UNISA ECONOMIC RESEARCH WORKING PAPER SERIES

INFORMATION TECHNOLOGY, INCOME INEQUALITY AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICAN COUNTRIES

Accepted*: Telecommunications Policy*

Nicholas M. Odhiambo

Working Paper 08/2022

June 2022

Nicholas M. Odhiambo
Department of Economics
University of South Africa
P. O. Box 392, UNISA
0003, Pretoria
South Africa
Emails: odhianm@unisa.ac.za / nmbaya99@yahoo.com

INFORMATION TECHNOLOGY, INCOME INEQUALITY AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICAN COUNTRIES

Abstract

In this paper, the dynamic relationship between ICT, income inequality and economic growth in sub-Saharan African (SSA) countries is examined during the period 2004-2014. Three ICT and three income inequality indicators were used to examine this linkage. The ICT indicators used include internet penetration, mobile phone penetration and fixed broadband subscription, while the income inequality indicators include the Gini coefficient, the Atkinson index and the Palma ratio. Using the Generalised Method of Moments (GMM) estimation technique, the study found that, on the whole, an increase in ICT development unconditionally leads to an increase in economic growth in the countries under study. The study also found that the threshold level of income inequality, which should not be exceeded in order for the positive impact of ICT on economic growth to be sustained, depends on the ICT proxy used and the income inequality indicator. Specifically, the study found that for ICT to have a sustained positive impact on economic growth, i) the Gini coefficient in the mobile penetration specification should not exceed 0.520; ii) the Gini coefficient and Atkinson index in the internet penetration specification should not exceed 0.531 and 0.560, respectively; and iii) the Gini coefficient, Atkinson index and Palma ratio in the fixed broadband subscriptions should not exceed 0.551, 0.633 and 4.664, respectively. Policy implications are discussed.

1. Introduction

The role of information and communication technologies (ICTs) in the process of economic development has attracted notable attention in recent decades. In previous studies, it has been argued that investment in ICT could serve as a key driver of productivity growth (see Niebel, 2014; Cardona et al., 2013; Stiroh (2005). This narrative has been further supported by the current digital divide between developing countries and developed countries. According to the World Economic Forum (2013), an increase in the digitisation of a country by 10% could lead to a 0.75% increase in GDP per capita. OECD (2010) also argues that ICT plays a major role in reducing poverty by creating new sources of income and new jobs. It has also been argued that the remarkable success in economic development in a country such as Singapore has been strongly linked to the vigorous efforts made by the country to embrace the ICT revolution (Vu, 2013).

Although African countries have made strides in updating their ICT infrastructure and have witnessed significant growth in the ICT sector in recent decades, the continent is still lagging behind other developing regions regarding internet access and usage. According to the World Bank (2020), 21 of the 25 least internet-connected countries in the world are in Africa, even though sub-Saharan Africa currently has one of the fastest internet growth rates in world[1]. Consequently, many African countries are currently giving priority to increasing the availability and affordability of broadband services. According to the ICT Development Index (2017), the top ranked countries in Africa in terms of ICT include: Mauritius, the Seychelles, South Africa, Cape Verde, Tunisia, Morocco, Algeria, Egypt, Botswana and Gabon[2].

[1] https://www.worldbank.org/en/topic/digitaldevelopment/overview
[2] https://www.itu.int/net4/ITU-D/idi/2017/index.html

The relationship between ICT and economic growth has been supported by a number of theories. The exogenous theories of Solow (1956) and Swan (1956), and the endogenous theories of Romer (1986), Lucas (1988), Romer (1990) and Lucas (1993) have all supported the link between ICT and economic growth. Although these theories differ in the nature of the transmission mechanism between ICT and economic growth, they all acknowledge the important role that technological change plays in economic growth and development (see also Fern´andez-Portillo et al., 2020). However, unlike exogeneous growth models, in which it is argued that technological progress is borne outside the economic system, in endogenous growth models technological change is considered as endogenous and, therefore, differs from one economic system to another.

The endogenous growth theories, therefore, predict increasing returns to scale in technology, which eventually leads to knowledge-based growth in the long run. The importance of the underlying role of ICT has also been emphasised by Asongu et al. (2019), who maintain that ICT boosts production efficiency, and increases competitiveness and the ability of public officials to manage institutions more effectively. According to Melia (2019), ICT could result in more economic inclusion of emerging market countries, valuable job opportunities for low-income workers and higher living standards for all. Despite the undeniable positive role of ICT in economic development, it has also been shown that ICT could worsen the distribution and the concentration of wealth as rents may be distributed more unevenly, thereby resulting in the greater marginalisation of the peripheral poor (Melia, 2019).

The role of ICT in economic development has also been supported by the World Bank. According to the World Bank (2012), ICT has the potential of reducing poverty, increasing productivity and boosting economic growth. A lack of adequate ICT infrastructure in developing countries has been found to be one of the factors that tend to contribute towards the widening of the gap between developed and developing countries (see Avgerou, 2003). It has also been shown that some ICT features seem to support a strategy of "technological leapfrogging", which could eventually narrow the productivity and output gap between industrialised and developing countries (Steinmueller, 2001). The productivity gain from ICT has also been linked to the ICT spill-over effects that occur when there is a decrease in the cost of transaction and an increase in the knowledge creation process as a result of ICT (Stiroh, 2002; Pilat, 2004).

Although the relationship between ICT and economic growth could be positive, negative or insignificant based on the ascent literature, it is possible that the introduction of a third modulating variable could either dampen the positive effect of ICT on economic growth or mitigate its negative effect. For this reason, in the current study, income inequality is included as a modulating variable in the nexus between ICT and economic growth in order to examine its effect on the ICT-growth nexus in SSA countries.

