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ICT Dynamics for Gender Inclusive Intermediary Education: Minimum Poverty and Inequality thresholds in Developing Countries

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Abstract

This study examines linkages between information and communication technology (ICT) dynamics, inequality, and poverty in order to establish critical masses of poverty and inequality that should not be exceeded in order for ICT dynamics to promote gender-inclusive education in 57 developing countries for the period 2012-2016. Poverty is measured with the poverty headcount ratio at national poverty lines (% of the population), while inequality is proxied by the Gini coefficient, the Atkinson index and the Palma ratio. The ICT dynamics are measured with 'internet access in school', 'virtual social network', 'personal computers', 'mobile phone penetration', 'internet penetration', and 'fixed broadband subscriptions.' The empirical evidence is based on interactive Generalized Method of Moments estimators from which thresholds are computed contingent on the validity of tested hypotheses. First, the Gini coefficient should not exceed 0.5618 in order for 'internet access in school' to positively affect inclusive education. Second, the poverty headcount ratio at national poverty lines (% of the population) should remain below 33.6842% in order for 'internet access in school' to favorably influence inclusive education. Third, the Palma ratio should not exceed 3.3766 in order for internet penetration to favorably affect inclusive education. Fourth, for personal computers to increase inclusive education, the Gini coefficient, Palma ratio and poverty headcount (% of the population) should not exceed 0.4781, 3.5294 and 17.7272, respectively. The study confirms the significant role technological deepening plays in advancing inclusive education by means of policies that reduce poverty and income inequality, with potentially wider applicability to other developing economies. The study has provided poverty and inequality levels that should not be exceeded in order for personal computers, internet penetration, and 'internet access in school' to promote gender-inclusive education.

Paper type: Research paper

Keywords: Inclusive, Education, Inequality, Technology, Thresholds.

1. Introduction

Information and communication technologies (ICTs), over the past decades, have been anticipated to improve the quality of education, the deepening of knowledge, and inclusive development (UNESCO, 2015, 2017). Corporate sustainability is also associated with inclusive development, which encompasses "*marginalized people, sectors, and countries in social, political and economic processes for increased human well-being, social and environmental sustainability, and empowerment*". Hence, inclusive education has gained renewed interest among scholars and policymakers, in the light of the fact that it is central to most SDGs (sustainable development Goals) (Asongu & Odhiambo, 2020)[1].

According to the definition presented in the post-2015 development agenda published by the United Nations Development Programme (UNDP), inclusive education refers to pooling the strengths, qualities, or skills of people in a community (World Bank, 2015). This dynamic relationship aims to make sure that all children, mainly those with special needs, can develop their full potential, autonomy, and self-determination by guaranteeing them access to the necessary learning activities (Ainscow, 1991). It encourages the whole community to favor the integration of all children in the various spheres of activity by favoring and promoting accessibility to activities in the natural environment for all children with or without disabilities. Inclusive education aims to support these people in their joint efforts for the education of the child. Inclusive education provides, among other things, tools that allow these people to sit together, clarify their mission, develop common educational projects (objectives or intervention plans), naturally support themselves in their role, learn from others and ensure children's educational success (Ajuwon, 2008; McConkey & Mariga, 2010a). The whole world attaches great importance to inclusive education. Despite this relevance, there are many gaps in equality among pupils and students with disabilities and special needs in low-income countries. Recent literature corroborates the perspective that in low-and middle-income countries, the fight against poverty is an

[1] Gender parity education, inclusive intermediary education, gender parity intermediary education and inclusive education are used interchangeably throughout the study.

essential factor for successful attempts to implement inclusive education systems (Bicaba et al., 2017; Asongu et al., 2019).

According to recent literature, researchers have described technology adoption as a channel that can enable developing countries to skip some stages of income inequality and technology exclusion to achieve inclusive education and development (Sofia & Christos, 2015). The dramatic increase in access to ICTs has been accompanied by numerous studies on their contribution to inclusive development and poverty reduction. The positioning of this research on the impact of ICT proxies and inequality on inclusive education is based on many factors. Against this background, the present research is positioned on determining the inequality thresholds that reduce the positive effect of ICTs on inclusive education in developing countries.

The closest study in the literature to the present research is Asongu et al. (2019) which assessed the nexuses between ICT, income inequality and inclusive education in 42 African countries from the period 2004-2014. The present study departs from the underlying research on at least four fronts: (i) The focus is beyond the scope of African countries because the present study focuses on developing countries. (ii) Owing to the data availability constraints (e.g. in the use of virtual social networks), this study employs data for the period 2012-2016. (iii) By extension, more ICT dynamics are engaged in this study, contrary to Asongu et al. (2019), because 'the use of virtual social network', 'internet access in school', and personal computer ownership are also taken on board. (iv) The relative pro-poor measures (i.e. inequality dynamics) used by the underlying study are complemented with an absolute pro-poor measure (i.e. poverty headcount ratio).

The rest of the article is structured as follows. In section 2, the literature review is presented by defining inclusive education as a goal of sustainable development in the context of this research. Then, thes hypotheses of this study are discussed in the same section, followed by an explanation of the methodology in section 3. Section 4 presents and discusses the empirical results. The study concludes in section 5 with implications and future research directions.

2. Literature Review

2.1 Inclusive Education as a Sustainable Development Goal

Inclusive education represents a fundamental channel for the success of a sustainable development strategy. In most sub-Saharan African countries, the education system suffers from partial special education (Anastasiou & Keller, 2011; Caldin, 2014). In these countries, the national educational systems adopted are limited in addition to special, and inclusion services that are much undeveloped. International statistics show that a low percentage of the children with special needs in the attendant countries obtain basic education (Carew et al., 2019).

