations which have made the most successful transition to a 'knowledge-based economy' from its 'product-based economy'. Moreover, the country could inspire African nations because its economic development level was almost the same as that of many African countries in the 1960s (Tchamyou, 2017). It is important to note that the emphasis on knowledge economy (KE) is because of the independent variables of interest in this study (i.e. education, ICT and lifelong learning) all border on KE.

A KE is one that uses knowledge as the main device of economic expansion (Asongu, 2017; Suh & Chen, 2007). It is an economy where knowledge is created, acquired, used and

disseminated with efficiency in order to improve economic development (Tchamyou, 2017; Chen & Dahlman, 2005). Contrary to some opinions and thoughts, the concept of KE is not necessarily associated with high technology. According to the narratives, the progression from a product-based economy to a KE takes into account measures like investing in long-term education, renovating the infrastructure of information, improving the capacity of innovation and promoting an environment that is favourable for economic prosperity and market transactions. The World Bank has then qualified four factors as pillars of knowledge economy, notably: (i) institutional regime and economic incentives which provide interesting economic policies and institutions; (ii) education which is continuously adapting and improving skills for the efficiency in the creation and usage of knowledge; (iii) information and communication technologies which effectively ease dissemination of knowledge and (iv) innovation in schools, companies, research institutes and other organisations. The above pillars are essential in the creation, acceptance, adoption and use of knowledge in every step of the production of knowledge in a domestic economy.

In some African countries, great emphasis has been placed on primary and secondary education for several decades, whereas tertiary education has been neglected as a medium for enhancing economic growth and mitigating poverty[2]. To substantiate this point, the Dakar summit of 2000 on "*Education for all*" focused only on the primary school education as a driver of social wellbeing while tertiary education was ignored (Bloom et al. 2006). According to the author, one reason for such inattention to higher education lies in the shortcomings of empirical evidence on the benefits of higher education in the processes of economic development and poverty reduction in a country. In this perspective of reducing poverty and exclusion, there is a global acknowledgement of the importance of improving financial inclusion and financial education for inclusive development. Particularly, a significant policy focus has been oriented towards the favourable connection between financial education and inclusive finance (Atkinson & Messy, 2013).

Second, on the potential penetration of ICT for development,Penard et al. (2012) stated that the penetration potential of ICT in Africa is high, whereas ICT penetration in the developed world has reached saturation levels. Asongu and le Roux (2019)have established evidence that ICT is relevant in improving inclusive human development in the African context. In this vein, policymakers can leverage on such penetration potential to address inequality-related

[2] Not all African countries have neglected tertiary education. For instance, a developing country like South Africa placed much emphasis on tertiary education as the main driver of development.

challenges of the post-2015 SDGs. Furthermore, Andrianaivo and Kpodar (2011) showed a substantial contribution of ICT to the economic development of Africa. On its recent 2016 publication entitled "*Digital Dividends*", the World Development Report has documented that internet access is sufficient but not enough. The report further clarifies that the maximisation of digital dividends entails a good understanding of the interaction between new technologies and essential factors for the development of economies. The report qualifies these factors as "*analog complements*" which have three components, namely: regulations; accountable institutions and improved skills (World Development Report, 2016). Digital technologies can significantly improve and enhance the underlying complements and therefore speed the pace of economic development. In the context of our study, the "*analog complements*" refers to education and lifelong.

Third, the 2016 publication of the World Bank on "*Poverty and shared prosperity - Taking on inequality*" has advocated that poverty has been decreasing significantly around the world, except in Africa. The report further points out the interest of mitigating inequality so that poverty can be ended by 2030, and if shared prosperity is boosted across the world (World Bank, 2016). According to the report, many countries have been unsuccessful in meeting the extreme poverty target set by the Millennium Development Goals (MDGs). This is in spite of the growth recovery, which started two decades ago (Fosu, 2015). Following this, Klasen (2016) reported the predominance of inequality in African countries when compared to other regions of the world. According to the narrative, Latin America is the only sub-region which surpasses in terms of inequality.

Fourth, this study complements the highlighted literature discussed in the above strands (for instance: Dahlman, 2007; Andrianaivo & Kpodar, 2011; Chavula, 2013; Klasen, 2016; Asongu, 2017, Tchamyou, 2017) by assessing the relevance of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth. ICT is considered as a policy or modulating variable because of its high penetration potential, unlike educational levels which have almost reached the maximum limit in some levels of education. In other words, in interactive regressions, a policy variable has economic meaning if it has a high potential for penetration, compared to the other constituent interacting variable.

The testable hypotheses are:

Hypothesis 1: ICT modulates education to reduce inequality and increase economic growth.

Hypothesis 2: ICT modulates lifelong learning to reduce inequality and increase economic growth.

The theoretical framework underpinning the nexus between information technology and economic outcomes such as inequality and economic prosperity (in terms of economic growth) accords with neoclassical theories for economic growth (Kwan & Chiu, 2015). Building on the corresponding literature, the fundamentals of the neoclassical growth models support the perspective that information technologypromotes economic prosperity and reduces income inequality in developing countries (Abramowitz, 1986; Bernard & Jones, 1996; Asongu, Nwachukwu & Aziz, 2018). The theoretical framework has been recently employed within the context of literature on nexuses between ICT and the socio-economic development of African countries (Uduji & Okolo-Obasi, 2018a, 2018b; Bongomin *et al*., 2018; Asongu*et al*., 2019a, 2019b). This theoretical perspective is supported with more insights into what follows.