Theoretically, higher income inequality could have a negative or positive impact on economic growth. Beginning with the negative effect, high income inequality could lead to a decrease in economic growth through various channels. First, high income inequality may be detrimental to economic growth through the so-called “endogenous fiscal policy” theory. Higher income inequality could result in political instability and social unrest, which are detrimental to growth (see Bertola 1993; Alesina and Rodrick 1994; Alesina and Perotti, 1996; Knack and Keefer, 2000, amongst others). Secondly, higher income inequality could have a harmful effect on economic growth due to underinvestment in human capital by the poorer segments of society. As a result of high-income inequality, the poorest segment of society may drop out of school if they cannot afford the fees, which may negatively affect the accumulation of human capital. This channel is referred to as the “human capital accumulation” theory (see Cingano, 2014). Thirdly, higher income inequality could also negatively affect growth if the adoption of advanced technologies is largely driven by the domestic demand.

Regarding the positive effect, higher income inequality could boost economic growth if i) it gives the incentives for individuals to invest in hard work and undertake risks that are associated with high rates of return (Mirrlees, 1971; Lazear and Rosen, 1981); and ii) if it promotes aggregate savings and, hence, capital accumulation, thereby reducing the propensity to increase consumption by the rich (Kaldor, 1956; Bourguignon, 1981).[3]

Although a number of studies have examined the direct link between ICT and economic growth in various African countries[4], very few studies have examined the role of income inequality in modulating the impact of ICT on economic growth. Even where such studies have been conducted, the empirical findings on the impact of ICT on economic growth at best remains inconclusive. The current study differs fundamentally from previous studies conducted in SSA in various ways. First, unlike in some previous studies, not only is the impact of ICT on economic growth examined, but also whether income inequality modulates the impact of ICT on economic growth. Secondly, three ICT proxies, namely mobile phone, Internet and broadband have been used in order to examine whether the impact of ICT on economic growth depends on the ICT proxy used. Thirdly, three income inequality indicators, namely the Gini coefficient, the Atkinson ratio and the Palma ratio have been used, thereby leading to three different specifications for each ICT proxy. Fourthly, in order to examine the modulating effect of income inequality on the ICT–growth nexus, three interaction terms have been computed for each of the ICT proxies, thereby leading to a total of nine interaction terms between ICT and income inequality proxies. The modulating effect of income inequality on the nexus between ICT and economic growth will inform policymakers as to whether income inequality plays a significant role in the ICT–growth nexus and whether they should simultaneously target both income inequality and ICT infrastructure development in their long-term quest for a sustained growth path. In addition, by using an interaction model, the current study is aimed at estimating threshold levels of income inequality, which should not be exceeded in order for the beneficial effects of ICT development on economic growth to be sustained. To our knowledge, this may be among the first few studies to examine in detail the dynamic relationship between ICT, income inequality and economic growth in SSA countries using the GMM model.

[3] For a detailed discussion on the positive and negative effects of high-income inequality on economic growth, see Cingano, F. (2014).
[4] These include Saidi et al. (2015) for the case of Tunisia, Adeleye and Eboagu (2019) with respect to 54 African countries; David and Grobler (2020) in relation to 46 African countries; and Kallal et al. (2021) for the case of Tunisia, among others.

The rest of the study is organised as follows: In Section 2, a summary is provided of previous empirical literature on the relationship between ICT and economic growth in developed and developing countries. In Section 3, the methodology used in the study is presented, while in Section 4, the empirical analysis is presented. Section 5 concludes the study.

2. Literature review

Although the role of ICT in economic growth has been investigated extensively in various countries, very few studies have been conducted in African countries. Some of the studies that have been done in African countries included studies such as Andrianaivo and Kpodar (2011), Saidi et al. (2015), Albiman and Sulong (2017), Adeleye and Eboagu (2019), Haftu (2019), David and Grobler (2020), Myovella et al. (2020), Solomon and Klyton (2020), Adeleye (2021), and Kallal et al. (2021). Andrianaivo and Kpodar (2011) examined the relationship between ICT, financial inclusion and growth using data from African countries during the period 1988-2007. Using the System GMM estimator, the study found that ICT, including mobile phone development, contribute significantly to economic growth. Saidi et al. (2015) investigated the effects of ICT on economic growth in Tunisia and found that ICT positively affects economic growth in Tunisia. Albiman and Sulong (2017) used linear and non-linear models to examine the impact of ICT on economic growth. Using disaggregate income groups within SSA region, the study found that although the linear impact of Internet penetration and usage is positive and significant for lower-middle-income countries, the results remain inconclusive compared to other ICT innovations. Adeleye and Eboagu (2019) examined the impact of ICT on economic growth in Africa based on data from 54 countries from 2005 to 2015. In the findings of their studies, among others, it was revealed that ICT development has a statistically significant positive impact on economic growth. In addition, it was revealed that the output elasticities of the three ICT indicators are significantly different and that the "leapfrogging" hypothesis holds. Haftu (2019) examined the impact of mobile phone and the Internet on economic growth using data from 40 sub-Saharan Africa (SSA) during the period 2006-2015. Using a two-step system GMM technique, the study found that the growth in mobile phone penetration has contributed significantly to economic growth in the region. It was found that a 10% increase in mobile phone penetration leads to a 1.2% change in GDP per capita. David and Grobler (2020) examined whether the ICT penetration level serves as an impetus for economic growth and development in Africa, and found that, in totality, ICT penetration has a positive impact on economic growth and development in Africa, and that the positive impact is higher in economic growth than in economic development. It was recommended that investments are required in fixed-line and internet access telecommunications in Africa in order to fully tap into the optimal impetus of ICT penetration for economic growth and development in the region. Myovella et al. (2020) examined the contribution of digitalisation to the economic growth of SSA in comparison with the OECD economies during the period 2006-2016. Using the generalised linear methods of moments (GMM) estimators, the study found that digitalisation has a positive contribution to economic growth in both groups of countries although broadband Internet and mobile telecommunications have different impacts for OECD and SSA countries. Solomon and Klyton (2020) examined the impact of the usage of digital technology on economic growth in 39 African countries using data from 2012 to 2016. By employing the system GMM estimator, the study found that individual usage of ICT is positively associated with growth. Adeleye (2021) examined the criticality of the ICT–trade nexus on economic and inclusive growth in 53 African countries during the period 2005-2015. Using mobile phones and fixed telephone subscriptions as indicators of ICT, the study found that in the main, ICT adoption significantly promotes economic and inclusive growth. Kallal et al. (2021) used a panel pooled mean group form of the autoregressive distributed lag model to investigate the relationship between ICT diffusion and economic growth in Tunisia. The study found that ICT has a positive effect on economic growth in the long run, but not in the short run. Furthermore, a negative effect was found, which was attributable to substantial investment bias.