According to Kniel and Kniel (2008), pupils and students with disabilities do not spend many years achieving basic education in a formal setting or are not even opportune to have the limited years of basic education in the light of the restricted opportunities in the country. It is worth noting that the United Nations Educational, Scientific and Cultural Organization (UNESCO) and multilateral donor institutions grant both technical and financial support to tackle concerns associated with deficiency in appropriate infrastructure and lack of trained teachers. Statistics confirm the perspective that countries in Sub-Saharan Africa need projects of sustainable program evaluation to supervise students with limited abilities and special needs to the special education system (Clouder et al., 2019). Researchers have suggested that combining technology tools with teachers' capabilities will solve the problem of inequality in the education system, especially in the emerging context (Srivastava & Shree, 2019). It has been shown that to manage this digital transformation needed in schools; there is also a need for the adoption of a new strategy of education (Hamburg, 2019). Researchers have shown that inclusive development is often guided by fighting against poverty and promoting inclusive education (Asongu et al., 2019).

Recently, studies have confirmed a significant difference between rural and urban schools in adopting inclusive education. However, rural schools show a poorer likelihood of implementing the accessibility requirements for an inclusive education system in resource rooms and training in sign language. The existing literature (Tikly, 2011; Le Fanu, 2014; Moreno et al., 2015) confirms the apparent gaps rural areas have in educational opportunities compared with urban areas, especially in the association with poverty. Also, recent research has been conducted on the benefits of digital tools in the educational areas of therapy and health to complement patients treated for motor, sensory and cognitive disorders.

Southgate et al. (2018) have investigated the nexus between inclusion and virtual immersive environments. The existing literature review of inclusive education shows that the diffusion of innovation and technology in schools can reduce the inequality between students and pupils with disabilities, especially in developing countries. Each pupil or student can be integrated into ordinary schools if there are appropriate mechanisms that can facilitate the accommodation of these students with special needs and disabilities. Moreover, it allows for the disadvantaged as well as persons constrained with disabilities to contribute towards societal development by liberating the maximum of their potential (Bakhshi et al., 2013; Ametepee & Anastasiou, 2015; Asongu et al., 2019).

In the light of the above insights from the extant literature, the following testable hypotheses can be formulated:

H_1. ICT has a positive impact on enhancing inclusive education.

H_2. Income inequality and poverty independently have a negative impact on inclusive education.

2.2 The interaction between ICT and inequality to stimulate inclusive education

According to a UNESCO publication (UNESCO, 2013), we can consider an education system as inclusive if schools provide an inclusive and equal education system to all children. When comparing low-income and high-income countries, there is a considerable gap in school integration in terms of the need for an inclusive education system that entails, *inter alia*, resource rooms, interpretation of sign language and measures to boost children's inclusion. Inequality in this context negatively influences the social inclusion of all children and students with special needs and disabilities.

Macroeconomic facts on the incidence of ICTs on inclusive development are growing at the national level. Several studies have reviewed the substantial bulk of extant literature, which confirms the relevance of ICT in driving economic growth. Given that ICT is playing a role in the inclusive development agenda at the global level, a steady decrease in absolute poverty is being experienced by emerging countries. It is also important to note that a major policy orientation in low-income countries has consisted of tailoring ICTs for inclusive development outcomes (Mariga et al., 2014). The corresponding analysis at the microeconomic level articulates the effects and channels through which ICTs boost economic prosperity and promote inclusive socio-economic development (Ali et al., 2020).

The present study is fundamental to investigating how much developing countries can profit from ICTs, mainly owing to the fact that citizens of the attendant countries allocate a significant portion of their income to technology adoption (Neaime & Gaysset, 2018; Asongu et al., 2019; Tchamyou et al., 2019a). In the same light of inclusive education, a recent literature review confirms the important association between ICTs and economic outcomes such as income inequality and economic boom (Asongu et al., 2019). The neoclassical theory supports the outlook on the relevance of ICTs in promoting inclusive development by means of economic prosperity (Kwan & Chiu, 2015; Asongu & Nwachukwu, 2018; Asongu et al., 2020).

Previous research conducted on sub-Saharan African countries has proven the existence of linkages between technology adoption and socio-economic development factors such as inclusive education. Therefore, whereas the research question is different from the underlying studies, more indicators such as ICT in schools and the use of the virtual social network are adopted in this research. These studies found that poverty reduction can be promoted by ICT through education for different explanations. Firstly, if technology adoption helps persons who are suffering from physical problems and disabilities (Asongu, 2015; Efobi *et al*., 2018), the corresponding favorable externalities can be more apparent when potential beneficiaries are well-informed on the advantages of leveraging information and communication digital tools to reduce such physical movements (Schuster et al., 2019). Secondly, digital tools provide people and firms with timely information. Thirdly, technology adoption can reduce the problem of asymmetric information, which represents transactions costs to governments, corporations and households (Tchamyou et al., 2019a, 2019b). The corresponding testable hypothesis is:

H_3. Inequality and poverty independently dampen the favorable effect of ICT on inclusive education

3. Data and Methodology

3.1 Data

To examine how technology adoption influences inclusive education contingent on inequality, we are consistent with the previous papers in merging data collected from various sources (Neaime & Gaysset, 2018; Ali et al., 2020; Tchamyou et al., 2019b; Asongu et al., 2019). The dynamic generalized method of moments (GMM) was employed in 57 developing countries for the period 2012-2016. The motivation for the temporal scope is determined by constraints in data available when the study was carried out. The first set of variables includes the indicators related to technology adoption collected from the World Economic Forum (WEF) and the Global Information Technology Report (GITR). The second set of indicators constitutes both inclusive and macroeconomic variables which are sourced from the World Development Indicators (WDI) of the World Bank, while the third entails indicators linked with ICTs, which are obtained from the database of the International Telecommunications Union (ITU).

