Information technology, inequality and adult literacy in developing countries

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Abstract
The study assesses linkages between information technology, inequality and adult literacy in 57 developing countries for the period 2012-2016. Income inequality is measured with the Gini coefficient while six dynamics of information technology are taken on board, namely: use of virtual social network, internet access in schools, internet penetration, mobile phone penetration, fixed broadband subscription and number of personal computer users. The findings show that only internet access in schools unconditionally promotes adult literacy. The corresponding inequality threshold that should not be exceeded in order for internet access in schools to continue promoting adult literacy is 0.739 of the Gini coefficient. Policy implications are discussed.

1. Introduction

The motivational factors underpinning the focus of this study on nexuses between information technology, income inequality and adult literacy, can be articulated along three main perspectives, notably: (i) the high potential for information technology ramifications in developing countries; (ii) the relevance of adult literacy in economic development and (iii) gaps in the attendant literature. These considerations are clarified in the subsequent paragraphs in the same chronology as highlighted.

First, over the past decades, the lives of many people have changed because of the increasing penetration of information technology which has enabled many individuals, businesses and governments to communicate more effectively, operate more efficiently and avoid costs, *inter alia* (Afutu-Kotey, Gough & Owusu, 2017; Abor, Amidu & Issahaku, 2018; Uduji & Okolo-Obasi, 2018a, 2018b; Gosavi, 2018; Asongu & Asongu, 2018; Issahaku, Abu & Nkegbe, 2018;

Humbani & Wiese, 2018; Minkoua Nzie, Bidogeza & Ngum, 2018). There is also a consensus in the literature that while such information technology penetration has almost reached saturation levels in technically advanced countries, developing nations and least developed countries still exhibit a high potential for the attendant penetration (Lashitew, van Tulder & Liasse, 2019; Tchamyou, Asongu, Odhiambo, 2019a; Tchamyou, Erreygers & Cassimon, 2019b; Asongu & Odhiambo, 2020). The growing uptake of the underlying information technology has facilitated innovation in many sectors; including the fostering of education systems where it is now possible to, *inter alia*, build on digital frameworks for distance learning which is leveraged by adults for the purpose of improving their literacy levels.

Second, adult literacy is particularly important in economic development and information technology is a means by which such education can be enhanced, especially in the light of the fact that adult learning is largely devoted to mature students who are already involved in the workforce. It follows that adult literacy is a means of human resource development because it provides workers, *inter alia*, with the opportunity of expanding their knowledge and gaining new skills (Blunch & Portner, 2011; Blunch, 2017; Allatt & Tett, 2019). In essence, the adult literacy rate within the remit of this study is the percentage of people aged 15 and above, who can both read and write in order to communicate effectively.

This study investigates how income inequality affects the nexus between information technology and adult literacy in the light of an apparent gap in the scholarly literature.

Third, the extant literature on adult literacy has focused on various areas of research, *inter alia*: the relevance of adult learning in problem-solving skills (Kim, 2020); female gender in faculty appointments (Cherrstorm & Alfred, 2020); the rewards of adult literacy for women that are less educated (Iniguez-Berrozpe, Elboj-Saso, Flecha & Marcaletti, 2020) and the participation of migrants in adult literacy (Bagci, 2019). Concerning the nexus between information technologies and adult literacy, the underlying associations can be grouped into six main strands according to Jin, Kim and Buamgatner (2019), notably: (i) ambivalent approaches towards usage of technology; (ii) the practical importance for users; (iii) intergenerational and interpersonal communication; (iv) experience from collaborative learning; (v) self-learning in the health sector and (vi) the emotional and affective motives. The second, fourth and fifth strands which are closest to the positioning of this study are further covered below.

First, in relation to the practical relevance of mobile technologies, Jin et al. (2019) have documented that information technologies provide practical advantages such as cognitive memory, language learning and financial resources (Ryu, Kim & Lee, 2009; Ginsburg, Cameron, Mendez, & Westhoff, 2016; Gatti, Brivio, & Galimberti, 2017; Tsai, Shillair,&Cotten,2017; Myhre, Mehl & Glisky, 2017). Second, adult also use information technology to benefit from collaborative learning (Hayes, van Stolk-Cooke & Muench, 2015; Harley & Fitzpatrick, 2009). Third, some studies are also consistent on the position that information technology is used by adults for health learning purposes (Lindsay, Smith, Bell & Bellaby, 2007; Nahm, Resnick, DeGrezia & Brotemarkle, 2009; Steinert, Haesner, Tetley & Steinhagen-Thiessen, 2016; Lee, Han & Jo, 2017; Østensen, Gjevjon, Øderud & Moen, 2017). This study complements the underlying literature by assessing the importance of inequality in the nexus between information technology and adult literacy. In effect, the study assesses inequality thresholds that should not be exceeded in order for information technology to positively influence adult literacy. Hence, by providing specific guidelines with which policy makers can act upon, the present study departs from the underlying strands of studies which have simply focused on nexuses between information technology and adult literacy. In essence,

we argue that simply providing such nexuses is not enough because policy makers need to be provided with actionable guidelines essential for the promotion of adult literacy. Inequality is used as a moderating variable because of the documented importance of disparities in income inequality in economic development outcomes associated with information technology (Asongu & Odhiambo, 2019, 2020).

It is also fundamental to emphasize how the focus of the present study departs from the extant literature on technological spillovers and forecasting, which has for the most part, been positioned on, *inter alia*: concerns pertaining to forecasting prospects of business (Amankwah-Amoah & Sarpong, 2016; Amankwah-Amoah, 2016; Amankwah-Amoah, Osabutey & Egbetokun, 2018); the incidence of technology spillovers in the development of enterprises of small and medium scales (Del Giudice, Scuotto, Garcia-Perez & Petruzzelli, 2019); the importance of inter-sectoral ramifications and technology spillovers in know-how linked to technology-driven innovations and developments of trade and patent markets (Stephan, Bening, Schmidt, Schwarz & Hoffmann, 2019; Cai, Sarpong, Tang & Zhao, 2020); learning technologies and knowledge diffusion from local and global perspectives (Zhang, Bauer, Yin & Xie, 2020); the relevance of knowledge externalities and information technology in the sustainable energy production (Miremadi, Saboohi & Arasti, 2019; Asongu, le Roux & Biekpe, 2018; Avom, Nkengfack, Fotio & Totouom, 2020) and role of information technology in improving human development outcomes (Asongu & le Roux, 2017).