Apart from the studies mentioned above, a number of studies have been conducted on the relationship between ICT and economic growth in other developing and developed countries. These include studies such as Colecchia and Schreyer (2002), Jalava and Pohjola (2008), Kuppusamy et al. (2009), Nasab and Aghaei (2009), Yousefi (2011), Ahmed and Ridzuan (2013), Ani et al. (2013), Sassi and Goaied (2013), Vu (2013), Lee and Brahmasrene (2014), Hwang and Shin (2017), Das et al. (2018), Niebel (2018), Pradhan et al. (2018), Makun and Devi (2019), Sinha and Sengupta (2019), Fernández-Portillo et al. (2020), Iqbal et al. (2020), Kurniawati (2020), Kurniawati (2020), Nair et al. (2020), Tripathi and Inani (2020), Appiah-Otoo and Song (2021), and Usman et al. (2021), among others.

Colecchia and Schreyer (2002) compared the impact of ICT capital accumulation on output growth in Australia, Canada, Finland, France, Germany, Italy, Japan, the United Kingdom and the United States of America, and found that over the past two decades, ICT has contributed between a 0.2 and 0.5 percentage point to economic growth annually, depending on the country. Jalava and Pohjola (2008) examined the roles of electricity and ICT in economic growth in Finland using the growth accounting approach, and found that ICT's contribution to GDP growth was three times as large as that of electricity over comparable periods of time. Kuppusamy et al. (2009) examined the effect of ICT investment carried out by the private and public sector on Malaysia's economic growth over the period 1992-2006. Using the autoregressive distributed lag (ARDL) econometrics approach, it was found that ICT investments undertaken in Malaysia have paid off, albeit at different scales in different economic sectors. Specifically, it was found that ICT investments made by the private sector seem to have contributed significantly to the growth of the country when compared with investments made by government. Nasab and Aghaei (2009) examined the effect of ICT on economic growth in 11 Organisation of Petroleum Exporting Countries (OPEC) member countries using the Generalized Method of Moments (GMM), and found that ICT investments affect the economic growth of OPEC member countries positively. Yousefi (2011) examined whether ICT has helped to improve economic growth in 62 developed and developing countries, and the extent thereof. The author found that the ICT plays a major role in the growth of high and upper-middle income groups, but fails to contribute to the growth of the lower-middle income group countries. Ahmed and Ridzuan (2013) examined the impact of ICT on economic growth in ASEAN[5] 5+3 countries consisting of Malaysia, Thailand, Singapore, Indonesia, the Philippines, Japan, Korea and China using a panel data set, and found that ICT has a positive impact on economic growth in ASEAN5 and ASEAN5+3 countries. It was, therefore, concluded that ICT plays an important role as an engine of growth for sustainable development in ASEAN5 and ASEAN5+3 countries. Ani et al. (2013) examined the effect of telecommunication development on economic growth in leading ICT developed countries in Africa, and found that telecommunication development in Africa have a positive and significant influence on economic growth. Sassi and Goaied (2013) examined the relationship between financial development, ICT diffusion and economic growth in 17 Middle East and North Africa (MENA) countries during the period 1960-2009. Using a standard growth model and a system GMM estimator, it was found, *inter alia*, that ICT diffusion has a positive impact on growth in the countries under study. Vu (2013) investigated the contributions of ICT to Singapore's economic growth during the 1990-2008 period and found that ICT capital played