Table 1 discloses the different sources of data and provides short definitions of all variables used in this paper. The list of countries along with regions and income levels used are provided in Table 2. Following recent literature, we control for remittances (Asongu et al., 2019). A schematic presentation of the hypotheses underpinning the study is reported in Figure 1. The summary statistics and the correlation matrix are presented in Tables 2 and 3.

It is important to clarify that though there are growing arguments on the importance of engaging more women in science education (Elu, 2018; Elu & Price, 2017), "*compared to the higher level of education and nursery education, the intermediary level of education (i.e. primary and secondary educational levels) has been documented to be more associated with positive macroeconomic externalities when countries are at initial stages of industrialization (Asiedu, 2014). For this reason, this study puts more emphasis on intermediary gender parity education*" (Asongu et al., 2021, p.2).

Figure 1. Theoretical framework and hypotheses

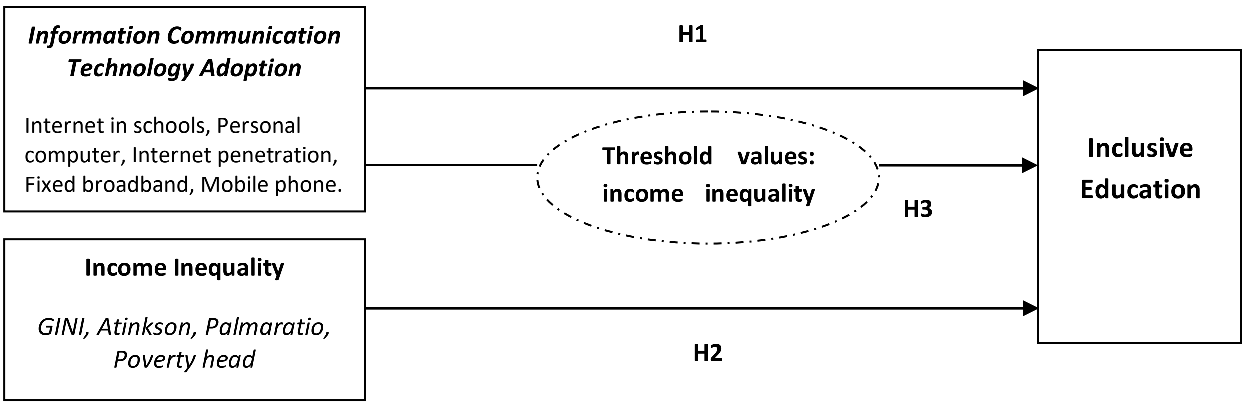

Table 1. Variables' definitions

Variables	**Definitions**	**Sources**
Inclusive education	School enrolment, primary and secondary (gross), gender parity index (GPI)	WDI
ICT adoption		
Internet access in schools	Internet access in schools	GTIR
Network	Use of virtual social network	GTIR
Internet penetration	Internet users (per 100 people)	WDI
Fixed broadband	Fixed broadband subscriptions (per 100)	WDI
Personal computer	Percentage of person equipped with a personal	WDI

	computer	
Mobile phone	Mobile cellular subscriptions (per 100 people)	WDI
Income inequality and Poverty		
Gini index	The Gini index is a measurement of the income distribution of a country's residents	GCIP
Atkinson index	The Atkinson index measures inequality by determining which end of the distribution contributed most to the observed inequality	GCIP
Palma ratio	The Palma ratio is defined as the ratio of the richest 10% of the population's share of gross national income divided by the poorest 40 % share".	GCIP
Poverty head ratio	Poverty headcount ratio at national poverty lines (% of the population)	WDI
Control variable		
Remittances	Remittances inflows to GDP (%)	WDI

Notes: **WDI:** World Bank Development Indicators. **GITR**: The Global Information Technology Report 2016. **GCIP**: Global Consumption and Income Project.

Table 2. Summary statistics

Variables	Observations	Mean	Std. Dev.	Min	Max
Inclusive education	285	0.9664608	0.0812813	0.69263	1.09519
Gini	285	0.5015195	0.0882828	0.257765	0.635562
Atkinson	285	0.5735448	0.1444646	0.191033	0.782067
Palma ratio	285	4.247133	1.93401	0.885076	8.40988
Poverty head	285	28.24167	15.76583	0.4	66.5
Mobile phone	285	73.44091	37.82005	8.26	175.302
Internet penetration	285	15.88425	14.41101	0.21	56.8
Personal computer	285	12.85059	14.8867	0.13	87.5
Fixed broadband	285	1.465743	2.824173	0.001	23.2193
Internet access in schools	285	3.001625	1.173599	1.339	5.05055
Use of virtual social network	285	4.472844	1.420783	2.57	6.23457
Remittances	285	4.057326	5.676065	0.0045	29.5917

Notes: Std.dev: standard deviation, **Min**= Minimum, **Max=**Maximum. **Inclusive education =** School enrolment, primary and secondary (gross), gender parity index (GPI), **Gini=** is a measurement of the income distribution of a country's residents, **Atinkson=** measures the percentage of total income that a particular society has to forego in order to improve citizens' share of income, **Palma ratio=** represents the ratio of national income shares of the top 10 per cent of households relative to the bottom 40 per cent, **Poverty head=** Poverty headcount ratio at national poverty lines (% of the population), **Mobile phone=** Mobile cellular subscriptions (per 100 people), **Internet penetration** = Internet users (per 100 people), **Personal computer** = Percentage of person equipped with a personal computer, **Fixed broadband =** Fixed broadband subscriptions (per 100), **Internet access in schools=** Use of internet in schools, **Use of virtual social network =** Use of virtual social network, **Remittances=** Remittances inflows to GDP (%).