Economic growth (inequality) can be promoted (mitigated) by ICT through education for a plethora of reasons. (i) While ICT enables people to limit physical displacement (Ureta, 2008; Shaikh & Karjaluoto, 2015; Asongu, 2015; Efobi *et al*., 2018), such benefits can be more apparent when citizens are educated on the benefits of leveraging on ICT to reduce such physical displacements. (ii) ICT provides citizens and firms with timely information and hence reduces information asymmetry that is costly to households, corporations and governments (Smith, Spence & Rashid, 2011; Tchamyou, 2019b). The education mechanism consolidates the relevance of such ICT in the underlying benefits, which ultimately increase respectively, household welfare, the productivity of firms and government effectiveness. Consistent with the underlying testable hypotheses, theseexternalities have a bearing on economic growth and inequality reduction.

The contemporary attendant literature on economic growth and inequality has not focused on the problem statement being assessed in this study. On the one hand, recent economic growth studies have largely been oriented towards country-specific narratives on output and inflation dynamics (Bonga-Bonga & Simo-Kengne, 2018); linkages between economic prosperity and financial access (Adam et al., 2017; Assefa & Mollick, 2017); nexuses between development assistance, uncertainty in development assistance and economic growth by sectors (Kumi et al., 2017); drivers of foreign investment in developing countries (Okafor et al., 2017); uncertainty in economic prosperity and access to finance (Muazu & Alagidede, 2017) and connections between volatility in economic prosperity and innovation (Yaya & Cabral, 2017).

On the other hand, the contemporary inequality literature in Africa has largely been concerned with, *inter alia*: the imperative to reinvent development assistance in order to promote inclusive economic development (Jones & Tarp, 2015; Asongu, 2016; Page & Söderbom, 2015); the connection between the distribution of income and external flows (Kaulihowa & Adjasi, 2018); nexuses between income and consumption (De Magalhães & Santaeulàlia-Llopis, 2018); linkages between corruption and the distribution of income (Sulemana & Kpienbaareh, 2018); inequality in opportunities for the female gender (Bayraktar & Fofack, 2018; Elu, 2018; Mannah-Blankson, 2018) and nexuses between information asymmetry, schooling, access to finance and the redistribution of income (Meniago & Asongu, 2018; Tchamyou, 2019a, 2019b).

The remaining sections of the study are structured as follows: the data and methodology are covered in section 2, 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 description

We analyse a sample of 48 African countries from 2004 to 2014. Four sources of data are used, notably: (i) the Global Consumption and Income Project (GCIP) for the income inequality variable; (ii) World Development Indicators (WDI) of the World Bank for ICT, economic growth andeducation variables; (iii) World Governance Indicators (WGI) of the World Bank for governance control variables, and (v) Principal Component Analysis used to derive the lifelong learning index (Educatex). The periodicity is due to data availability constraints.

Borrowing from recent literature on education and knowledge economy (Tchamyou, 2019a; Tchamyou, 2017; Asongu &Tchamyou, 2019),lifelong learning can be measured and defined as the combined knowledgeacquired during three educational levels, which are: primary, secondary and tertiary education. Building on these levels of education, we thus employ Principal Component Analysis (PCA) to derive a composite indicator named "*Educatex*". PCA is a method used in statistics to transform a large set of correlated indicators into a small set of uncorrelated composite indicators. The new composite indicators contain most information available in the original data. The information criterion employed to find out the number of common factors to retain is from Kaiser (1974) and Jolliffe (2002). They recommend keeping factors with eigen values higher than one. From Appendix 1, we can see

that the first principal component satisfies this criterion. The corresponding lifelong learning composite "Educatex", accounts for 82.5% of the information contained in primary, secondary and tertiary school enrolments.

Consistent with the literature on ICT (Efobi et al., 2018; Tchamyou et al., 2019; Sassi & Goaied, 2013; Chavula, 2013), we proxy ICT measures with internet penetration rate per 100 people, mobile phone penetration rate per 100 people, and fixed broadband subscription per 100 people.

Following the literature oninequality(Beck et al., 2007, Meniago & Asongu, 2018;Tchamyou, 2019b) we use the common Gini index as a measurement of income inequality and the real GDP growth as a proxy for economic growth.Accordingly, GDP growth is in annual percentage while the Gini index is a measurement of income distribution among residents in a country.

We control for factors which could potentially impact income inequality and economic growth, notably: financial depth; political stability and remittances (Demirguc-Kunt et al., 2017; Tchamyou, 2019a).Demirguc-Kunt et al. (2017) found evidence that financial depth, which is a concept related but different from financial inclusion, is a factor contributing to shared economic growth and overall development[3]. We expect remittances to reduce income inequality because they have been documented to be mostly used for consumption purposes (Ssozi & Asongu, 2016). However, the opposite effect of remittances on income inequality can occur because the majority of migrantsoriginate from middle- and high-income households. Hence remittances can increase inequality (Anyanwu, 2011).We can also expect a decrease in inequality with political stability because it provides a favourable environment for economic prosperity and by extension appealing conditions for the equitable distribution of benefits resulting from the underlying economic development (Tchamyou, 2019a).