[5] Association of Southeast Asian Nations

a substantial role in Singapore's growth, contributing a 1.0 percentage point to GDP growth and a 0.8 percentage point to average labour productivity (ALP) growth in the 1990-2008 period. Lee and Brahmasrene (2014) examined the relationships between ICT, carbon dioxide (CO_2) emissions and economic growth in nine members from the Association of Southeast Asian Nations (ASEAN). Using panel annual data constructed from 1991 to 2009, it was found that ICT development has a highly significant positive effect on economic growth. Hwang and Shin (2017) investigated the role of ICT-specific technological change in Korea's past and future, and found that ICT accounted for almost 40% of Korean economic growth from 2000 to 2012, despite the fact that the average portion of output from ICT-producing sectors out of the total output was only approximately 20%. Das et al. (2018) examined the joint effects of ICT and financial development on per capita economic growth in a sample of 43 developing countries. Using the system GMM technique, it was found that the individual effect of ICT (internet, telephone and mobile) on economic growth is positive and significant when the entire panel of developing countries is included in the regression. Niebel (2018) analysed the impact of ICT on economic growth in developing, emerging and developed countries, and found that ICT contributes substantially to economic growth, not only in developed, but also in developing and emerging countries. In a study aimed at examining the relationship between ICT infrastructure and economic growth in G-20 countries, Pradhan et al. (2018) found that there is a positive association among ICT infrastructure (broadband and Internet), consumer price index and economic growth in the countries under study. Makun and Devi (2019) examined the effect of ICT on economic output in the Republic of Fiji Islands during the period 1990-2016. Using the autoregressive distributed lag bounds approach to cointegration, it was found that, in the long run, a 1% increase in the respective measures of ICT will lead to an increase in output per capita between 0.04 and 0.06 per cent. However, in the short run, mobile cellular subscription and cell phone number have a positive coefficient elasticity, but lacks significance in the current period. Sinha and Sengupta (2019) examined the dynamic interrelationships among foreign direct investment (FDI) inflows, ICT expansion and economic growth in 30 Asia-Pacific developing countries during the period of 2001-2017. Using the panel fully modified ordinary least squares, dynamic ordinary least squares, pooled mean group estimator, mean group estimator and dynamic fixed effects methods, it was revealed that FDI and ICT have positive and significant effects on economic growth. Fernández-Portillo et al. (2020) examined the impact of ICT development on economic growth in 23 European Union countries that are also part of the OECD and found that ICT drives economic growth within the framework of developed European economies. Iqbal et al. (2020) examined the effect of ICT on migration and economic growth in 59 Belt and Road (BRI) countries during the period 2000-2017. Using, *inter alia*, fully modified OLS (FMOLS), it was found that there is positive association between ICT and economic growth in BRI countries. Kurniawati (2020) examined the relationship between ICT infrastructure, innovation development and economic growth in OECD countries, and found clear evidence suggesting that economic growth is positively correlated with ICT mobile, ICT Internet, innovation and macroeconomic variables. Tripathi and Inani (2020) investigated the impact of ICT on economic growth for the member countries of the South Asian Association for Regional Cooperation (SAARC), namely Bangladesh, India, Sri Lanka and Pakistan during the 1990-2014 period. Using panel data techniques, it was found that a 1% increase in the adoption of teledensity enhances economic growth by at least 0.028%, *ceteris paribus*. However, the impact of ICT on economic growth was found to be highest in India, followed by Sri Lanka, Bangladesh and Pakistan, respectively. Appiah-Otoo and Song (2021) examined the impact of ICT on economic growth in 123 countries consisting of rich and poor countries. Using the principal component analysis (PCA), it was found that ICT increases economic growth in rich and poor countries. It was also found that the gains from ICT in poor countries are larger than that of rich countries. More recently, Usman et al.

(2021) analysed the effects of ICT on economic performance and energy consumption in four South Asian economies during the period of 1990-2018. Using the bounds testing approach to cointegration and error correction model, it was found that, in the long-run, ICT significantly and positively contribute to the economic growth of India only.

Apart from the studies mentioned above, in a few studies, the impact of ICT development on economic growth has been found to be mixed, negative or not significant at all (Raheem et al., 2020; Ishida, 2015). In other studies, it was also found that the relationship between ICT and economic growth differs from country to country (Stanley et al., 2018; Yousefi, 2011). Raheem et al. (2020) examined the impact of ICT and financial development (FD) on carbon emissions and economic growth for the G7 countries for the period 1990-2014. Using the PMG model, it was found that ICT and FD have no meaningful effect on economic growth. Ishida (2015) estimated the long-run relationship between ICT, energy consumption and economic growth in Japan using an ARDL bounds testing approach and found that ICT investment contributes directly to a moderate reduction in energy consumption, but not to an increase in GDP. Stanley et al. (2018) examined the differential impact of ICT on developed and developing countries, and the differential impact of different types of ICT, such as landlines, cell phones, computer technology and internet access. Using meta-regression analysis to 466 estimates drawn from 59 econometric studies, little evidence was found that the internet has had a positive impact on growth. It was also found that developed countries gain significantly more from computing than developing countries. The study concluded that the effect of ICT on economic growth appears largely contingent on the level of development, the type of ICT and the interaction between the two. Yousefi (2011) examined whether ICT has helped to improve economic growth using data from 62 countries for the period 2000-2006. It was found that although the investments in ICT and NICT capitals result in similar marginal contributions to the total output growth for all income groups combined, the contribution figures are higher for the upper-middle income group countries than those for the high-income group. The study concluded that ICT plays a major role in the growth of high and upper middle-income groups, but fails to contribute to the growth of the lower middle-income group countries.

Aside from the above-mentioned studies, there are other empirical studies that have focused on the link between income inequality and economic growth, though with mixed results. While in some of these studies, either a negative or positive relationship was found between higher income inequality and economic growth, in others, the relationship between income inequality and economic growth was found to depend on the country's initial level of income. Studies that found higher income inequality to be associated with lower economic growth include those conducted by Alesina and Rodrik (1994), Persson and Tabellini (1994), Atems and Jones, 2015), Bartak and Jabłoński (2019), among others. Alesina and Rodrik (1994), while examining the relationship between politics and economic growth using a simple endogenous growth model, found that inequality in land and income ownership is negatively correlated with subsequent economic growth. In an attempt to examine whether inequality is harmful to growth using data from 56 countries during the period 1960-1985, Persson and Tabellini (1994) found a large and significant negative relationship between inequality and economic growth in democracies. Atems and Jones (2015) examined the effects of inequality on per capita income and the effects of per capita income on income inequality in the United States (US) during the period 1930-2005. Using annual US state-level income inequality data and panel vector autoregressive (VAR) models, the study found that shocks to the Gini index have a significant and negative impact on the level of per capita income. The study also found that the relationship between inequality and per capita income varies over time. More recently, Bartak and Jabłoński (2019), while using data from OECD countries during the period 1990–2014 to examine whether income inequality impedes the growth rates, found that income inequality affects economic growth negatively.