While the focus of the present study is closest to the last stream of the underlying strand of technological forecasting literature, as it pertains to human development externalities, it nonetheless also departs from the attendant stream on many fronts, *inter alia*, by: (i) employing Tobit regressions instead of the Generalized Method of Moments in the light of constraints in the behavior of the outcome variables; (ii) focusing on adult literacy instead of inclusive human development; (iii) engaging more information technology mechanisms; (vi) focusing on developing countries for which data are available instead of an exclusive scope of Sub-Saharan Africa and (v) engaging a moderating policy syndrome of inequality and by extension, providing policy makers with inequality thresholds that should not be exceeded if information technology dynamics are to improve adult literacy.

It is worthwhile to clarify that the present study is relevant to policy makers, especially as it pertains to the achievement of sustainable development goals (SDGs) such as SDG4 (i.e. ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all) and SDG10 (i.e. reducing inequality within and among countries). This is essentially because the study aims to provide policy makers with information technology dynamics that are more positively related to adult literacy (i.e. SDG4) as well as levels of income inequality that should not be exceeded (i.e. SDG10) in order for the underlying SDG4 to be promoted within the remit of adult literacy. It is worthwhile to also articulate that quality education is fundamental in the economic and sustainable development of nations (Petrov, 2017; Achuo, Asongu & Dinga, 2021) and learning is at all levels is a means by which inclusive education can be improved and consolidated (Ferrer-Estévez & Chalmeta, 2021; Heleta & Bagus, 2021).

The rest of study is structured as follows. The theoretical framework and intuition for the nexuses between inequality, information technology and adult learning are engaged in Section 2. The data and methodology are covered in Section 3 while the empirical findings are covered in Section 4. Section 5 concludes with implications and future research directions.

2. Theoretical framework and nexuses between inequality, information technology and adult learning

2.1 Theoretical framework

This can be discussed in three main theoretical strands, related to the: (i) diffusion of innovation theory; (ii) theory of perceived attributes and (iii) individual innovativeness theory. These theories are elicited in the passages that follow.

First, the diffusion of innovation theory which is one of the most dominant in the information technology literature maintains that diffusion entails a more holistic perspective which encompasses a plethora of theoretical views that are linked to the overall notion of diffusion (Rogers, 1995; Hashim, 2008). According to the theoretical framework, the underlying process of diffusion represents innovation that is created and adopted by elements of society, notably: innovation per se, the characterized of society in which such innovation is introduced and mechanisms by which such information about innovation can be spread (Rogers, 1995). Moreover, according to Rogers (1995), four main theories are consistent with information diffusion, namely: (i) the theory of perceived attributes; (ii) the rate of adoption theory; (iii) the individual innovativeness theory and (iv) the innovation-decision theory. The present study focuses on the theory of perceived attributes and the individual innovativeness theory. They are engaged in the following passages.

Second, the theory of perceived attributes is founded on the perspective that individuals are willing to adopt a specific innovation especially in information technology because they perceive that such an innovation has a plethora of favorable attributes, *inter alia*: (i) a comparative advantage over existing innovations in information technology; (ii) the compatibility of the innovation with past experience, existing values and practices of the person adopting the innovation; (iii) the less complexity of the innovation; (iv) ability to try the innovation before adopting the innovation and (v) the characteristic of observable results when the innovation is adopted (Rogers, 1995; Hashim, 2008). These attributes are in line with the problem statement in the present study because they are broadly consistent with the adoption and use of information technology for literacy purposes by adults.

Third, the individual innovativeness theory fundamentally builds on specificities of the person who adopts the innovation and the time of adopting the attendant innovation. According to the corresponding literature, four main categories of such adopters are apparent (Rogers, 1995; Hashim, 2008). The first category features innovators who are obviously pioneers and risk-takers while the second is composed of early adopters who come on board for early training and equally help in making the innovation known. In the third group, an early majority fraction is motivated by early adopters and innovators while the fourth group entails the late majority who adopt to maximize their interests. Laggards or the skeptical fraction makes-up the last group.

The above theoretical underpinnings are consistent with technology adoption models, especially as it pertains to the nexus between information technology and inclusive development (Ndoya & Asongu, 2021). The three fundamental theories which are in accordance with those discussed previously are: the theory of reasoned action (TRA), theory of planned behavior (TPB) and technology acceptance model (TAM).

In the light of the above, it is apparent that the dynamics of the diffusion theory reflect a theoretical framework through which the nexus between information technology and adult

literacy can be examined. However, the introduction of inequality as a moderating variable for the underlying nexus also needs to be theoretically justified.

2.2. Linkages between adult learning, inequality and information technology

The section presents the theoretical argument that the discussed positive nexus between information technology and adult literacy in Section 2.1 can be inhibited by income inequality. This is essentially because when the income gap widens in society, less individuals may have the financial means with which to leverage on information technology to improve their knowledge and acquire new skills. This is broadly consistent with Lee and Desjardins (2019). It is important to note that social inequality can seriously constraint adult learning (Lee, 2018), especially through information technology. It follows that adult learning and education are contingent not only on the diffusion of innovation and attributes of individuals (as discussed in Section 2.1.), but also on the attendant socio-economic context (Bourdieu & Wacquant, 1992; Willingham, 2012; Boeren, 2016; Lee & Desjardins, 2019). Such socio-economic context is captured within the framework of this study by income inequality. The premise of inequality in the discussed nexuses in Section 2.1 is further justified in what follows.

Tchamyou (2020) and Tchamyou et al. (2019a) conclude on a significant nexus between information and communication technology (ICT), education and lifelong learning while Rubenson (2009) is of the position that patterns of inequality affect adult learning participation. The conception of social inequality underlying the studies in this section from Habibis and Walter (2015) and Butler and Watt (2007) are in line with the definition of income inequality used in the present study. For instance, "*differences between groups of people that are hierarchical in nature and the hierarchical distribution of social, political, economic, and cultural resources*" (Habibis & Walter, 2015, p. 2) is consistent with the Gini coefficient employed in this study which measures how income is distributed across the population of a country.