Appendix 2 discloses the definitions and sources of variables. Appendix 3 presents the summary statistics and the sample of countries and Appendix 4 the correlation matrix. From the summary statistics, we can notice the comparability of the variables based on the mean values and substantial variability in indicators based on the corresponding standard deviations. We control for the degree of substitution among indicators using the correlation matrix. The purpose of such control is to avoid issues of multicollinearity. This issue is

[3] It is important to note that financial depth includes both the poor and the rich while with financial inclusion, the poor have more access to finance.

apparent among ICT variables. This is why they are distinctly specified in order to avoid misspecification in equations.

2.2. Estimation technique: Interactive Generalised Method of Moments

To investigate the role of ICT in modulating the effect of education, lifelong learning on income inequality and economic growth, we adopt the Interactive Generalised Method of Moments as estimation technique. It is based on Roodman (2009a, 2009b), which is an extension of Arellano and Bover (1995).The motivation for choosing this empirical strategy is threefold:first, we are using data structure in the panel, which is consistent with the GMM. Hence, cross-country variations are not eliminated. Second, the requirement of the GMM is to have the number of cross-sections (N) higher than the number of time series (T), this requirement is met in our case given that we have N = 48 and T = 11.Third, this is a robust technique because it controls for endogeneity by means of instrumentation (simultaneity) and accounting for time-invariant omitted variables. Besides this, it restricts over-identification (or the proliferation of instruments) and controls for cross-sectional dependence (Baltagi, 2008; Love & Zicchino, 2006). Following Brambor et al. (2006), constituent elements have all been integrated into specifications. Given that the *one-step*process only takes into account homoscedasticity, we choose the *two-step* procedure which controls for heteroscedasticity.

We can then summarise the estimation technique with the subsequent equations in levels (1) and first difference (2):

$$DEP_{i,t} = \sigma_0 + \sigma_1 DEP_{i,t-\tau} + \sigma_2 EDU_{i,t} + \sigma_3 ICT_{i,t} + \sigma_4 Inter_{i,t} + \sum_{h=1}^{5} \delta_j W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$DEP_{i,t} - DEP_{i,t-\tau} = \sigma_1 (DEP_{i,t-\tau} - DEP_{i,t-2\tau}) + \sigma_2 (EDU_{i,t} - EDU_{i,t-\tau}) + \sigma_3 (ICT_{i,t} - ICT_{i,t-\tau})$$
$$+ \sigma_4 (Inter_{i,t} - Inter_{i,t-\tau}) + \sum_{h=1}^{5} \delta_j (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \quad (2)$$

where, $DEP_{i,t}$ is the dependent variable (income inequality and economic growth) of country i inperiod t ; EDU is lifelong learning (*Educatex*) and education (primary, secondary and tertiary school enrolments); $Inter$ is the interaction between, on the on hand,lifelong learning and ICT and on the on hand, education and ICT ($EDU \times ICT$); ICT represents ICT indicators (mobile phone, internet and fix broadband); σ_0 is a constant; τ is the lagging coefficient (due to issues in degree on freedom, it is equal to one in this study); W represents the vector of

control variables (*financial depth; political stability and remittances*), ξ_t is the time-specific constant, η_i is the country-specific effect, and $\varepsilon_{i,t}$ is the error term.

The following paragraph briefly discusses main characteristics of the GMM, namely: identification, simultaneity and exclusion restrictions.

It has been documented in recent literature that all explaining variables are presumed to be suspected endogenous (or predetermined) whereas years (or time-invariant variables) are expected to be strictly exogenous (Asongu & Nwachukwu, 2016; Tchamyou & Asongu, 2017). This is mainly because it is not likely for time-invariant variables to be endogenous in the first difference (Roodman, 2009b).Consequently, the process employed to treat *ivstyle* (years) is '*iv (years, eq(diff))*'and the *gmmstyle* is used to deal with suspected endogenous variables. In the light of the above, years or time-invariant variables influence the dependent variables (income inequality and economic growth) by means of the predetermined variables (education, lifelong learning and ICT). Furthermore, the Difference in Hansen Test (DHT) is the statistical test used to assess the validity of the exclusion restriction for instrument exogeneity. It follows that the null hypothesis of the DHT test should not be rejected for time-invariant variables to influence inequality and economic growth exclusively via education, lifelong learning and ICT. It is worthwhile articulating the fact that, in the GMM approach, the DHT is the information criterion required for examining whether years are strictly exogenous. Besides the rejection of the null hypothesis of the SarganOver-identifying Restrictions test in the instrumental variable process indicates that the dependent variables are not exclusively explained by instruments, via the suspected endogenous variables (Beck et al., 2003).