Studies that found support for a positive relationship between income inequality and economic growth, on the other hand, include studies, such as Li and Zou (1998), Forbes (2000), Joshi (2017), and da Silva (2020), among others. This narrative is also in line with the theoretical work by Galor and Zeira (1993). As an example, while examining whether income inequality is harmful for growth, Li and Zou (1998) found that contrary to the previous results obtained by Alesina and Rodrik and Persson and Tabellini, income inequality is positively, and in most cases, significantly associated with economic growth. While reassessing the relationship between income inequality and economic growth using an improved data set on income inequality, Forbes (2000) found that in the short and medium term, an increase in income inequality has a significant positive relationship with subsequent economic growth. While examining the impact of income inequality on economic growth in India using a cross-country approach, Joshi (2017) found a strong significant positive impact of the existence of inequality on economic growth in Indian states. While investigating the dynamic relationship between income inequality and economic growth using state-level data for Brazil, Da Silva (2020) found that inequality shocks lead to higher economic growth; hence, supporting the view that higher inequality benefits economic growth in poor countries.

In between these two extremes are studies in which it was found that the relationship between income inequality and economic growth differs from country to county and over time. While examining the relationship between income inequality and economic growth, Shin (2012) found that higher inequality can retard growth in the early stage of economic development, but can at the same time encourage growth in a near steady state. While examining the effects of income inequality on aggregate output using panel data from 104 countries during the period 1970-2010, Brueckner and Lederman (2015) found that, although on average, income inequality has a significant negative effect on transitional GDP per capita growth and the long-run level of GDP per capita, its impact varies by level of economic development. In particular, it was found that in poor countries, income inequality has a significant positive effect on gross domestic product per capita. In examining the relationship between income inequality and economic growth using data from 112 emerging countries during the period 1980-2014, Caraballo et al. (2017) found that income inequality has a positive influence on economic growth for richer countries and a negative influence for poorer countries. While examining the role of initial income in the inequality–growth nexus, Brueckner and Lederman (2018) found that in low-income countries, transitional growth is boosted by greater income inequality, while in high income countries, inequality has a significant negative effect on transitional growth. More recently, while re-examining the relationship between income inequality and economic growth using data from 63 countries during the period 1991-2017, Balcilar et al. (2021) found that the relationship between income inequality and growth takes the form of an inverted U-shape. In the main, it was found that income inequality initially has a positive impact on growth only up to an average Gini coefficient threshold of 35.92 and that beyond this level, it negatively affects economic growth.

Based on the attendant literature reviewed in this section, it is clear that in most of the previous studies, the focus was on either the relationship between ICT and economic growth or on the link between income inequality and economic growth, thereby leaving a wide gap in the empirical literature on the relationship between ICT development, income inequality and economic growth. In particular, studies that have focused on the modulating effect of income inequality on the ICT–growth nexus are scant, making the current study timely.

3. Methodology

GMM specification

In this study, an extension of the difference GMM technique developed by Roodman is used. The technique has numerous advantages, which have been documented in previous studies, such as Asongu and Odhiambo (2020a, 2020b), Tchamyou (2019a, 2019b), Odhiambo (2020), and Adekunle (2021), among others. The GMM approach has been found to be stronger than other techniques as it limits the proliferation of instruments, thereby producing more robust estimates (see Asongu and Odhiambo, 2020b, 2020c). Moreover, the GMM approach has been found to be suitable when the number of countries (cross-sections) is significantly higher than the periods (years) for each cross-section (country)[6]. Since the number of cross-sections in this study is 40 and the number of time periods is 11, the GMM is likely to yield more robust results than other estimation techniques. The number of cross-sections used in this study was largely informed by the availability of adequate and reliable data for the key variables employed in the study.

Based on Odhiambo (2020), Tchamyou et al. (2019a, 2019b), Asongu and Odhiambo (2020a), and Asongu et al. (2019), the GMM model used in this study can be presented as follows:

Variables in levels

$$y_{i,t} = \sigma_0 + \sigma_1 y_{i,t-\tau} + \sigma_2 ICT_{i,t} + \sigma_3 INEQUAL_{i,t} + \sigma_4 ICTxINEQUAL_{i,t} + \sum_{h=1}^{2} \delta_h CV_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

[6] See also Asongu and Odhiambo (2019).

Variables in First Difference

$$y_{i,t} - y_{i,t-\tau} = \sigma_1(y_{i,t-\tau} - y_{i,t-2\tau}) + \sigma_2(ICT_{i,t} - ICT_{i,t-\tau}) + \sigma_3(INEQUAL_{i,t} - INEQUAL_{i,t-\tau}) + \sigma_4(ICTxINEQUAL_{i,t} - ICTxINEQUAL_{i,t-\tau}) + \sum_{h=1}^{2} \delta_h(CV_{h,i,t-\tau} - CV_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \quad (2)$$

where, $y_{i,t}$denotes economic growth measure by GDP growth of country *i* in period *t.* ICT refers to the information technology of country *i* in period *t*. ICT is measured by three proxies, namely: i) mobile phone subscriptions per 100 people, ii) internet subscriptions per 100 people and iii) fixed broadband subscriptions. INEQUAL denotes income inequality measurement of country *i* in period *t*. Income inequality is measured by three proxies, namely: the Gini coefficient, the Atkinson index and the Palma ratio (Asongu and Odhiambo, 2019a; Asongu and Odhiambo, 2019b). ICT*xINEQUAL* represents the interactions between various indicators of inequality and ICT (in other words, *ICTxGini*, *ICTxAtkinson,* and ICT*xPalma*)[7]. *CV* is a vector of control variables. τ represents the coefficient of auto-regression, $\hat{\iota}_t$is the time-specific constant, and $\eta_i$is the country-specific effect.

Identification and exclusion restrictions

Following Odhiambo (2020), Asongu and Odhiambo (2019a), Dewan and Ramaprasad (2014), two procedures are used in this study, namely the GMM style procedure to estimate the predetermined or variables suspected to be endogenous, and the 'ivstyle' – 'iv (years, eq (diff))' procedure to address the time-invariant omitted variables. To address the endogeneity problem,

[7] See also Adekunle et al. (2020), Odhiambo (2020) and Asongu and Odhiambo (2021), among others.

lagged regressors are used as instruments for forward-differenced variables in the model. The motivation for this approach is to ensure that the fixed effects are removed and, hence, can no longer have any influence on the investigated nexuses.