Countries (57): Armenia, Bangladesh, Benin, Bhutan, Bolivia, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Chad, Côte d'Ivoire, Egypt, El Salvador, Ethiopia, Gambia, Georgia, Ghana, Guatemala, Guinea, Guyana, Haiti, Honduras, India, Indonesia, Kenya, Kyrgyz Republic, Lao PDR, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Moldova, Morocco, Mozambique, Myanmar, Nepal, Nicaragua, Nigeria, Pakistan, Philippines, Rwanda, Senegal, Sierra Leone, Sri Lanka, Swaziland, Syria, Tajikistan, Timor-Leste, Uganda, Ukraine, Vietnam, Yemen, Zambia and Zimbabwe.

3.2 Methodology

The research model was developed based on the latest studies focusing on the GMM estimations technique. This paper employs the GMM estimation approach for a multitude of reasons articulated in the extant literature (Tchamyou et al., 2019a; Asongu & Odhiambo, 2020).

The first argument for adopting a GMM estimation model is the higher number of periods for each country in our sample. The cross-sections exceed the number of periods. Accordingly, the estimation is conducted for five periods from 57 countries. Hence, it is apparent that years are less than 57 countries in numerical value. An unbalanced annual panel dataset for the period 2012-2016 is used. The motivation for the adopted periodicity was informed by data availability constraints when the study was done. All the independent variables were included as there were no high correlations between them. According to the goodness of fit information criterion on persistence, it is apparent from the correlation matrix that the level series of the inclusive education variable is closely connected to its first lag series.

In the light of the above, the nature of the inclusive education model often has a dynamic effect because it is closely connected to its earlier value. Accordingly, it has been reported in the recent empirical studies that researchers should consider the dynamic effect when conducting panel data estimation (Neaime & Gaysset, 2018; Tchamyou et al., 2019b; Vu & Asongu, 2020). This is usually established by adding a lagged dependent variable as an explanatory variable in the model. Hence, the correlation matrix in Table 3 indicates that inclusive education exhibits persistence since its correlation coefficient corresponding to the level and first lag series is as high as 0.997 (Asongu et al., 2018; Asongu & Odhiambo, 2019; Tchamyou et al., 2019a). Ultimately, given that the structure of the dataset is a panel, the GMM approach on which it is applied enables cross-country differences to be taken on board.

The following equations in level (1) and first difference (2) summarize the standard *system* GMM estimation procedure.

$$IE_{i,t} = \sigma_0 + \sigma_1 IE_{i,t-\tau} + \sigma_2 IT_{i,t} + \sigma_3 IQ_{i,t} + \sigma_4 ITIQ_{i,t} + \sigma_5 R_{i,t} + \eta_i + \xi_t + \varepsilon_{i,t}$$

(1)

$$IE_{i,t} - IE_{i,t-\tau} = \sigma_1(IE_{i,t-\tau} - IE_{i,t-2\tau}) + \sigma_2(IT_{i,t} - IT_{i,t-\tau}) + \sigma_3(IQ_{i,t} - IQ_{i,t-\tau}) + \sigma_4(ITTQ_{i,t} - ITIQ_{i,t-\tau}) + \sigma_5(R_{i,t} - R_{i,t-\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau})$$

(2)

Where, $IE_{i,t}$ represents an indicator of inclusive education (i.e. "School enrolment, primary and secondary (gross), gender parity index (GPI)") of country i in period t, σ_0 is a constant, IT entails information and communication technology (internet access in school, use of virtual social network, internet penetration, fixed broadband subscriptions, personal computers and mobile phone penetration), IQ reflects an income inequality measurement (i.e. the Gini coefficient, the Palma ratio and the Atkinson index), $ITIQ$ entails interactions between ICT and inequality indicators, R represents remittances, τ is the coefficient of auto-regression which is one within the framework of this study because a one year lag appropriately captures past information, ξ_t is the time-specific constant, η_i is the country-specific effect and $\varepsilon_{i,t}$ the error term.

Table 3. Correlation matrix

	INC	INC(-1)	GINI	ATK	PALM	POV	MOB	INTER	FIX	COMP	ICTS	NET	REM
INC	1												
INC(-1)	0.991	1											
GINI	-0.022	-0.004	1										
ATK	-0.068	-0.049	0.943	1									
PALM	-0.081	-0.053	0.923	0.943	1								
POV	0.036	0.033	0.029	0.103	0.066	1							
MOBILE	0.104	0.112	-0.111	-0.118	-0.179	0.040	1						
INTER	0.204	0.185	-0.188	-0.133	-0.183	0.078	0.632	1					
FIX	0.166	0.150	-0.148	-0.143	-0.234	-0.013	0.526	0.711	1				
COMP	0.104	0.101	-0.054	-0.066	-0.143	0.092	0.331	0.578	0.538	1			
ICTSC	0.207	0.200	-0.179	-0.160	-0.173	-0.020	0.710	0.621	0.523	0.185	1		
NET	0.156	0.181	-0.031	-0.006	-0.004	0.070	0.694	0.519	0.344	0.082	0.821	1	
REM	0.107	0.085	0.036	0.177	0.052	0.324	0.099	0.212	0.128	0.090	0.032	0.075	1

Notes: **INC=** School enrolment, primary and secondary (gross), gender parity index (GPI) **, INC(-1)=** School enrolment, primary and secondary (gross), gender parity index t-1 (GPI)**, Gini=** is a measurement of the income distribution of a country's residents**, ATK=** measures inequality by determining which end of the distribution contributed most to the observed inequality**, PALM=** Poverty headcount ratio at national poverty lines (% of the population).**, POV=, MOB=** Mobile cellular subscriptions (per 100 people)**, Com=** Percentage of person equipped with a personal computer, **INTER=** Internet users (per 100 people)**, Fix=** Fixed broadband subscriptions (per 100)**, ICTS=** Internet access in schools, **Net=** Use of virtual social network**, REM=** Remittances inflows to GDP (%).