3.Empirical results and discussion

Table 1 and Table 2,respectively present findings corresponding to income inequality and economic growth. Overall, the information criteria usedto assess the validity[4] of the models are overwhelmingly valid. We compute net effects in order to examine the complementary role of ICT in the effect of education and lifelong learning on income inequality and

[4]"*First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR(2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fischer test for the joint validity of estimated coefficients is also provided*" (Asongu & De Moor, 2017, p. 200).

economic growth.For instance, in the third column of Table 2, the net effect is computed from the interaction between primary school enrolment and fixed broadband subscriptions, and we obtain -1.279([12.016×0.753] + [-10.328]), where: -10.328 is the unconditional effect of primary school; 12.016 is the conditional effect from the interaction between fixed broadband and primary school enrolment, and 0.753 is the mean value of fixed broadband. This computation is consistent with recent interactive regression literature (Agoba et al., 2019).

The following findings can be established on the linkages between ICT, income inequality, economic growth and educational levels. First, in Table 1, (i) both interactions between mobile phone and primary school education on the one hand and internet and primary school education, on the other hand, are decreasing income inequality. (ii) All the ICT variables (mobile phone, internet and fixed broadband) are interacting with secondary school education to decrease income inequality. (iii) No significant results are found in the interaction betweenICT variables and tertiary school enrolment on the one hand, and lifelong learning and ICT indicators on the other hand. (iv) Significant control variables are overwhelmingly presenting the expected signs, except for political stability, which is overall positive. Accordingly, political stability can increase economic growth at the same increase inequality if the fruits from economic growth are not equitably distributed across the population. This is unfortunately the case in Africa in the light of the motivation of this study in the introduction and recent literature (Asongu & Kodila-Tedika, 2017).

Second, concerning economic growth (Table 2), (i) there are two significant findings from the interaction between fixed broadband and primary school enrolment on the one hand, and from the interaction between fixed broadband and lifelong learning on the other hand. (ii) Interactions between mobile phone and primary school education on the one hand and between mobile phone and secondary school, on the other hand, are not significant. (iii) No significant results are found when interacting ICT variables with tertiary school enrolment. (iv) As in Table 1, significant control variables display the expected sign, except for political stability. Overall, in the light of the computed net effects, while the two investigated hypotheses highlighted in the introduction are not overwhelmingly valid, there is, however, room for implications based on specific educational and ICT dynamics.

4. Concluding remarks and future research directions

The study has assessed the role of information and communication technology (ICT) in modulating the effect of education and lifelong learning on income inequality and economic

growth. It has focused on a sample of 48 African countries from 2004 to 2014. The empirical evidence is based on the generalised method of moments (GMM), and the lifelong learning is measured as the combined knowledge acquired during primary, secondary and tertiary education. We use the common Gini index to measure income inequality and real GDP growth as a proxy of economic growth. The following main results have been established. First, mobile phone and internet interact each with primary school education to decrease income inequality. Second, all ICT indicators interact with secondary school education to exert a negative impact on the Gini index. Third, fixed broadband distinctly interacts with primary school education and lifelong learning to have a positive effect on economic growth. Fourth, ICT indicators do not significantly influence inequality and economic growth through tertiary school and lifelong learning. These main findings are further substantiated.

First, compared to other educational levels, primary school (secondary school) provides favourable conditions for more positive redistribution of income (economic growth). This is in accordance with the literature (see Petrakis & Stamatakis, 2002; Asiedu, 2014; Tchamyou, 2019a) which has shown that primary education has a comparative advantage in terms of social returns in the context of less industrialised economies. In essence, we are consistent with Tchamyou (2019a) in arguing that most African economies rely on primary and informal sectors which do not necessitate a high level of education from an economic operator. Our findings also confirm those of Abdullah et al. (2015), who stated that education (mainly primary and secondary schooling) is particularly efficient in mitigating inequality in Africa.Moreover, the fourthSustainable Development Goal of the United Nations (i.e. "*Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*") (UNESCO, 2015) underscores the need and the importance of promoting and intensifying education in early childhood and improving learning outcomes in early education, especially at the primary level. This is in spite of the high rate of primary school enrolment in sub-Sahara African countries, which has nearly reached thatof developed countries (Gove, 2017).The policy implication which we can derive from this is that primary education is the fundamental basis in the relevance of higher educational levels in the impact of education on income inequality. The logic behind this implication is that the redistributive aspect of lifelong learning is an essential factor which is driven by primary schooling.

Second, our results show that lifelong learning does not significantly reduce income inequality through ICT. This result counteracts those of Tchamyou (2019a) who finds that the

combined knowledge gained through educational levels (primary, secondary and tertiary school enrolments) has more relevance in decreasing income inequality. This contradictory result may be due to the fact that the study of Tchamyou (2019a) uses interactions between financial access and education (as well as lifelong learning) to reduce income inequality; whereas in our study, we complement education and lifelong learning with ICT indicators. We thus find that the effects of education, especially primary school enrolment and lifelong learning, are relevant in boosting economic growth via fixed broadband. Consistent with this result, the United Nations Development of Economic and Social Affairs (UNDESA) in its 2012 report on "*Boosting development with broadband and ICTs*" emphasised on the importance of improving and strengthening ICT and broadband to fight global poverty and famine worldwide and by extension boost economic growth (UNDESA, 2012). An implication to this is that investing in education and better ICT access will, in the long run, reduce inequality and improve growth in the post-2015 development era.