There is a bulk of literature supporting the negative role of inequality in adult learning and education (ALE). Kilpi-Jakonen, de Vilhena and Blossfeld (2015) support this nexus from a cross-country job-related ALE framework while three dimensions of social inequality (i.e. entailing skills, education and economic dynamics of inequality) are used to examine nexuses among them within the framework of disparities in social origins in the ALE engagement. Duncan and Murnane (2011) support the narrative from the perspective of intergeneration inequality whereas Green, Green and Pensiero (2015) and the OECD (2013) concur with the narrative from the prism of education inequality. Van Damme (2014) is sympathetic with the narrative from the perspective of wage inequality while Lee and Desjardins (2019) establish that ALE is unfavorably affected by social inequalities.

In the light of the information in Sections 2.1 and 2.1, the following testable hypotheses will be examined in the empirical section.

Hypothesis 1: Information technology is positively associated with adult literacy.

Hypothesis 2: Inequality undermines the positive nexus between information technology and adult literacy and hence, some thresholds of inequality should not be exceeded in order for the positive linkage in *Hypothesis 1* to be maintained.

3. Data and methodology
3.1 Data

The study focuses on a panel of 57 developing countries for the period 2012 to 2016. The number of countries and corresponding periodicity are contingent on constraints in data availability at the time of the study, notably, owing the constraints in obtaining data on virtual social network. The sampled countries are: 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 & Zimbabwe.

The data is obtained from three main sources, namely: (i) World Development Indicators (WDI) of the World Bank; (ii) the Global Consumption and Income Product (GCIP) and (iii) the Global Information Technology Report (GTIR). The main outcome variable which is the adult literacy rate is obtained from WDI. The choice of this outcome variable is informed by contemporary adult literacy literature (Ahmad, Batul & Saleem, 2019; Batul, Haseeb & Sattar, 2019).

Six main information technology variables are obtained from the GTIR and WDI, namely: (i) 'use of virtual social network' and 'internet access in schools' from the GTIR and (ii) internet penetration, mobile phone penetration, fixed broadband subscriptions and number of personal computer (PC) users from WDI. The choice of the underlying information technology dynamics is also informed by contemporary literature on the subject (Afutu-Kote et al., 2017; Abor et al., 2018; Uduji & Okolo-Obasi, 2018a, 2018b; Gosavi, 2018; Issahaku et al., Nkegbe, 2018; Humbani & Wiese, 2018).

Consistent with Tchamyou (2019, 2020), the Gini coefficient from the GCIP is employed to measure income inequality. It can be defined as an indication of the statistical dispersion meant to represent wealth distribution or income of residents in a nation.

Three control variables from WDI are taken on board, namely: remittances, the population and inclusive education. The choice of these indicators is in line with contemporary inclusive education and human development literature (Mlachila, Tapsoba & Tapsoba, 2017; Asongu & Kodila-Tedika, 2017; Asongu, Orim & Nting, 2019; Tchamyou, 2020; Adejumo, Asongu & Adejumo, 2021). Remittances are anticipated to influence the outcome variable negatively while the other remaining variables are expected to have the opposite effect. The unexpected incidence of remittances is based on empirical evidence documenting that remittances promote exclusive development in developing countries because most of those migrating abroad are from rich households (Anyanwu, 2011; Meniago & Asongu, 2018). Hence remittance inflows are on average, expected to affect the outcome variable negatively because such remittances are skewed towards the rich fractions of the population. The definitions of variables, summary statistics and correlation matrix are disclosed in Appendix 1, Appendix 2 and Appendix 3, respectively.

3.2 Methodology

The empirical strategy adopted in this study is in line with the documented literature on the importance of adopting an empirical strategy that is consistent with the behavior of data (Kou, Lu, Peng & Shi, 2012; Kou, Peng & Wang, 2014; Kou, Ergu, Chen, Lin, 2016; Asongu & Nwachukwu, 2016; Kou, Chao, Peng & Alsaadi, 2019a; Kou, Yang, Xiao, Chen & Alsaadi, 2019b). Accordingly, the choice of the Tobit regression model in this study is in line with contemporary Tobit-centric literature on the consistency of the estimation technique with outcome variables that have a specific range (Lashitew et al., 2019; Ajide, Raheem & Asongu,

2019). As argued by Kumbhakar and Lovell (2000), Koetter and Vins (2008), Ariss (2010) and Coccorese and Pellecchia (2010), the Ordinary Least Squares (OLS) technique is not appropriate for estimating an outcome variable that is by construction censored from 0 to 100. This is the case with the literacy rate that varies from 0% to 100% (see Appendix 2). This is essentially because the attendant OLS approach would generate inconsistent estimates given that the approach does not take into account differences in the conditional probability of literacy for restricted observations such as nations that have 0% literacy rate or 100% literacy rate (Amemiya, 1984).

In the light of the insights above, the Tobit model adopted in this study is a double censored or two-limit estimation technique that accounts for the censoring of the literacy rate at the extreme points of the literacy distribution. The following equations reflect the mainstream Tobit estimation approach (Tobin, 1958; Carson & Sun, 2007).

$$y_{i,t}^{*} = \alpha_0 + \beta X_{i,t} + \varepsilon_{i,t} \ , \tag{1}$$

where $y_{i,t}^{*}$ is a latent response variable, $X_{i,t}$ is an observed $1 \times k$ vector of explanatory variables and $\varepsilon_{i,t} \approx$ i.i.d. N(0, σ²) and is independent of $X_{i,t}$. Contrary to observing $y_{i,t}^{*}$, we observe $y_{i,t}$:

$$y_{i,t} = \begin{cases} y_{i,t,}^{*} \ if \ y_{i,t}^{*} > \gamma \\ 0, \ if \ y_{i,t}^{*} \leq \gamma, \end{cases} \tag{2}$$

where γ is a non-stochastic constant. In follows that, the value of $y_{i,t}^{*}$ is missing when it is less than or equal to γ.