4. Empirical results

The empirical findings are disclosed in this section in Tables 4-6. Table 4 presents results pertaining to linkages between 'internet access in school', 'use of virtual social network', inequality, poverty and inclusive education. Table 5 focuses on nexuses between internet penetration, fixed broadband subscriptions, inequality, poverty and inclusive education, while Table 6 is concerned with nexuses between computer usage, mobile phone penetration, inequality, poverty and inclusive education. Each table consists of eight specifications with four specifications corresponding to each ICT dynamic. For each ICT dynamics, four corresponding specifications are relevant to regressions involving, the Gini coefficient, the Atkinson index, the Palma ratio and the poverty headcount ratio. In accordance with GMM-centric literature, four criteria of information are used to assess the validity of results [2]. Based on these criteria, the estimated models are valid overwhelmingly.

In the light of the tested hypotheses, it is important to note that thresholds at which inequality and poverty dampen the positive relevance of ICT dynamics on inclusive education are only computed when two conditions are met: (i) ICT has a positive incidence on inclusive education (i.e. the validity of Hypothesis 1) and (ii) the interactions between 'inequality and ICT' or between 'poverty and ICT' have a negative incidence on the outcome variable (i.e. the validity of Hypothesis 3). Moreover, in the corresponding specifications in which Hypotheses 1 and 3 are valid, Hypothesis 2 is also overwhelming valid. It follows that in the presentation of results in Tables 4-6: (i) 'not applicable' (n.a) is assigned to the space provided for thresholds when at least one estimated coefficient needed for the computation of thresholds is not significant and (ii) 'not specifically applicable' (n.s.a) is assigned either

[2] "*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 Fisher test for the joint validity of estimated coefficients is also provided*" (Asongu & De Moor, 2017, p.200).

because the model is invalid or the corresponding threshold has the unexpected signs.

It is worthwhile to put the computation of thresholds in more perspective with an example. In the second column of Table 4, corresponding to the first specification, the threshold related to the Gini coefficient is 0.5618 (0.0309/0.0550). In this computation, 0.0309 corresponds to the unconditional incidence of 'internet access in school' on inclusive education while 0.055 is the absolute value of the interactive estimation between the Gini coefficient and 'internet access in school'. This computation framework to provide more insights for policy prescription is consistent with contemporary interactive regressions literature (Tchamyou, 2019; Asongu & Acha-Anyi, 2020). It follows that in order for the incidence of 'internet access in school' on inclusive education to remain positive, inequality, as proxied by the Gini coefficient should not exceed 0.5618.

The following main findings can be established in Table 4. First, the Gini coefficient should not exceed 0.5618 in order for 'internet access in school' to positively affect inclusive education. Second, the poverty headcount ratio at national poverty lines (% of the population) should remain below 33.6842% in order for 'internet access in school' to favorable influence inclusive education. Third, for the use of the virtual social networks to promote inclusive education, the Palma ratio should be less than 9.1153. Unfortunately, the Palma ratio is not within the statistical range (i.e. 0.8850 to 8.4098) provided in the summary statistics. Conversely in Table 5, the Palma ratio that should not exceed 3.3766 for internet penetration to favorably affect inclusive education is within statistical/policy range. In Table 6, for personal computers to increase inclusive education, the Gini coefficient, Palma ratio and poverty headcount should not exceed 0.4781, 3.5294 and 17.7272%.

Table 4. ICT in school, social network, inequality, poverty and inclusive education

	Dependent variable: School enrolment, primary and secondary (gross), gender parity index (GPI)	
	Internet access in school (ICTschool)	Use of Virtual social network(Network)