Future research can investigate if the established results are empirically valid from country-specific perspectives. This may guide policymakers on more focused policy implications, because this study has employed the GMM which eliminates country-specific effects. Like in most studies on inequality, a caveat to this study is that the story on inequality and associated development indicators with which it is connected is strongly influenced by elements of inequality the Gini index can capture compared to those that it is difficult for it to capture. Székely and Hilgert (1999) provide insights into what is behind the measurements of inequality. Investigating how the underlying factors of inequality that can easily be calibrated (compared to those that cannot easily be captured), is also a worthwhile future research orientation.

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Table 1: Education, ICT and Inequality

	Dependent variable: Gini index											
	Primary School Enrolment			Secondary School Enrolment			Tertiary School Enrolment			Lifelong Learning		
	Mobile	Internet	BroadB	Mobile	Internet	BroadB	Mobile	Internet	BroadB	Mobile	Internet	BroadB
Constant	**0.582****	-0.1009	**0.250****	-0.071	**-0.854****	-0.208	0.056	**-0.237***	0.016	0.271	-0.203	0.240
	(0.018)	(0.694)	**(0.031)**	(0.710)	**(0.019)**	(0.206)	(0.758)	**(0.060)**	(0.752)	(0.506)	(0.230)	(0.411)
Gini(-1)	**0.979*****	**0.862*****	**0.959*****	**0.932*****	**0.820*****	**0.932*****	**1.004*****	**0.963*****	**0.993*****	**0.930*****	**0.888*****	**0.941*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
PSE	0.003	0.013	-0.002	---	---	---	---	---	---	---	---	---
	(0.655)	(0.277)	(0.628)									
SSE	---	---	---	**-0.009****	-0.007	**-0.011*****	---	---	---	---	---	---
				(0.050)	(0.278)	**(0.000)**						
TSE	---	---	---	---	---	---	-0.001	**0.0001**	**0.002****	---	---	---
							(0.552)	**(0.869)**	**(0.013)**			
LL (Educatex)										**0.003***	-0.0007	-0.0009
										(0.064)	(0.546)	(0.555)
Mobile	**0.0003*****	**---**	**---**	**0.0001*****	**---**	**---**	**0.00003*****	---	---	-2.49e-06	---	---
	(0.000)			**(0.000)**			**(0.001)**			(0.939)		
Internet	---	**0.002*****	**---**	---	0.0007	---	---	0.00003	---	---	-0.00008	---
		(0.003)			(0.133)			(0.248)			(0.248)	
BroadB	---	**---**	0.0001	---	---	**0.004****	---		**0.0002***	**---**	**---**	0.0002
			(0.974)			**(0.060)**		---	**(0.057)**			(0.308)
Mobile ×PSE	**-0.0003*****	---	---	---	---	---	---		---	---	---	---
	(0.000)											
Mobile×SSE	---	---	---	**-0.0001*****	---	---	---	---	---	---	---	---
				(0.000)								
Mobile ×TSE	---	---	---	---	---	---	-3.36e-06	---	---	---	---	---
							(0.810)					
Mobile ×LL	---	---	---	---	---	---	---	---	---	0.00002	---	---
										(0.116)		
Internet ×PSE	---	**-0.002*****	**---**	**---**	**---**	**---**	**---**	**---**	---	---	---	---
		(0.002)										
Internet ×SSE	---	**---**	**---**	**---**	**-0.0008***	**---**	**---**	**---**	---	---	---	---
					(0.052)							
Internet ×TSE	---	**---**	**---**	**---**	**---**	**---**	**---**	1.49e-06	---	---	---	---
								(0.966)				
Internet ×LL	---	---	---	---	---	---	---	**---**	---	---	0.00006	---
											(0.653)	