It is relevant to note that for the Tobit model, the following assumptions are apparent, notably: (i) residuals are distributed normally and (ii) the latent dependent variable is unbounded and reflects a linear function of the independent variables (Amemiya, 1984). In line with Lashitew et al. (2019), two marginal impacts can be observed from the independent variables, one shows the marginal effects of the explanatory indicators on the latent, unobserved adult literacy rate while the other reflects the observed, censored adult literacy rate. Consistent with Lashitew et al. (2019), the section on empirical results discloses the marginal effects on the censored, observed adult literacy rate because they are more feasible in economic interpretation.

4. Empirical results

Prior to presenting the empirical results, it is worthwhile to highlight the testable hypotheses motivating the empirical section, notably: (i) *Hypothesis 1* is the position that information technology is positively associated with adult literacy while (ii) according to *Hypothesis 2*, inequality undermines the positive nexus between information technology and adult literacy and hence, some thresholds of inequality should not be exceeded in order for the positive linkage in *Hypothesis 1* to be maintained.

The empirical results are provided in this section in Table 1 which is divided into five columns. The first column discloses the variables and information criteria while the next six columns provide nexuses between inequality, information technology and adult literacy. It is apparent from the findings that both Hypotheses 1-2 are valid exclusively for 'internet access in school'. The corresponding inequality threshold that should not be exceeded in order for internet access in schools to continue promoting adult literacy is 0.739 (i.e. 39.678/53.633). The significant control variables have the expected signs.

Table 1: Information technology, inequality and adult literacy

	Use of virtual social network	Internet access in schools	Internet penetration	Mobile phone penetration	Fixed Broadband subscriptions	Personal Computer
Dependent variables: Adult literacy						
Social Network(SN)	13.516	---	---	---	---	---
	(0.382)					
Internet in school(IS)	---	39.678***	---	---	---	---
		(0.008)				
Internet penetration (IP)	---	---	0.587	---	---	---
			(0.547)			
Mobile Phone (Mobile)	---	---	---	0.406	---	---
				(0.228)		
Fixed BroadBand(BB)	---	---	---	---	1.8951	---
					(0.727)	
P. Computer (PC)	---	---	---	---	---	0.406
						(0.228)
Gini Coefficient (Gini)	55.490	200.458**	9.554	20.022	-2.852	20.022
	(0.699)	(0.029)	(0.711)	(0.623)	(0.853)	(0.623)
SN × Gini	-13.442	---	---	---	---	---
	(0.647)					
IS × Gini	---	-53.633**	---	---	---	---
		(0.062)				
I P × Gini	---	---	0.417	---	---	---
			(0.846)			
Mobile × Gini	---	---	---	-0.352	---	---
				(0.604)		
BB × Gni	---	---	---	---	2.495	---
					(0.829)	
PC × Gini	---	---	---	---	---	-0.352
						(0.604)
Remittances	0.452	0.344	-0.407	0.206	.196	0.206
	(0.150)	(0.119)	(0.288)	(0.414)	(0.907)	(0.424)
Population	3.285	-0.380	0.304	1.802	2.709	3.944*
	(0.181)	(0.859)	(0.879)	(0.413)	(0.364)	(0.091)
Inclusive education	81.475***	66.492***	66.498***	78.894***	73.024***	91.580***
	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)
Thresholds	na	0.739	na	na	na	na

Observations	117	117	117	117	116	116

***,**,*: significance levels at 1%, 5% and 10% respectively. dy/dx: average marginal effects

Concerning the nexus of these findings with the extant literature, by confirming both tested hypotheses, the study confirms two strands of studies discussed in the introduction and Section 2 within the same empirical framework, notably: a positive association between information technology and adult literacy (Lindsay *et al*., 2007; Harley & Fitzpatrick, 2009; Nahm *et al*., 2009; Ryu *et al*., 2009; Hayes *et al*., 2015; Ginsburg *et al*., 2016; Steinert *et al*., 2016 ; Gatti *et al*., 2017; Tsai *et al*., 2017; Lee *et al*., 2017 ; Myhre *et al*., 2017 ; Østensen *et al*., 2017; Jin *et al*., 2019) and the negative role of inequality in reducing adult learning and education (Van Damme, 2014; Duncan & Murnane, 2011; Kilpi-Jakonen *et al*., 2015; Green *et al*., 2015; Lee & Desjardins, 2019). It follows that this study reconciles two strands of the literature within the same empirical framework.

5. Concluding implications and future research directions

The study assesses linkages between information technology, inequality and adult literacy in 57 developing countries for the period 2012-2016. Income inequality is measured with the Gini coefficient while six dynamics of information technology are taken on board, namely: use of virtual social network, internet access in schools, internet penetration, mobile phone penetration, fixed broadband subscriptions and number of personal computer users. The findings show that only internet access in schools unconditionally promote adult literacy. The corresponding inequality threshold that should not be exceeded in order for internet access in schools to continue promoting adult literacy is 0.739 of the Gini coefficient. Policy implications are discussed in the light of sustainable development goals, notable in relation to inequality, information technology and adult literacy.

On the front of inequality, it is relevant to note that most of the targets of millennium development goals (MDGs), especially that pertaining to extreme poverty, could not be achieved in most developing countries because of inequality or the unequal distribution of fruits of economic prosperity. According to some projections, most poverty-oriented sustainable development goals (SDGs) would also not be achieved in developing countries unless inequality is mitigated (Bicaba, Brixiová & Ncube, 2017). This study is in line with the underlying scholarly perspective in the sense that the inequality threshold that should not be exceeded in order for information technology to improve the literacy of adults has been provided. It follows that policy makers have been provided with an actionable guideline of inequality that if exceeded, information technology would not promote adult literacy accordingly. Hence, in tailoring policies designed to leverage on information technology in order to improve literacy in general and adult literacy in particular in the post-2015 development agenda, inequality thresholds should be taken board.