Variables and information criteria	*Gini*	*Atkinson*	*Palma Ratio*	*Poverty Head*	*Gini*	*Atkinson*	*Palma Ratio*	*Poverty Head*
Constant	0.3096 **(0.000)*****	0.438 **(0.000) *****	0.3459 **(0.000) *****	0.3292 **(0.000)*****	0.3995 **(0.000) *****	0.351 **(0.000) *****	0.3157 **(0.000**) *******	0.3535 **(0.000) *****
Inc (-1)	0.5797 **(0.000) *****	0.618 **(0.000) *****	**0.6416 (0.000) *****	**0.6076 (0.000) *****	0.5974 **(0.000) *****	0.632 **(0.000) *****	0.6586 **(0.000) *****	0.6354 **(0.000) *****
ICT in school	0.0309 **(0.002) *****	-0.0190 **(0.000) ****	0.0019 **(0.004)* ****	0.0128 **(0.000) *****	---	---	---	---
Use of Network	---	---	---	---	0.0074 (0.436)	0.0026 **(0.035)****	0.00474 **(0.000) *****	-0.0032 **(0.000) *****
Gini	0.1710 **(0.045) ****	---	---	---	-0.0244 (0.780)	---	---	---
Atkinson	---	-0.141 **(0.000)*****	---	---	---	-0.0172 **(0.085)***	---	---
Palma ratio	---	---	-0.0025 **(0.091) ***	---	---	---	0.00036 (0.636)	---
Poverty Head	---	---	---	0.0015 **(0.000)*****	---	---	---	-0.00012 (0.130)
Gini ×ICTschool	-0.0550 **(0.007)*****	---	---	---	---	---	---	---
Gini ×Network	---	---	---	---	-0.0138 (0.435)	---	---	---
Atkinson ×ICTschool	---	0.0396 **(0.000)*****	---	---	---	---	---	---
Atkinson ×Network	---	---	---	---	---	-0.00034 (0.854)	---	---
Palma×ICTschool	---	---	0.00035 **(0.012)****	---	---	---	---	---
Palma ×Network	---	---	---	---	---	---	-0.00052 **(0.000)*****	---
Poverty ×ICTschool	---	---	---	-0.00038 **(0.000)*****	---	---	---	---
Poverty×Network	---	---	---	---	---	---	---	0.00014 **(0.000)*****
Remittances	0.0008 **(0.000) ****	0.00061 **(0.000) *****	0.0003 **(0.000)*****	0.00025 **(0.009) *****	0.00025 (0.333)	0.00068 **(0.000) *****	0.000267 (**0.003) *****	-0.00010 **(0.026) ****
Time effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Thresholds	0.5618	nsa	nsa	33.6842	na	na	9.1153	nsa
AR(1)	(0.047)	(0.094)	(0.094)	(0.082)	(0.050)	(0.095)	(0.091)	(0.094)
AR(2)	**(0.831)**	**(0.798)**	**(0.826)**	**(0.823)**	**(0.316)**	**(0.764)**	**(0.822)**	**(0.778)**
Sargan OIR	(0.026)	(0.088)	(0.074)	(0.043)	(0.014)	(0.097)	(0.010)	(0.038)
Hansen OIR	**(0.708)**	**(0.651)**	**(0.586)**	**(0.597)**	**(0.614)**	**(0.393)**	**(0.279)**	**(0.559)**
DHTfor instruments								
(a)GMM instruments for levels **H excluding group** **DIF (null, H=exogenous)**	**(0.639)** **(0.612)**	**(0.412)** **(0.832)**	**(0.396)** **(0.754)**	**(0.738)** **(0.363)**	**(0.695)** **(0.709)**	**(0.468)** **(0.321)**	**(0.324)** **(0.313)**	**(0.503)** **(0.549)**
(b)IV(year , eq(diff)) **H excluding group** **Dif(null, H=exogenous)**	**(0.658)** **(0.888)**	**(0.611)** **(0.875)**	**(0.547)** **(0.783)**	**(0.566)** **(0.728)**	**(0.765)** **(0.688)**	**(0.368)** **(0.533)**	**(0.305)** **(0.177)**	**(0.517)** **(0.874)**
Fisher	**284.98*****	**34444.17* ****	**8832.2*****	**442.1*****	**2031.75** ***	**5352.08** ***	**3763.9*****	**7367.41*****
Instruments	33	33	33	33	33	33	33	33
Countries	57	57	57	57	57	57	57	57
Observations	285	285	285	285	285	285	285	285

Note: p values are reported in brackets. *** (p< .01),** (p < .05),* (p < .10): Significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Overidentifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher 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. n.a: not applicable because at least one estimated coefficient needed for the computation of thresholds is not significant. nsa: not specifically applicable either because the model is invalid or the corresponding thresholds has the unexpected signs.

Table 5. Internet penetration, fixed broadband, inequality, poverty and inclusive education

	Dependent variable: School enrolment, primary and secondary (gross), gender parity index (GPI)							
	Internet penetration (Internet)				**Fixed broadband (BroadB)**			
Variables and information criteria	*Gini*	*Atkinson*	*Palma ratio*	*Poverty head*	*Gini*	*Atkinson*	*Palma ratio*	*Poverty head*
Constant	0.077 **(0.000) *****	0.098 **(0.000) *****	0.082 **(0.000) *****	0.0062 **(0.000) *****	0.0400 **(0.000) *****	0.0751 **(0.000) *****	0.0641 **(0.000) *****	0.0133 (0.656)
Inc (-1)	0.909 **(0.000)*****	0.900 **(0.000) *****	0.914 **(0.000) *****	0.997 **(0.000) *****	0.9572 **(0.000) *****	0.9456 **(0.000)*****	0.9365 **(0.000) *****	0.9872 **(0.000) *****
Internet penetration	0.0004 (0.143)	0.00012 (0.575)	0.000286 **(0.019) ****	0.000035 (0.767)	---	---	---	---
Fixed Broadband (BroadB)	---	---	---	---	0.00056 (0.799)	-0.00406 **(0.001)*****	0.00035 (0.453)	0.000256 (0.434)
Gini	0.0254 **(0.016) ****	---	---	---	0.0110 (0.213)	---	---	---
Atkinson	---	0.00145 (0.782)	---	---	---	-0.03164 **(0.001)**	---	---
Palma ratio	---	---	0.001044 **(0.079)***	---	---	---	0.0004 **(0.038)**	---
Poverty head	---	---	---	0.0001486 **(0.001) *****	---	---	---	0.00022 (0.366)
Gini ×Internet	-0.00075 (0.200)	---	---	---	---	---	---	---
Gini ×BroadB	---	---	---	---	-0.00208 (0.649)	---	---	---
Atkinson×Internet	---	-0.000207 (0.615)	---	---	---	---	---	---
Atkinson× BroadB	---	---	---	---	---	0.006366 **(0.002)*****	---	---
Palma × Internet	---	---	-0.0000847 **(0.012)**	---	---	---	---	---
Palma ×BroadB	---	---	---	---	---	---	-0.000213 (0.144)	---
Poverty × Internet	---	---	---	- 0.0000135 **(0.000)**	---	---	---	---
Poverty × BroadB	---	---	---	---	---	---	---	-0.000319 **(0.001) *****
Remittances	0.0002 **(0.000)*****	0.0003 **(0.000) *****	0.00021 **(0.036) ****	0.0006 **(0.001) *****	-0.0000 (0.757)	0.00018 **(0.020) ****	0.00006 (0.267)	-0.0005 (0.825)
Time effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Thresholds	na	na	3.3766	Na	na	Nsa	na	na
AR(1)	(0.036)	(0.033)	(0.033)	(0.089)	(0.030)	(0.032)	(0.031)	(0.017)
AR(2)	**(0.316)**	**(0.262)**	**(0.291)**	**(0.250)**	**(0.314)**	**(0.319)**	**(0.315)**	**(0.296)**
Sargan OIR	**(0.920)**	**(0.835)**	**(0.825)**	**(0.692)**	**(0.979)**	**(0.915)**	**(0.935)**	**(0.394)**
Hansen OIR	**(0.613)**	**(0.623)**	**(0.652)**	**(0.990)**	**(0.486)**	**(0.467)**	**(0.323)**	**(0.978)**
DHT for instruments (a)GMM instruments for levels H excluding group	(0.009) **(0.496)**	(0.057) **(0.542)**	(0.061) **(0.497)**	(0.015) **(0.562)**	(0.048) **(0.470)**	(0.036) **(0.542)**	(0.074) (0.096)	(0.067) **(0.851)**
DIF (null, H=exogenous) (b)IV(year , eq(diff)) H excluding group Dif(null, H=exogenous)	**(0.581) (0.530)**	**(0.630) (0.296)**	**(0.611) (0.638)**	**(0.985) (1.000)**	**(0.432) (0.892)**	**(0.421) (0.691)**	**(0.276) (0.909)**	**(0.969) (0.994)**
Fisher	**1.11e+06*****	**23193.29*****	**266736.51*****	**610880*****	**1.56e+06*****	**111952*****	**47854.8*****	**117304*****
Instruments	33	33	33	33	33	33	33	33