BroadB×PSE	---	---	-0.00009 (0.988)	---	---	---	---	---	---	---	---	---
BroadB×SSE	---	---	---	---	---	**-0.004*** **(0.055)**	---	---	---	---	---	---
BroadB×TSE	---	---	---	---	---	---	---	---	-0.0001 (0.147)	---	---	---
BroadB×LL	---	---	---	---	---	---	---	---	---	---	---	-0.0001 (0.714)
Pol. Stability	-0.001 (0.120)	0.002 (0.198)	0.0007 (0.300)	**0.002**** **(0.031)**	**0.006***** **(0.001)**	**0.003***** **(0.000)**	0.0001 (0.906)	-0.0002 (0.593)	**-0.001***** **(0.000)**	-0.0003 (0.709)	**0.003***** **(0.000)**	**0.002***** **(0.007)**
Fin. Depth	**-0.0001**** **(0.017)**	**-.0001***** **(0.005)**	**-0.00006***** **(0.002)**	0.00001 (0.778)	-0.00003 (0.540)	**-0.00002*** **(0.070)**	0.00001 (0.442)	6.48e-06 (0.682)	-6.47e-06 (0.180)	**-0.0002***** **(0.008)**	-0.00002 (0.516)	**-0.0001***** **(0.002)**
Remittances	**-0.0003***** **(0.000)**	**-0.0001*** **(0.089)**	0.00001 (0.869)	**-0.0001*** **(0.085)**	0.00001 (0.927)	0.0001 (0.253)	**-0.0003***** **(0.000)**	**-0.0003***** **(0.000)**	0.00001 (0.504)	-0.00004 (0.499)	0.00006 (0.316)	0.00006 (0.457)
Net effects	n.a.	n.a.	n.a.	-0.013	n.a.	-0.014	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
AR(1)	**(0.233)**	**(0.227)**	**(0.270)**	**(0.232)**	**(0.228)**	**(0.271)**	**(0.167)**	**(0.164)**	**(0.155)**	**(0.192)**	**(0.184)**	**(0.308)**
AR(2)	**(0.290)**	**(0.300)**	**(0.331)**	**(0.322)**	**(0.337)**	**(0.330)**	**(0.355)**	**(0.212)**	**(0.166)**	**(0.311)**	**(0.318)**	**(0.340)**
Sargan OIR	**(0.323)**	**(0.161)**	**(0.675)**	**(0.255)**	**(0.135)**	**(0.744)**	(0.000)	(0.001)	**(0.550)**	**(0.385)**	**(0.169)**	**(0.933)**
Hansen OIR	**(0.708)**	**(0.939)**	**(0.576)**	**(0.877)**	**(0.941)**	**(0.647)**	**(0.387)**	**(0.294)**	**(0.884)**	**(0.779)**	**(0.641)**	**(0.918)**
DHT for instruments (a)Instruments in levels												
H excluding group	**(0.878)**	**(0.880)**	**(0.523)**	**(0.691)**	**(0.818)**	**(0.690)**	**(0.883)**	**(0.821)**	**(0.550)**	**(0.606)**	**(0.801)**	**(0.676)**
Dif(null, H=exogenous)	**(0.463)**	**(0.836)**	**(0.525)**	**(0.824)**	**(0.873)**	**(0.507)**	**(0.167)**	**(0.126)**	**(0.897)**	**(0.731)**	**(0.434)**	**(0.894)**
(b) IV (years, eq(diff))												
H excluding group	**(0.652)**	**(0.950)**	**(0.546)**	**(0.848)**	**(0.916)**	**(0.627)**	**(0.326)**	**(0.241)**	**(0.849)**	**(0.788)**	**(0.617)**	**(0.898)**
Dif(null, H=exogenous)	**(0.792)**	**(0.294)**	**(0.468)**	**(0.647)**	**(0.924)**	**(0.421)**	**(0.940)**	**(0.947)**	**(0.789)**	**(0.313)**	**(0.439)**	**(0.628)**
Fisher	**8820.89*****	**3337.70*****	**21043.25*****	**8657.31*****	**1603.35*****	**10920.59*****	**4843.66*****	**3021.71*****	**10283.59*****	**3033.90*****	**8029.53*****	**4585.47*****
Instruments	28	28	28	28	28	28	28	28	28	28	28	28
Countries	42	42	41	41	41	40	39	39	39	41	41	40
Observations	287	283	260	266	261	239	230	228	210	264	260	229

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. na: not applicable due to the insignificance of marginal effects and/or unconditional effect of ICT.

Table 2: Education, ICT and Economic Growth

	Dependent variable: Economic Growth											
	Primary School Enrolment			Secondary School Enrolment			Tertiary School Enrolment			Lifelong Learning		
	Mobile	Internet	BroadB	Mobile	Internet	BroadB	Mobile	Internet	BroadB	Mobile	Internet	BroadB
Constant	140.329	95.997	-78.246	73.632	3.982	-111.176	-330.566	**-216.500****	14.885	-209.376	-118.653	85.918
	(0.385)	(0.405)	(0.542)	(0.568)	(0.970)	(0.295)	(0.150)	**(0.035)**	(0.908)	(0.328)	(0.333)	(0.532)
GDPg(-1)	0.072	0.049	**0.112***	**0.149****	0.055	**0.145*****	0.086	0.054	0.036	**0.140****	0.035	0.057
	(0.421)	(0.374)	**(0.056)**	**(0.037)**	(0.254)	**(0.002)**	(0.215)	(0.291)	(0.467)	**(0.012)**	(0.531)	(0.172)
PSE	6.745	**9.920*****	**-10.328*****	---	---	---	---	---	---	---	---	---
	(0.161)	**(0.009)**	**(0.027)**									
SSE	---	---	---	2.422	-1.529	**-4.405*****	---	---	---	---	---	---
				(0.420)	(0.421)	**(0.004)**						
TSE	---	---	---	---	---	---	-0.502	**-2.219***	-0.706	---	---	---
							(0.811)	**(0.089)**	(0.430)			
LL(Educatex)	**---**	---	---	**---**	---	---	**---**	---	---	0.445	-0.054	-0.617
										(0.515)	(0.950)	(0.353)
Mobile	**0.329*****	---	---	**0.093*****	---	---	**-0.038*****	**---**	---	**-0.030***	---	---
	(0.000)			**(0.000)**			**(0.006)**			**(0.048)**		
Internet	---	0.546	**---**	---	-0.001	---	**---**	**-0.096****	---	---	-0.029	---
		(0.240)			(0.992)			**(0.021)**			(0.181)	
BroadB	---	**---**	**-12.281*****	---	---	-0.094	---	---	**-0.305***	**---**	**---**	**-0.255*****
			(0.001)			(0.920)			**(0.066)**			**(0.000)**
Mobile ×PSE	**-0.341*****	---	---	---	---	---	---	---	---	---	---	---
	(0.000)											
Mobile×SSE	---	---	---	**-0.096*****	---	---	---	---	---	---	---	---
				(0.000)								
Mobile ×TSE	---	---	---	---	---	---	0.006	---	---	---	---	---
							(0.532)					
Mobile ×LL	---	---	---	---	---	---	---	---	---	-0.001	---	---
										(0.748)		
Internet ×PSE	---	-0.597	---	---	---	---	---	**---**	---	---	---	---
		(0.189)										
Internet ×SSE	---	---	---	---	-0.024	---	---	---	---	---	---	---
					(0.837)							
Internet ×TSE	---	---	---	---	---	---	---	0.036	---	---	---	---
								(0.236)				
Internet ×LL	---	---	---	---	---	---	---	---	---	---	**-0.066*****	---
											(0.000)	