Information technology as reported in this study promotes adult learning and education and hence, policy makers of sampled countries should improve the implementation of measures designed to facilitate universal access in information technologies that are compatible with favorable learning outcomes. Accordingly, the premise that information technology still has a high penetration in developing countries is evidence of the fact that policy makers can leverage on it to improve education and lifelong learning outcomes which, are indispensible for development in the 21st century. Hence, addressing demand-side and supply-side barriers to the information technology ecosystems should entail, *inter alia*: reducing socio-economic

inequalities, promoting analogue and digital skills and adapting the attendant technologies to local realities.

If information technology is enhanced and inequality levels are kept in check, adult literacy would naturally improve and by extension, enhance human resources and economic developments. In essence, there are a plethora of advantages associated with adult learning, *inter alia*: (i) such education enables adults to acquire valuable know-how that is relevant in expanding their knowledge at the professional level as well as in improving their career prospects; (ii) consolidating numeracy and literary in adulthoods provides citizens with the prospect of reaching their full potential and (iii) adults are also provided with valuable skills that can be deployed in many scenarios, especially at the workplace.

The established findings are particularly relevant to policy makers in view of achieving two main SDGs, notably: SDG4 focusing on inclusive education and SDG10 oriented towards the reduction of inequalities. By establishing specific information technology dynamics that are positively related to adult literacy, the study has contributed towards the achievement of SDG4. Moreover, by providing a threshold of income inequality, the study is contributing towards SDG10 not least, because the study also recommends that inequality levels should be kept below the 0.739 Gini coefficient if internet access is to promote adult literacy. It follows that above the 0.739 Gini coefficient, internet access is a necessary but not as sufficient condition for promoting of adult literacy while below the corresponding threshold, internet access becomes a necessary and sufficient condition for the promotion of adult literacy. In order words, the responsiveness of adult literacy to internet access in schools in a negative function income inequality such that existing income inequality levels should be maintained below the 0.739 Gini coefficient in order for internet access to promote adult literacy. In order to keep the recommended income inequality level in check, both governments and civil society in sample countries need to work towards, *inter alia*, improving the formulation and implementation of policies that enhance the equitably delivery of public goods and services as well as employment opportunities and social mobility avenues.

In order to improve the established findings in this study, future research could focus on other moderating policy syndromes that influence the favorable incidence of information technology on adult learning and education and by extension, lifelong learning. Moreover, given country specificities in the engaged dynamics of information technology and inequality, relevant estimation approaches should be considered in order to provide country-specific guidelines of inequality that dampen the positive nexus between information technology and adult literacy. Moreover, the finding should be treated as linkages or nexuses because causal inferences cannot be established in the light of the estimation approach and corresponding periodicity. There are issues that future studies on the subject should, *inter alia*, address.

Appendices

Appendix 1: Definitions of Variables

Variables	Signs	Definitions of variables (Measurements)	Sources
Adult Literacy	AdultL	Literacy rate, adult total (% of people ages 15 and above)	WDI
Social Network	SocialN	Use of virtual social network. "In your country, how widely are virtual social networks used (e.g., Facebook, Twitter, LinkedIn)? [1 = not at all used; 7 = used extensively]"	GTIR
Internet in School	InternetS	Internet access in schools. "Internet access in schools. In your country, to what extent is the Internet used in schools for learning purposes? [1 = not at all; 7 = to a great extent]"	GTIR
Internet Penetration	Internet P	Internet users (per 100 people)	WDI
Mobile Phones	Mobile	Mobile celluar subscriptions (per 100 people)	WDI
Fixed BroadBand	BroadB	Fixed broadband subscriptions (per 100)	WDI
Personal Computer	PC	Percentage of person equipped with a personal computer	WDI
Inequality	Gini	The Gini index is a measurement of the income distribution of a country's residents	GCIP
Remittances	Remit	Remittances inflows to GDP (%)	WDI
Population	Pop	Logarithm of the total population	WDI

Inclusive education	IncluEdu	School enrolment, primary and secondary (gross), gender parity index (GPI)	WDI

WDI: World Development Indicators of the World Bank. GTIR: Global Information Technology Report. It important to note that while the values from the GTIR theoretically range from 1 to 7, when there is no official data, zero is assigned.

Appendix 2: Summary statistics (2012-2016)

	Mean	SD	Minimum	Maximum	Observations
Adult Literacy	71.882	19.428	26.176	99.773	262
Social Network	4.828	0.674	2.571	6.234	264
Internet at School	3.240	0.843	1.339	5.050	264
Internet Penetration	17.147	14.230	0.210	56.800	264
Mobile Penetration	79.282	32.857	8.262	175.302	264
Fixed BroadBand	1.625	2.930	0.001	23.219	257
Personal Computer	13.629	14.981	0.130	87.500	264
Gini Coefficient	0.501	0.088	0.257	0.635	217
Remittances	4.363	5.772	0.004	29.591	265
Population (log)	6.946	0.652	5.599	8.269	255
Inclusive Education	0.966	0.081	0.692	1.095	181

S.D: Standard Deviation.

Appendix 3: Correlaton matrix (uniform sample size 116)

	AdultL	SocialN	InternetS	InternetP	Mobile	BroadB	PC	Gini	Remit	Pop	IncluEdu
AdultL	1.000										
SocialN	0.397	1.000									
InternetS	0.596	0.637	1.000								
InternetP	0.602	0.578	0.680	1.000							
Mobile	0.496	0.617	0.587	0.578	1.000						
BroadB	0.536	0.492	0.585	0.756	0.492	1.000					
PC	0.519	0.513	0.582	0.860	0.561	0.774	1.000				
Gini	-0.097	-0.137	-0.328	-0.239	-0.135	-0.140	-0.169	1.000			
Remit	0.170	0.107	0.096	0.405	0.181	0.184	0.411	0.016	1.000		
Pop	0.021	-0.125	0.057	0.028	-0.130	-0.006	-0.070	0.235	-0.073	1.000	
IncluEdu	0.455	0.357	0.347	0.326	0.145	0.234	0.255	-0.119	0.134	-0.091	1.000

AdultL: Adult Literacy. SocialN: Social Network. InternetS: Internet at School. InternetP: Internet Penetration. Mobile: Mobile Phone Penetration. BroadB: Fixed BroadBand Subscriptions. PC: Personal Computers. Gini: Gini Coefficient. Remit: Remittances. Pop: Population. IncluEdu: Inclusive Education.

