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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 a virtual social network, Internet access in schools, Internet penetration, mobile phone penetration, fixed broadband subscription, and a number of personal computer users. The empirical evidence is based on interactive Tobit regressions. The findings show that only Internet access in schools unconditionally promotes adult literacy. The corresponding inequality threshold that should not be exceeded for Internet access in schools to continue promoting adult literacy is 0.739 of the Gini coefficient. Policy implications are discussed.

Keywords Information technology · Inequality · Adult literacy · Inclusive development

JEL Classification D10 · D14 · D31 · D60 · O30

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

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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 et al., 2017; Abor et al., 2018; Uduji & Okolo-Obasi, 2018a, 2018b; Gosavi, 2018; Asongu & Asongu, 2018; Issahaku et al., 2018; Humbani & Wiese, 2018; MinkouaNzie et al., 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 et al., 2019; Tchamyou et al., 2019a, 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 et al., 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 et al. (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 et al.,

2009; Ginsburg et al., 2016; Gatti et al., 2017; Tsai et al., 2017; Myhre et al., 2017) . Second, adults also use information technology to benefit from collaborative learning (Hayes et al., 2015; Harley & Fitzpatrick, 2009). Third, some studies are also consistent in the position that information technology is used by adults for health learning purposes (Lindsay et al., 2007; Nahm et al., 2009; Steinert et al., 2016; Lee et al., 2017; Østensen et al., 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 upon which policy makers can act, the present study departs from the underlying strands of studies that have simply focused on the 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 et al., 2018); the incidence of technology spillovers in the development of enterprises of small and medium scales (Del Giudice et al., 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 et al., 2019; Cai et al., 2020); learning technologies and knowledge diffusion from local and global perspectives (Zhang et al., 2020); the relevance of knowledge externalities and information technology in sustainable energy production (Miremadi et al., 2019; Asongu et al., 2018; Avom, et al., 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 et al., 2022) and learning 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 the study is structured as follows. The theoretical framework and intuition for the nexuses between inequality, information technology, and adult learning are engaged in the "Theoretical Framework and Nexuses Between Inequality, Information Technology, and Adult Learning" section. The data and methodology are covered in the "Data and Methodology" section, while the empirical findings are covered in the "Empirical Results" section. The "Concluding Implications and Future Research Directions" section concludes with implications and future research directions.

Theoretical Framework and Nexuses Between Inequality, Information Technology, and Adult Learning

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 characteristics 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 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) 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 the 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, the theory of planned behavior, and the technology acceptance model.

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.

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 the "Theoretical Framework" section 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 constrain 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 the "Theoretical Framework" section), 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 the "Theoretical Framework" section is further justified in what follows.

Tchamyou (2020) and Tchamyou et al. (2019a) conclude on a significant nexus between information and communication technology, 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) is 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 et al. (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 et al. (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 the "Theoretical Framework" section, 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.

Data and Methodology

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 to the constraints in obtaining data on the virtual social network. The sampled countries are as follows: 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.

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 et al., 2019; Batul et al., 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 the number of personal computer users from WDI. The choice of the underlying information technology dynamics is also informed by contemporary literature on the subject (Afutu-Kotey et al., 2017; Abor et al., 2018; Uduji & Okolo-Obasi, 2018a, 2018b; Gosavi, 2018; Issahaku et al., 2018; Humbani & Wiese, 2018).

Consistent with Tchamyou (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 et al., 2017; Asongu & Kodila-Tedika, 2017; Asongu et al., 2019; Tchamyou, 2020; Adejumo et al., 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). 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 Table 2, Appendix Table 3, and Appendix Table 4, respectively.

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 et al., 2012, 2014, 2019a, 2019b; Asongu & Nwachukwu, 2016). 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 et al., 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 Table 3). 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, σ^2) 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. It 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.

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

Table 1 Information technology, inequality, and adult literacy

	Dependent variables: adult literacy					
	Use of virtual social network	Internet access in schools	Internet penetration	Mobile phone penetration	Fixed broadband subscriptions	Personal computer
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)		

Table 1 (continued)

	Dependent variables: adult literacy					
	Use of virtual social network	Internet access in schools	Internet penetration	Mobile phone penetration	Fixed broadband subscriptions	Personal computer
BB × Gni	—	—	—	—	2.495	—
					(0.829)	
PC × Gini	—	—	—	—	—	− 0.352
						(0.604)
Remittances	0.452	0.344	− 0.407	0.206	0.196	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

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.

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 "Theoretical Framework and Nexuses Between Inequality, Information Technology, and Adult Learning" sections within the same empirical framework, notably, a positive association between information technology and adult literacy (Lindsay et al., 2007; Harley & Fitzpatrick, 2009; Nahmet al., 2009; Ryu et al., 2009; Hayes et al., 2015; Ginsburg et al., 2016; Steinert et al., 2016; Gattiet al., 2017; Tsaiet al., 2017; Lee et al., 2017; Myhre et al., 2017; Østensenet al., 2017; Jinet 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.

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, the 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 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 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, especially those 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 SDGs would also not be achieved in developing countries unless inequality is mitigated (Bicaba et al., 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 on 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 to 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 indispensable for economic development in the twenty-first century. Hence, addressing demand-side and supply-side barriers to the information technology ecosystems should entail, inter alia, reducing socio-economic inequalities, promoting analog 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 development. 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 a sufficient condition for promoting adult literacy, while below the corresponding threshold, Internet access becomes a necessary and sufficient condition for the promotion of adult literacy. In other words, the responsiveness of adult literacy to Internet access in schools negatively affects income inequality, so existing income inequality levels should be maintained below the 0.739 Gini coefficient 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 equitable 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 engaging 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. These are issues that future studies on the subject should, inter alia, address.

Appendices

Table 2 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 cellular 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 is 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

Table 3 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

SD standard deviation

Table 4 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

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