BroadB×PSE	---	---	**12.016*** (0.001)**	---	---	---	---	---	---	---	---	---
BroadB×SSE	---	---	---	---	---	-0.105 (0.911)	---	---	---	---	---	---
BroadB×TSE	---	---	---	---	---	---	---	---	0.054 (0.607)	---	---	---
BroadB×LL	---	---	---	---	---	---	---	---	---	---	---	**-0.490*** (0.000)**
Pol. Stability	-0.567 (0.380)	**-1.186** (0.030)**	-0.314 (0.489)	**0.752** (0.017)**	0.454 (0.380)	**0.823*** (0.008)**	**1.976*** (0.006)**	**3.266*** (0.000)**	**2.529*** (0.000)**	**0.910** (0.027)**	**0.847* (0.098)**	0.624 (0.210)
Fin. Depth	-0.047 (0.114)	-0.024 (0.299)	-0.008 (0.629)	-0.053 (0.108)	**-0.027* (0.074)**	0.009 (0.367)	0.008 (0.486)	0.005 (0.740)	**-0.028*** (0.005)**	-0.007 (0.849)	-0.022 (0.332)	0.013 (0.644)
Remittances	0.034 (0.447)	**-0.056** (0.016)**	0.062 (0.132)	0.054 (0.477)	0.044 (0.424)	**0.111*** (0.009)**	**0.075* (0.064)**	**0.094** (0.034)**	0.017 (0.727)	**-0.112*** (0.001)**	-0.068 (0.110)	**-0.051** (0.014)**
Net effects	n.a.	n.a.	-1.279	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
AR(1)	(0.061)	(0.051)	(0.044)	(0.057)	(0.090)	(0.060)	(0.030)	(0.025)	(0.035)	(0.020)	(0.029)	(0.025)
AR(2)	**(0.513)**	**(0.465)**	**(0.479)**	**(0.542)**	**(0.483)**	**(0.580)**	**(0.505)**	**(0.543)**	**(0.594)**	**(0.459)**	**(0.438)**	**(0.539)**
Sargan OIR	**(0.184)**	**(0.291)**	**(0.155)**	**(0.170)**	(0.085)	(0.071)	**(0.196)**	**(0.287)**	**(0.803)**	**(0.296)**	**(0.243)**	**(0.117)**
Hansen OIR	**(0.870)**	**(0.514)**	**(0.244)**	**(0.588)**	**(0.294)**	**(0.319)**	**(0.438)**	**(0.687)**	**(0.633)**	**(0.692)**	**(0.391)**	**(0.439)**
DHT for instruments												
(a)Instruments in levels												
H excluding group	**(0.986)**	**(0.719)**	**(0.676)**	**(0.782)**	**(0.555)**	**(0.905)**	**(0.102)**	**(0.213)**	**(0.626)**	**(0.250)**	**(0.132)**	(0.080)
Dif(null, H=exogenous)	**(0.580)**	**(0.343)**	**(0.128)**	**(0.387)**	**(0.205)**	**(0.118)**	**(0.795)**	**(0.892)**	**(0.529)**	**(0.867)**	**(0.676)**	**(0.844)**
(b) IV (years, eq(diff))												
H excluding group	**(0.849)**	**(0.495)**	**(0.234)**	**(0.528)**	**(0.244)**	**(0.268)**	**(0.391)**	**(0.625)**	**(0.618)**	**(0.711)**	**(0.348)**	**(0.536)**
Dif(null, H=exogenous)	**(0.530)**	**(0.399)**	**(0.345)**	**(0.752)**	**(0.790)**	**(0.756)**	**(0.602)**	**(0.911)**	**(0.396)**	**(0.272)**	**(0.572)**	**(0.116)**
Fisher	**12.00***	**7.25 ***	**10.78***	**22.78***	**2.83***	**10.94***	**14.74***	**6.62***	**29.39***	**15.20***	**12.76***	**55.69***
Instruments	28	28	28	28	28	28	28	28	28	28	28	28
Countries	42	42	41	41	41	40	39	39	39	41	41	40
Observations	287	283	260	266	261	239	230	228	210	264	260	229

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. na: not applicable due to the insignificance of marginal effects and/or unconditional effect of ICT.