References

Abor, J. Y., Amidu, Y., & Issahaku, H., (2018). "Mobile Telephony, Financial Inclusion and Inclusive Growth", *Journal of African Business*, 18(4), pp. 430-453.

Achuo, E. D., Asongu, S. A., & Dinga, G. D. (2022). "Addressing the Educational Crisis in Cameroon: Policy Syndromes, Arguments, Views, Theory and Agenda", *African Governance and Development Institute Working Paper* No. 22/097, Yaoundé.

Adejumo, O. O., Asongu, S. A., &Adejumo, A. V. (2021). "Education enrolment rate vs employment rate: Implications for sustainable human capital development in Nigeria". *International Journal of Educational Development*, 83, 102385.

Afutu-Kotey, R. L., Gough, K. W., & Owusu, G., (2017). "Young Entrepreneurs in the Mobile Telephony Sector in Ghana: From Necessities to Aspirations", *Journal of African Business*, 18(4), pp. 476-491.

Ahmad, N., Batul, E., & Saleem, R., (2019). "The Long Run and Short Run Relationship between Poverty and Literacy Rate in Pakistan", *Pakistan Business Review*, 20(4), pp. 875–885.

Ajide, K. B., Raheem, I. D., & Asongu, S. A., (2019). "Dollarization and the "Unbundling" of Globalization in sub-Saharan Africa", *Research in International Business and Finance*, 47 (January), pp. 398-409.

Allatt, G., & Tett, L. (2019). "Adult literacy practitioners and employability skills: resisting neo-liberalism?" *Journal of Education Policy*, 34(4), pp. 577-594.

Amankwah-Amoah, J., (2016). "Global business and emerging economies: Towards a new perspective on the effects of e-waste". *Technological Forecasting and Social Change*, 105 (April), pp. 20-26.

Amankwah-Amoah, J., Osabutey, E., & Egbetokun, A. (2018). "Contemporary challenges and opportunities of doing business in Africa: The emerging roles and effects of technologies". *Technological Forecasting and Social Change*, 131(June), pp. 171-174.

Amankwah-Amoah, J., & Sarpong, D., (2016). "Historical pathways to a green economy: The evolution and scaling-up of solar PV in Ghana, 1980-2010". *Technological Forecasting and Social Change*, 102(January), pp. 90-101.

Amemiya, T., (1984). "Tobit models: a survey". *Journal of Econometrics*, 24 (1–2), pp.3–61.

Anyanwu, J. C., (2011). "International Remittances and Income Inequality in Africa". *African Development Bank Working Paper* No. 135, Tunis.

Ariss, R. T., (2010). "On the Implications of Market Power in Banking: Evidence from Developing Countries", *Journal of Banking and Finance*, 34(4), pp. 765-775.

Asongu, S. A., & Asongu, N., (2018). "The comparative exploration of mobile money services in inclusive development", *International Journal of Social Economics*, 45(1), pp.124-139.

Asongu, S. A., & Kodila-Tedika, O., (2017)."Is Poverty in the African DNA (Gene)?", *South African Journal of Economics*, 85(4), pp. 533-552.

Asongu, S. A., & le Roux, S., (2017). "Enhancing ICT for inclusive human development in Sub-Saharan Africa", *Technological Forecasting and Social Change*, 118(May), pp. 44–54.

Asongu, S. A., le Roux, S., & Biekpe, N., (2018). "Enhancing ICT for environmental sustainability in sub-Saharan Africa", *Technological Forecasting and Social Change*, 127(February), pp. 209-216.

Asongu, S. A., & Nwachukwu, J. C., (2016). "The Role of Governance in Mobile Phones for Inclusive Human Development in Sub-Saharan Africa". *Technovation* 55-56 (September-October), pp. 1-13.

Asongu, S. A., & Odhiambo, N. M., (2019). "Mobile banking usage, quality of growth, inequality and poverty in developing countries", *Information Development*, 35(2), pp. 303-318.

Asongu, S. A., & Odhiambo, N. M., (2020). "Inequality and gender inclusion: Minimum ICT policy thresholds for promoting female employment in Sub-Saharan Africa", *Telecommunications Policy*, 44(4), 101900.

Asongu, S. A., Orim, S-M, I., & Nting, R. T., (2019). "Inequality, Information Technology and Inclusive Education in Sub-Saharan Africa", *Technological Forecasting and Social Change*, 146(September), pp. 380-389.

Avom, D., Nkengfack, H., Fotio, H. K., & Totouom, R., (2020). "ICT and environmental quality in Sub-Saharan Africa: Effects and transmission channels", *Technological Forecasting and Social Change*, 155, June 2020, 120028.

Bagci, S. E., (2019). "Migration and Participation in Adult Education: The Matthew Effect on Immigrants", *Adult Education Quarterly*, 69(4), pp. 271-294.

Batul, E., Haseeb, M. A., & Sattar, S. A., (2019). "Examining the Relationship between Literacy Rate and Poverty in Pakistan", *Kashmir Economic Review*, 28(1), pp. 1-22.

Bicaba, Z., Brixiová, Z., & Ncube, M., (2017). "Can Extreme Poverty in Sub-Saharan Africa be Eliminated by 2030?," *Journal of African Development*, 19(2), pp. 93-110.

Blunch, N-H., (2017). "Adult literacy programs in developing countries." *IZA World of Labor* (2017).
https://wol.iza.org/articles/adult-literacy-programs-in-developing-countries/long (Accessed: 08/04/2020).

Blunch, N-H, & Portner, C. C., (2011). "Literacy, skills, and welfare: Effects of participation in adult literacy programs." *Economic Development and Cultural Change*, 60(1), pp. 17-66.

Boeren, E. (2016). Lifelong learning participation in a changing policy context: An interdisciplinary theory. New York, NY: Palgrve MacMillan.

Bourdieu, P., & Wacquant, L. (1992). An invitation to reflexive sociology. Chicago, IL: University of Chicago Press.

Butler, T., & Watt, P. (2007). Understanding social inequality. Thousand Oaks, CA: Sage.