Countries	57	57	57	57	57	57	57	57
Observations	285	285	285	285	285	285	285	285

Note: p values are reported in brackets. *** (p< .01),** (p < .05),* (p < .10): Significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Overidentifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher 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 because at least one estimated coefficient needed for the computation of net effects is not significant. nsa: not specifically applicable because the conditional effect between ICT and inequality is not negative. n.a: not applicable because at least one estimated coefficient needed for the computation of thresholds is not significant. nsa: not specifically applicable either because the model is invalid or the corresponding thresholds has the unexpected signs.

Table 6. Personal computers, mobile phones, inequality, poverty and inclusive education

	Dependent variable: School enrolment, primary and secondary (gross), gender parity index (GPI)							
	Personal Computers (Computer)				**Mobile phone (Mobile)**			
Variables and information criteria	*Gini*	*Atkinson*	*Palma ratio*	*Poverty head*	*Gini*	*Atkinson*	*Palma ratio*	*Poverty Head*
Constant	0.0534 **(0.000) *****	0.0837 **(0.000) *****	0.0684 **(0.000) *****	0.00209 (0.740)	0.0172 **(0.012) ****	0.0354 **(0.000) *****	0.0261 **(0.000) *****	0.00158 (0.901)
Inc (-1)	0.9364 **(0.000) *****	0.9245 **(0.000) *****	0.9339 **(0.000) *****	0.9948 **(0.000) *****	0.9828 **(0.000) *****	0.9778 **(0.000) *****	0.9920 **(0.000) *****	1.005 **(0.000) *****
Computer	0.000899 **(0.000) *****	0.00012 (0.245)	0.00024 **(0.000) *****	0.00039 **(0.038) ****	---	---	---	---
Mobile	---	---	---	---	0.0001 (0.167)	0.0002 (0.605)	-0.00007 **(0.017) ****	-0.00004 (0.261)
Gini	0.02438 **(0.018) ****	---	---	---	0.01670 (0.178)	---	---	---
Atkinson	---	-0.01177 **(0.007)*****	---	---	---	-0.0081 (0.407)	---	---
Palma ratio	---	---	-0.00036 (0.430)	---	---	---	-0.0018 **(0.021) ****	-
Poverty head	---	---	---	0.00039 **(0.017) ****	---	---	---	0.00013 (0.538)
Gini ×Computer	-0.00188 **(0.000) *****	---	---	---	---	---	---	---
Gini ×Mobile	---	---	---	---	-0.0003 **(0.011) ****	---	---	---
Atkinson×Computer	---	-0.0003 (0.126)	---	---	---	---	---	---
Atkinson×Mobile	---	---	---	---	---	-0.00018 **(0.020) ****	---	---
Palma ×Computer	---	---	-0.000068 **(0.000)**	---	---	---	---	---
Palma ×Mobile	---	---	---	---	---	---	-2.762 (0.595)	---
Poverty ×Computer	---	---	---	-0.000022 **(0.000)**	---	---	---	---
Poverty ×Mobile	---	---	---	---	---	---	---	-1.93 (0.531)
Remittances	0.00006 **(0.044) ****	0.00019 **(0.008)*****	0.0002 **(0.031) ****	0.0003 **(0.098) ***	-0.0001 **(0.028) ****	0.00008 **(0.040) ****	0.00003 (0.654)	0.00019 (0.331)
Time effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Thresholds	0.4781	nsa	3.5294	17.7272	na	na	Na	na
AR(1)	(0.042)	(0.035)	(0.040)	(0.010)	(0.044)	(0.046)	(0.048)	(0.220)
AR(2)	**(0.317)**	**(0.316)**	**(0.321)**	**(0.298)**	**(0.309)**	**(0.309)**	**(0.298)**	**(0.282)**
Sargan OIR	(0.077)	(0.048)	(0.048)	(0.047)	(0.021)	(0.013)	(0.0691)	(0.012)
Hansen OIR	**(0.568)**	**(0.406)**	**(0.676)**	**(0.499)**	**(0.668)**	**(0.609)**	**(0.574)**	**(0.347)**
DHT for instruments								