Appendices

Appendix 1: Principal Component Analysis (PCA) for education indicators

Education dimensions		Component Matrix (Loadings)			First PC	Eigen Value	Indexes
		PSE	SSE	TSE			
Education	School	0.581	0.612	0.535	0.825	2.474	Educatex
	Enrolment	-0.550	-0.188	0.813	0.143	0.431	
		0.599	-0.767	0.228	0.031	0.093	

"PC: Principal Component. PSE: Primary School Enrolment. SSE: Secondary School Enrolment. TSE: Tertiary School Enrolment.Educatex is the first principal component of primary, secondary and tertiary school enrolments.

Appendix 2: Definitions of Variables

Variables	Signs	Definitions (Measurements)	Sources
Gini Index	Gini	"*The Gini index is a measurement of the income distribution of a country's residents*".	GCIP
Economic Growth	GDPg	Gross Domestic Product growth (% annual)	WDI
Primary School	PSE	School enrollment, primary and secondary (gross), gender parity index (GPI)	WDI
Secondary School	SSE	School enrollment, secondary (gross), gender parity index (GPI)	WDI
Tertiary School	TSE	School enrollment, tertiary (gross), gender parity index (GPI)	WDI
Lifelong Learning	Educatex	Principal Component of PSE, SSE and TSE	Authors
Mobile Phones	Mobile	Mobile cellular subscriptions (per 100 people)	WDI
Internet	Internet	Internet users (per 100 people)	WDI
Fixed Broad Band	BroadB	Fixed broadband subscriptions (per 100 people)	WDI
Political Stability	PolS	"*Political stability/no violence (estimate): measured as the perceptions of the likelihood that the government will be destabilised or overthrown by unconstitutional and violent means, including domestic violence and terrorism*"	WGI
Financial Depth	FinDepth	Money Supply (% of GDP)	FDSD
Remittances	Remit	Remittance inflows to GDP (%)	FDSD

WDI: World Bank Development Indicators of the World Bank. WGI: World Bank Governance Indicators of the World Bank. FDSD: Financial Development and Structure Database of the World Bank. GCIP: Global Consumption and Income Project.

Appendix 3: Summary statistics (2004-2014)

	Mean	SD	Minimum	Maximum	Observations
Gini index	0.582	0.035	0.488	0.851	527
Economic Growth	5.102	4.224	-36.699	33.735	528
Primary School Enrollment	0.923	0.106	0.600	1.105	363
Secondary School Enrollment	0.874	0.203	0.333	1.422	338
Tertiary School Enrollment	0.775	0.437	0.064	3.295	293
Lifelong Learning (Educatex)	0.005	0.919	-3.522	2.309	319
Mobile Phone Penetration	48.455	38.082	0.209	171.375	524
Internet Penetration	8.929	11.543	0.031	56.8	519
Fixed Broad Band	0.753	1.924	0	14.569	434
Political Stability	-0.490	0.867	-2.687	1.182	528
Financial Depth	35.460	22.409	4.383	108.899	503
Remittances	4.250	6.475	0.00003	50.818	471

S.D: Standard Deviation.

Appendix 4: Correlation matrix

			Education variables			ICT variables			Control variables			
Gini	GDPg	PSE	SSE	TSE	Educatex	Mobile	Internet	BroadB	PolS	FinDepth	Remit	
1.000	0.076	0.181	0.181	0.058	-0.016	0.003	0.030	-0.047	0.449	-0.223	0.171	Gini
	1.000	-0.066	-0.176	-0.158	-0.125	-0.220	-0.272	-0.145	0.048	-0.155	-0.054	GDPg
		1.000	0.859	0.608	0.599	0.488	0.498	0.388	0.381	0.318	0.304	PSE
			1.000	0.697	0.596	0.473	0.493	0.324	0.404	0.339	0.468	SSE
				1.000	0.455	0.622	0.705	0.662	0.321	0.212	0.173	TSE
					1.000	0.273	0.301	0.113	0.148	0.287	0.213	Educatex
						1.000	0.818	0.675	0.283	0.301	-0.028	Mobile
							1.000	0.796	0.268	0.437	0.014	Internet
								1.000	0.388	0.392	-0.123	BroadB
									1.000	0.353	0.160	PolS
										1.000	0.100	FinDepth
											1.000	Remit

Gini: Gini Index. GDPg: Economic Growth. PSE : Primary School Enrollment. SSE : Secondary School Enrollment. LL: Lifelong Learning. Moblie: Mobile phone penetration. Internet: Internet penetration. BroadB: Fixed Broad band subscriptions. PolS; Political Stability. FinDepth: Financial Depth. Remit: Remittances.