Based on the work done by Arellano and Bover (1995) and Love and Zicchino (2006), the Helmert transformation approach was used in order to remove any fixed effects that could be associated with error terms and which may potentially lead to biasness in the empirical model (see also Asongu and Nwachukwu, 2016; Asongu and De Moor, 2017). This involves forward mean-differencing of the variables used in the model. The Helmert (forward-orthogonal) transformation approach requires the mean of future observations to be subtracted from the variables, rather than the previous observations being subtracted from the current observations (see Roodman, 2009a). The aim of this approach is to ensure that there are orthogonal conditions between forward-differenced variables and their lagged values (Roodman, 2009a; Asongu and De Moor, 2017). This transformation also helps in preventing data loss for all observations of all cross-sections, except for the last value of each cross-section. This is because the lagged values do not enter into the formulae, but they remain valid as instruments (Roodman, 2009b:104; Asongu and Nwachukwu, 2016; Asongu and De Moor, 2017).

Regarding the exclusion restrictions, the Difference in Hansen Test (DHT) was used in this study to test the validity of the exclusion restriction (see Asongu and Odhiambo, 2019a; Asongu and Nwachukwu, 2016). According to the Hansen test, the instruments can only explain the dependent variable exclusively via suspected endogenous variables if the alternative hypothesis is rejected (see Tchamyou and Asongu, 2017; Tchamyou, 2020; Odhiambo, 2020).

Data

The data used in this study were obtained from various sources. The dependent variable, namely economic growth, was measured by the growth rate of GDP, which was obtained from the World Developing Indicators. The ICT proxies, namely internet penetration, mobile phone penetration rate and fixed broadband subscription, were also obtained from the World Development Indicators. The income inequality variables, namely the Gini coefficient, the Atkinson index and the Palma ratio were obtained from the Global Consumption and Income Project (GCIP). Based on the extant literature, i) the Gini coefficient indicates wealth distribution across the population, ii) the Atkinson index determines which end of the distribution mostly contributes to the observed inequality, and iii) the Palma ratio shows the ratio income share of the top 10% to that of the bottom 40% (see Asongu and Odhiambo, 2020d; Odhiambo, 2020; Meniago and Asongu, 2018; Tchamyou et al., 2019a). Political stability, which is the first control variable, has been obtained from the World Governance Indicators. The variable captures the perceptions of the likelihood that the government will be destabilised or overthrown by unconstitutional or violent means. In accordance with the extant literature, political instability diminishes the productive, as well as the transactional capacities of the economy, thereby leading to adverse effects on investment and future economic growth (Dalyop, 2019). Hence, the impact of political stability on economic growth is expected to be positive and statistically significant. Remittance, which has been used as the second control variable, is measured by remittance inflows as a percentage of GDP, and the data were obtained from the World Development Indicators. In line with previous studies, the impact of remittance on economic growth may be positive or negative[8]. A summary of the definitions and sources of the variables used in this study are provided in Appendix 1, while the summary statistics and the correlation matrix are presented in Appendices 2 and 3, respectively.

[8] See, for example, Sutradhar, 2020.

4. Empirical analysis

The results reported in Table 1 show that, on the whole, an increase in ICT unconditionally leads to an increase in economic growth. This finding has been found in six of the nine specifications. It is also consistent with some of the previous studies, such as Andrianaivo and Kpodar (2011), Saidi et al. (2015), David and Grobler (2020), among others, in which ICT was found to have a positive impact on economic growth. Specifically, the results show that when mobile phone penetration is used as a proxy for ICT development, the coefficient of ICT in economic growth equation is found to be positive and statistically significant in the Gini specification, but not in the Atkinson and Palma ratio specifications. When internet penetration is used a proxy, the coefficient of ICT in economic growth equation is found to be positive and statistically significant in the Gini and Atkinson specifications, but not in the Palma ratio specification. Finally, when fixed broadband subscription is used as a proxy, the coefficient of ICT is found to be positive and statistically significant in all the three income inequality specifications (i.e., the Gini coefficient, the Atkinson and the Palma ratio specifications).

The results also show that, on the whole, income inequality consistently interacts with ICT to influence the economic growth process in the sampled countries, although the magnitude depends on the proxy used and the level of ICT development. When mobile phone penetration is used as a proxy for ICT development, the interaction between income inequality and ICT is found to have a significant influence on economic growth in the Gini and Atkinson specifications, but not in the Palma ratio specification. However, when internet penetration and fixed broadband subscriptions are used, the interaction between income inequality and ICT is found to have a significant influence on economic growth in all the three income inequality specifications.

In order to examine the threshold level at which inequality affects the impact of ICT development on economic growth, the study computed threshold values for each income inequality proxy. The results show that the positive impact of ICT on economic growth can change to negative if the following inequality levels are exceeded, namely: i) 0.520 (0.232/0.446) for the Gini coefficient in the case of mobile penetration specification; ii) 0.531 (0.479/0.902) and 0.560 (0.277/0.495) for the Gini and Atkinson specifications in the case of the internet penetration specification; and iii) 0.551(6.257/11.352), 0.633(3.920/6.191) and 4.664 (1.180/0.253) for the Gini, Atkinson and Palma ratio specifications, respectively, in the case of fixed broadband subscription. In these computations, the numerator in parentheses represents the unconditional impact of the various proxies of ICT on economic growth, while the denominator represents the absolute value of the conditional impact pertaining to the interaction between the various proxies of income inequality and ICT (see Asongu et al. 2020).