(a)GMM instruments for levels H excluding group DIF (null, H=exogenous)	(0.091) **(0.280)**	(0.047) **(0.149)**	(0.074) **(0.408)**	(0.012) **(0.339)**	(0.046) **(0.711)**	(0.036) **(0.460)**	(0.066) **(0.288)**	(0.015) **(0.485)**
(b)IV(year, eq(diff)) H excluding group Dif(null, H=exogenous)	**(0.515) (0.835)**	**(0.356) (0.821)**	**(0.656) (0.447)**	**(0.967) (0.851)**	**(0.622) (0.732)**	**(0.554) (0.913)**	**(0.531) (0.639)**	**(0.966) (1.000)**
Fisher	**71235.6*****	**81547.6*****	**286541*****	**154938*****	**94601*****	**21065.95*****	**18596.79*****	**63535.47*****
Instruments	33	33	33	33	33	33	33	33
Countries	57	57	57	57	57	57	57	57
Observations	285	285	285	285	285	285	285	285

Note: p values are reported in brackets. *** (p< .01),** (p < .05),* (p < .10): Significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Overidentifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher 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 because at least one estimated coefficient needed for the computation of net effects is not significant. nsa: not specifically applicable because the conditional effect between ICT and inequality is not negative. n.a: not applicable because at least one estimated coefficient needed for the computation of thresholds is not significant. nsa: not specifically applicable either because the model is invalid or the corresponding thresholds has the unexpected signs.

5. Concluding implication and future research directions

The purpose of the study has been to investigate nexuses between dynamics of ICT, poverty, income inequality and inclusive education in order to provide inequality and poverty thresholds that, when exceeded, dampen the favorable effect of ICT in promoting gender-inclusive education in 57 developing countries for the period 2012-2016. Poverty is measured with the poverty headcount ratio at national poverty lines (% of the population).In contrast, three proxies of inequality are considered, namely: the Gini coefficient, the Atkinson index and the Palma ratio. The engaged ICT indicators include fixed broadband subscriptions, internet penetration, mobile phone penetration, personal computers, 'internet access in school' and 'virtual social network'. Interactive GMM is employed as the empirical strategy for the study, and three main hypotheses are tested from which scholarly- and policy-relevant findings are established.

First, the Gini coefficient should not exceed 0.5618 in order for 'internet access in school' to positively affect inclusive education. Second, the poverty headcount ratio at national poverty lines (% of the population) should remain below 33.6842% in order for 'internet access in school' to favorably influence inclusive education. Third, the Palma ratio should not exceed 3.3766 in order for internet penetration to favorably affect inclusive education. Fourth, for personal computers to increase inclusive education, the Gini coefficient, Palma ratio and poverty headcount (% of the population) should not respectively, exceed, 0.4781, 3.5294 and 17.7272.

In the light of the above, this study has both scholarly and practical relevance because corresponding findings provide poverty and inequality levels that should not be exceeded in order to personal computers, internet penetration and 'internet access in school' to promote gender-inclusive education. The established critical masses make economic sense and have policy relevance because they are within the statistical limits provided in the summary statistics. In a nutshell, the findings have also confirmed the significant role technological deepening plays in advancing inclusive education by means of policies that reduce poverty and income inequality, with potentially wider applicability to other developing economies.

Beyond the above immediate tangible implications, it is also worth noting that this study's findings are particularly relevant to SDG 5 (i.e. "*achieve gender equality and empower all women and girls*"). Therefore, given the corresponding SDG, gender equality in education and by extension, the empowerment of girls and women can be feasibly enhanced when policies promoting ICT access and deepening are complemented with inclusive development measures that reduce income inequality and poverty. The essence of promoting ICT penetration simultaneously with policies designed to reduce inequality and poverty is twofold: (i) most of the sampled developing countries were still far from achieving the millennium development goal (MDG) extreme poverty target about five years ago (Asongu & le Roux, 2019; Tchamyou, 2020a, 2020a) despite a common denominator of growth resurgence and (ii) current projections establish that unless poverty and inequality are mitigated by means of inclusive growth, most of the countries will not achieve many poverty- and inequality-oriented SDGs (Bicaba et al., 2017). It follows that as a policy implication, to promote gender empowerment and by extension, gender equality as well as other

SDGs linked to poverty and income inequality, ICT access and inclusive development policies should be adopted in the light of the established policy critical masses or thresholds in this study.

In summary, the above recommendations are particularly relevant in the formulation of concrete education and development policies in the context of a developing country setting because while approximately 160 trillion USD in global GDP is lost as a result of gender economic exclusion, most of the attendant loss is apparent in developing countries (World Bank, 2018).

It is important to clarify how the findings have largely gone in the established direction has been discussed in Section 2. Accordingly, these findings have, for the most part shown that inequality and poverty levels need to be kept in check in order for ICT dynamics to improve inclusive education in the sampled countries. While measures by which poverty and inequality can be reduced do not directly emerge from the empirical analysis, the following suggestions are worth considering by sampled countries in view of reducing poverty and inequality: increasing the minimum wage, expanding earned income tax, building assets for working families, fighting residential segregation and making the tax code more progressive.

Future studies can unfold this strand of research by considering other inclusive development mechanisms by which inclusive gender education and by extension, inclusive gender economic participation can be enhanced. Moreover, taking on board other SDGs within the framework of how they are affected by income inequality and poverty by means of ICT dynamics is worthwhile.

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