Cai, H.,, Sarpong, D., Tang, X., & Zhao, G., (2020). "Foreign patents surge and technology spillovers in China (1985-2009): evidence from the patent and trade markets". *Technological Forecasting and Social Change*, 151 , 119784.

Carson, R. T., & Sun, Y., (2007)."The Tobit model with a non-zero threshold", *Econometrics Journal*, 10(3), pp. 488-502.

Cherrstorm, C. A., & Alfred, M. V., (2020). "Women's Midlife Career Transition to Tenured/Tenure-Track Faculty in Adult Education", *Adult Education Quarterly*, 70(1), pp. 44-63.

Coccorese, P., &Pellecchia, A., (2010). "Testing the 'Quiet Life' Hypothesis in the Italian Banking Industry", *Economic Notes by BancadeiPaschi di Siena SpA*, 39(3), pp. 173-202.

Del Giudice, M., Scuotto, V., Garcia-Perez, A., & Petruzzelli, A. M., (2019). "Shifting Wealth II in Chinese economy. The effect of the horizontal technology spillover for SMEs for international growth", *Technological Forecasting and Social Change*, 145(August), pp. 307-316.

Duncan, G. J., & Murnane, R. J. (2011). Introduction: The American dream, then and now. In G. J. Duncan and R. J. Murnane (Eds.), Whither opportunity? Rising inequality, schools, and children's life chances (pp. 3-25). New York, NY: Russell Sage Foundation Press.

Gatti,F. M., Brivio, E. ,& Galimberti, C. (2017). "'The future is ours too': Atraining process to enable the learning perception and increase self-efficacy in the use of tablets in the elderly'. *Educational Gerontology*, 43(4), pp. 209-224

Ginsburg, H. J., Cameron, R., Mendez, R.V., & Westhoff, M. (2016). "Helping others use social media: Age stereotypes when estimating learner Ks success". *Psychology, Society & Education*, 8(1), pp.1-12.

Gosavi, A., (2018). "Can mobile money help firms mitigate the problem of access to finance in Eastern sub-Saharan Africa", *Journal of African Business*, 18(4), pp. 343-360.

Green, A., Green, F., & Persiero, N. (2015). "Cross-country variation in adult skills inequality: Why are still levels and opportunities so unequal in Anglophone countries?" *Comparative Education Review*, 59(4), pp. 595–619.

Ferrer-Estévez, M., &Chalmeta, R. (2021). "Integrating Sustainable Development Goals in educational institutions". *The International Journal of Management Education*, 19(2), 100494.

Habibis, D., & Walter, M. (2015). Social inequality in Australia: Discourses, realities and futures (2nd ed.). South Melbourne: Victoria Oxford University Press.

Harley, D., & Fitzpatrick,G. (2009). "YouTube and intergenerational communication: The case of Geriatric1927". *Universal Access in the Information Society*, 8(1), pp.5-20.

Hashim, J. (2008). "Learning barriers in adopting ICT among selected working women in Malaysia", *Gender in Management*, 23(5), pp. 317-336.

Hayes, M., van Stolk-Cooke, K., & Muench, F. (2015). "Understanding facebook use and the psychological effects of use across generations". *Computers in Human Behavior*, 49(C), pp. 507-511.

Heleta, S., & Bagus, T. (2021). "Sustainable development goals and higher education: leaving many behind". *Higher Education*, 81(1), pp. 163-177.

Humbani, M., & Wiese, M., (2018). "A Cashless Society for All: Determining Consumers' Readiness to Adopt Mobile Payment Services", *Journal of African Business*, 18(4), pp. 409-429.

Iniguez-Berrozpe, T., Elboj-Saso, C., Flecha, A., & Marcaletti, F., (2020). "Benefits of Adult Education Participation for Low-Educated Women", *Adult Education Quarterly*, 70(1), pp. 64-88.

Issahaku, H., Abu, B. M., and Nkegbe, P. K., (2018). "Does the Use of Mobile Phones by Smallholder Maize Farmers Affect Productivity in Ghana?", *Journal of African Business*, 19 (3), pp. 302-322.

Jin, B., Kim, J., & Buamgatner, L. M., (2019). "Informal Learning of Older Adults in Using Mobile Devices: A Review of the Literature", *Adult Education Quarterly*, 70(1), pp. 6-25.

Kilpi-Jakonen, E., de Vilhena D. V., & Blossfeld, H-P. (2015). "Adult learning and social inequalities: Processes of equalization or cumulative disadvantage?" *International Review of Education*, 61(4), pp. 529–546.

Kim, S., (2020). "A Quasi-Experimental Analysis of the Adult Learning Effect on Problem-Solving Skills", *Adult Education Quarterly*, 70(1), pp. 6-25.

Koetter, M., & Vins, O., (2008). "The Quiet Life Hypothesis in Banking-Evidence from German Savings Banks", Department of Finance, Goethe University, *Working Paper Series: Finance and Accounting* No. 190, Frankfurt.

Kou, G., Chao, X., Peng, Y., &Alsaadi, F. E., (2019a). "Machine learning methods combined with financial systemic risk", *Technological and Economic Development of Economy*, DOI: https://doi.org/10.3846/tede.2019.8740.

Kou, G., Yang, P., Xiao, F., Chen, Y., &Alsaadi, F. E., (2019b). "Evaluation of feature selection methods for text classification with small datasets using multiple criteria decisionmaking methods", *Applied Soft Computing*, DOI:https://doi.org/10.1016/j.asoc.2019.105836.

Kou, G., Ergu, D., Chen, Y., & Lin, C., (2016). "Pairwise comparison matrix in multiple criteria decision making", *Technological and Economic Development of Economy*, 22(5), pp. 738-765.

Kou, G., Lu, Y., Peng, Y., & Shi, Y., (2012). "Evaluation of Classification Algorithms using MCDM and Rank Correlation", *International Journal of Information Technology & Decision Making*, 11(1), pp. 197-225.

Kou, G., Peng, Y., & Wang, G., (2014). "Evaluation of clustering algorithms for financial risk analysis using MCDM methods", *Information Sciences*, 275(August), pp. 1-12.

Kumbhakar, S. C., & Lovell, C. A. K., (2000).*Stochastic Frontier Analysis*, Cambridge MA: Cambridge University Press.