The results also show that the impact of the first control variable (in other words, political stability) on economic growth is positive and statistically significant in the Atkinson and Palma ratio specifications when ICT is measured by Internet penetration and fixed broadband subscriptions. This is confirmed by the coefficient of political stability in the Atkinson and Palma ratio specifications, which has been found to be positive and statistically significant when ICT is measured by Internet penetration and fixed broadband subscriptions, but not by mobile phone penetration. This implies that an increase in political stability leads to an increase in economic growth as stable and predictable governments tend to attract long-term investment. This finding is consistent with previous studies, such as Radu (2015) for the case of Romania, Ramadhan et al. (2016) for the case of Tanzania, and Jaouadi et al. (2014) for the case of developing countries, among others. The results of the second control variable (remittance) show that remittance has a positive effect on economic growth in the Gini specification when ICT is measured by fixed broadband subscriptions. This finding is consistent with previous studies, such as Pradhan et al. (2008) for the case of developing countries, Sutradhar (2020) for the case of India, and Fayissa and Nsiah (2010) for the case of the case of African countries.

Four main information criteria have been used to assess the validity of the estimated GMM models, namely: 1) the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals; 2) the Sargan and Hansen over-identification restrictions (OIR) tests; 3) the Difference in Hansen Test (DHT) for exogeneity of instruments, and 4) the Fisher test for the joint validity of the estimated coefficients (see also Odhiambo, 2020). It is worth mentioning that the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant as their null hypotheses assume that the instruments are not correlated with the error terms (see Asongu and De Moor, 2017). In order to limit the proliferation of instruments, efforts have been made to ensure that the number of instruments is lower than the number of cross-sections as far as possible. The diagnostic test results show that, on the whole, model used in this study is valid.

Table 1: ICT, Inequality and Economic growth

	Dependent variable: GDP growth (GDPg)								
	Mobile Phone Penetration			Internet Penetration			Fixed Broadband Subscriptions		
	Gini	Atkinson	Palma	Gini	Atkinson	Palma	Gini	Atkinson	Palma
Constant	-7.247 (0.171)	Omitted	5.826** (0.034)	-0.953 (0.715)	3.483 (0.336)	Omitted	0.010 (0.996)	4.173 (0.228)	4.282*** (0.000)
GDPg(-1)	**0.249*** (0.000)**	**0.301*** (0.000)**	**0.306*** (0.000)**	**0.194*** (0.000)**	**0.232*** (0.000)**	**0.216*** (0.000)**	**0.182*** (0.000)**	**0.218*** (0.000)**	**0.200*** (0.000)**
Mobile Phone(Mob)	**0.232*** (0.009)**	0.081 (0.270)	-0.012 (0.644)	---	---	---	---	---	---
Internet	---	---	---	**0.479*** (0.000)**	**0.277*** (0.003)**	0.046 (0.352)	---	---	---
Broadband	---	---	---	---	---	---	**6.257*** (0.000)**	**3.920** (0.027)**	**1.180*** (0.000)**
Gini Coefficient (Gini)	**23.171** (0.012)**	---	---	**6.754* (0.077)**	---	---	**5.931** (0.039)**	---	---
Atkinson Index (Atkinson)	---	9.053 (0.352)	---	---	-0.723 (0.878)	---	---	0.637 (0.886)	---
Palma Ratio (Palma)	---	---	0.019 (0.949)	---	---	-0.141 (0.411)	---	---	-0.019 (0.808)
Mob × Gini	**-0.446*** (0.003)**	---	---	---	---	---	---	---	---
Mob × Atkinson	---	**-0.164* (0.097)**	---	---	---	---	---	---	---
Mob × Palma	---	---	-0.002 (0.481)	---	---	---	---	---	---
Internet × Gini	---	---	---	**-0.902*** (0.000)**	---	---	---	---	---
Internet × Atkinson	---	---	---	---	**-0.495*** (0.000)**	---	---	---	---
Internet × Palma	---	---	---	---	---	**-0.016*** (0.007)**	---	---	---
Broadband × Gini	---	---	---	---	---	---	**-11.352*** (0.000)**	---	---
Broadband × Atkinson	---	---	---	---	---	---	---	**-6.191****	---

								(0.020)	
Broadband × Palma	---	---	---	---	---	---	---	---	**-0.253*** **
									(0.000)
Political Stability	1.110	1.294	0.900	1.288	**1.83***	**1.712***	0.550	**0.818****	**0.799***
	(0.126)	(0.171)	(0.332)	(0.112)	**(0.053)**	**(0.075)**	(0.230)	**(0.038)**	**(0.097)**
Remittance	-0.008	-0.016	-0.018	0.053	0.084	0.069	**-0.061***	-0.008	-0.015
	(0.857)	(0.835)	(0.776)	(0.378)	(0.119)	(0.226)	**(0.064)**	(0.872)	(0.769)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects of ICT	-0.029	na	na	-0.049	-0.072	na	-0.395	-0.444	-0.453
Inequality Thresholds	0.520	na	na	0.531	0.559	na	0.551	0.633	4.664
AR(1)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)
AR(2)	**(0.811)**	**(0.701)**	**(0.708)**	**(0.850)**	**(0.759)**	**(0.810)**	**(0.545)**	**(0.462)**	**(0.477)**
Sargan OIR	**(0.711)**	**(0.743)**	**(0.838)**	**(0.702)**	**(0.651)**	**(0.736)**	**(0.352)**	**(0.541)**	**(0.568)**
Hansen OIR	**(0.213)**	**(0.532)**	**(0.324)**	**(0.325)**	**(0.293)**	**(0.435)**	**(0.314)**	**(0.501)**	**(0.396)**
DHT for instruments									
(a)Instruments in levels									
H excluding group	**(0.257)**	**(0.524)**	**(0.543)**	**(0.357)**	**(0.229)**	**(0.251)**	**(0.389)**	**(0.393)**	**(0.397)**
Dif(null, H=exogenous)	**(0.243)**	**(0.470)**	**(0.251)**	**(0.321)**	**(0.362)**	**(0.522)**	**(0.295)**	**(0.501)**	**(0.364)**
(b) IV (years, eq(diff))									
H excluding group	(0.078)	**(0.546)**	**(0.402)**	**(0.619)**	**(0.837)**	**(0.525)**	**(0.286)**	**(0.603)**	**(0.353)**
Dif(null, H=exogenous)	**(0.539)**	**(0.446)**	**(0.296)**	**(0.198)**	**(0.113)**	**(0.348)**	**(0.421)**	**(0.376)**	**(0.301)**
Fisher	**41.15*** **	**170.31*** **	**17.38*** **	**29.53*** **	**7.54*** **	**130.49*** **	**100.46*** **	**32.76*** **	**40.66*** **
Instruments	32	32	32	32	32	32	32	32	32
Countries	40	40	40	40	40	40	38	38	38
Observations	376	376	376	370	370	370	324	324	324