Lashitew, A. A., van Tulder, R., & Liasse, Y., (2019). "Mobile phones for financial inclusion: What explains the diffusion of mobile money innovations?", *Research Policy*, 48 (5), pp. 1201-1215.

Lee, J., (2018). "Conceptual foundations for understanding inequality in participation in adult learning and education for international comparisons". *International Journal of Lifelong Education*, 37(3), pp. 297–314.

Lee, J., & Desjardins, R., (2019). "Inequality in adult learning and education participation: the effects of social origins and social inequality", *International Journal of Lifelong Learning*, 38(3), pp. 339-359.

Lee, E., Han, S., & Jo, S. H. (2017). "Consumer choice of on-demand mHealthapp services: Context and contents values using structural equation modeling". *International Journal of Medical Informatics*, 97(January), pp. 229-238.

Lindsay,S., Smith,S., Bell,F., & Bellaby, P. (2007). "Tackling the digital divide: Exploring the impact of ICT on managing heart conditions in a deprived area". *Information, Communication & Society*, 10(1), pp. 95-114.

Minkoua Nzie, J. R., Bidogeza, J. C., & Ngum, N. A., (2018)."Mobile phone use, transaction costs, and price: Evidence from rural vegetable farmers in Cameroon", *Journal of African Business*, 19(3), pp. 323-342.

Miremadi, I., Saboohi, Y., & Arasti, M., (2019). "The influence of public R&D and knowledge spillovers on the development of renewable energy sources: The case of the Nordic countries", *Technological Forecasting and Social Change*, 146(September), pp. 450-463.

Mlachila, M., Tapsoba, R., & Tapsoba, S. J. A., (2017). "A Quality of Growth Index for Developing Countries: A Proposal", *Social Indicators Research*, 134(2), pp. 675–710.

Myhre, J. W., Mehl, M. R., & Glisky, E. L. (2017). "Cognitive benefits of online social networking for healthy older adults". Journals of Gerontology Series B: Psychological *Sciences & Social Sciences*, 72(5), pp. 752-760.

Nahm, E., Resnick, B., DeGrezia, M., & Brotemarkle, R. (2009). "Use of discussion boards in a theory-based health website for older adults". *Nursing Research*, 58(6), pp. 419-426.

Ndoya, H., & Asongu, S. A., (2021). "Digital divide, globalization and income inequality in sub-Saharan African countries: analysing cross-country heterogeneity", *Social Responsibility Journal*, DOI: 10.1108/SRJ-07-2022-0277.

OECD. (2013). OECD employment outlook 2013. Paris: OECD Publishing.

Østensen, E.,Gjevjon, E. R., Øderud,T., & Moen, A. (2017). "Introducing technology for thriving in residential long-term care". *Journal of Nursing Scholarship: An Official Publication of Sigma Theta Tau International Honor Society of Nursing*, 49(1), pp. 44-53.

Petrov, A. N. (2017). Human capital and sustainable development in the Arctic: Towards intellectual and empirical framing. In Northern Sustainabilities: Understanding and addressing change in the circumpolar world (pp. 203-220). Springer, Cham.

Rogers, E.M. (1995). Diffusion of Innovations, 4th ed., The Free Press, New York, NY.

Rubenson, K., (2009). Lifelong learning: Between humanism and global capitalism. In P. Jarvis (Eds.), The Routledge international handbook of lifelong learning (pp. 411-422). New York, NY: Routledge.

Ryu, M., Kim, S., & Lee, E. (2009). "Understanding the factors affecting online elderly user's participation in video UCC services". *Computers in Human Behavior*, 25(3), pp. 619-632.

Steinert,A., Haesner, M., Tetley, A., & Steinhagen-Thiessen, E. (2016). "Self-monitoring of health-related goals in older adults with use of a smartphone application". *Activities, Adaptation &Aging*, 40(2), pp. 81-92.

Stephan, A., Bening, C. R., Schmidt, C. R., Schwarz, M., & Hoffmann, V. H., (2019). "The role of inter-sectoral knowledge spillovers in technological innovations: The case of lithium-ion batteries", *Technological Forecasting and Social Change*, 148, November 2019, 119718.

Tchamyou, V. S., (2020). "Education, Lifelong learning, Inequality and Financial access: Evidence from African countries". *Contemporary Social Science*, 15(1), pp. 7-25.

Tchamyou, V. S., Asongu, S. A., & Odhiambo, N. M., (2019a). "The role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa", *African Development Review*, 31(3), pp. 261-274.

Tchamyou, V.S., Erreygers, G., & Cassimon, D., (2019b). "Inequality, ICT and Financial Access in Africa", *Technological Forecasting and Social Change*,139(February), pp. 169-184.

Tobin, J., (1958). "Estimation of relationships for limited dependent variables". *Econometrica* 26(1), pp. 24-36.

Tsai, H. S., Shillair, R., & Cotten, S. R. (2017). "Social Support and "Playing Around": An Examination of How Older Adults Acquire Digital Literacy With Tablet Computers". *Journal of Applied Gerontology*, 36(1), pp. 29-55.

Uduji, J.I. & Okolo-Obasi, E. N., (2018a). "Adoption of improved crop varieties by involving farmers in the e-wallet programme in Nigeria". *Journal of Crop Improvement*, 32 (5), pp. 717-737.

Uduji, J.I. & Okolo-Obasi, E. N., (2018b). "Young rural women's participation in the e-wallet programme and usage intensity of modern agricultural inputs in Nigeria", *Gender, Technology and Development*, 22(1), pp. 59-81.

Van Damme, D. (2014). "How closely is the distribution of skills related to countries' overall level of social inequality and economic prosperity?" *OECD Education Working Papers* No. 105. OECD, Paris.

Willingham, D. T. (2012). "Ask the cognitive scientist: Why does family wealth affect learning?" *American Educator*, 36(1), pp. 33–39.

Zhang, S., Bauer, N., Yin, G., & Xie, X., (2020). "Technology learning and diffusion at the global and local scales: A modeling exercise in the REMIND model", *Technological Forecasting and Social Change*, 151, February 2020, 119765.