Note: ***,**,* = significance levels at 1%, 5% and 10% respectively.
DHT = Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif = Difference. OIR = Over-identifying Restrictions Test.
The values in bold refer to: 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests; and b) the validity of the instruments in the Sargan and Hansen OIR tests.
0.586, 0.705 and 6.457 are respectively mean values of the Gini coefficient, the Atkinson index and the Palma ratio.
Na = not applicable because at least one estimated coefficient needed for the computation of net effects is not significant.

5. Conclusion

In this study, the dynamic relationship between ICT, income inequality and economic growth is examined using data from SSA countries during the period 2004–2014. The study was motivated by the role of ICT in economic growth and the scourge of high inequality in many sub-Saharan African countries. The study aims at examining whether the ICT development spurs economic growth in sub-Saharan African countries. It also aims at examining whether income inequality modulates the impact of ICT on economic growth. Three proxies of ICT and three proxies of income inequality are used to examine these linkages. The ICT indicators used include: internet penetration rate, mobile phone penetration rate and fixed broadband subscription, while the income inequality indicators used include the Gini coefficient, the Atkinson index and the Palma ratio. Using the GMM estimation techniques, the study found that, on the whole, an increase in ICT unconditionally leads to an increase in economic growth in most of the ICT specifications. The results also show that the magnitude of the impact of ICT on economic growth varies with the proxy used to measure the level of ICT development. Specifically, the study found that ICT increases economic growth when: 1) mobile phone penetration is used as a proxy for ICT in the Gini specification; 2) Internet penetration is used as a proxy for ICT in the Gini coefficient and Atkinson index specifications; and 3) broadband subscriptions are used as a proxy for ICT in all the three income inequality specifications (i.e., the Gini coefficient, the Atkinson and the Palma ratio). Overall, the results show that fixed broadband subscriptions have the highest impact on economic growth, followed by internet penetration and mobile phone penetration. The results further show that there is a threshold level of income inequality above which the positive impact of ICT on economic growth becomes negative. In the main, the results show that the positive impact of ICT on economic growth is likely to become negative if the following inequality levels are exceeded: i) 0.520 for the case of the Gini coefficient in the mobile penetration specification; ii) 0.531 and 0.5595 for the cases of the Gini coefficient and Atkinson index, respectively, in the internet penetration specification; and iii) 0.551, 0.633 and 4.664 for the Gini coefficient, Atkinson index and Palma ratio specifications, respectively, in the case of fixed broadband subscriptions.

The study, therefore, recommends that policymakers in SSA should upscale their ICT infrastructure in order to maintain the upward growth trajectory, which the region has enjoyed in recent years. This will also enable the region to address its current ICT deficit, which has been found to be one of the contributing factors to its economic fragility. In particular, the study recommends that policymakers in the region expand their investment in fixed broadband infrastructure, which has been found to have the highest positive impact on economic growth in relative terms in this study. The study also recommends that policymakers should pay special attention to the income inequality in SSA, which has been found to nullify the positive impact of ICT indicators on economic growth beyond certain thresholds. In particular, the study recommends that the established income inequality thresholds reported in this study should not be exceeded in order for ICT to promote economic growth in the countries under study. This is especially important given the fact that the SSA region currently has the highest income inequality in the world after Latin America. An increase in income inequality beyond the established thresholds is likely to inhibit access to information technology, which could ultimately lead to a negative impact on economic growth.

Future studies could be premised on establishing whether the role of income inequality in modulating the impact of ICT on economic growth could be dependent on the initial levels of income. In addition, engaging country-specific studies with relevant and robust empirical strategies is also worthwhile for more targeted policy implications.

References

Adeleye, N and Eboagu, C. (2019). Evaluation of ICT development and economic growth in Africa. *Netnomics*, Volume 20, pp. 31-53.

Adeleye, BN., Adedoyin, F. and Nathaniel, S. (2021). The criticality of ICT-trade nexus on economic and inclusive growth. Information Technology for Development, Volume 27, Issue 2.

Adekunle, IA., Williams, TO., Omokanmi, OJ. and Onayemi, SO. (2020). The Mediating Role of Institutions in The Remittance–Growth Relationship: Evidence from Nigeria. ECONOMIC ANNALS, Volume LXV, No. 227 / October – December.

Adekunle, IA (2021). On the search for environmental sustainability in Africa: the role of governance. Environmental Science and Pollution Research (2021), Volume 28, pp. 14607–14620.

Ahmed, EM and Ridzuan, R. (2013). The Impact of ICT on East Asian Economic Growth: Panel Estimation Approach. *Journal of the Knowledge Economy*, Volume 4, pp. 540-555.

Alesina, A., & Rodrik, D. (1994). Distributive politics and economic growth. The Quarterly Journal of Economics, 109(2), 465–490. https://doi.org/10.2307/2118470.

Albiman, MM. and Sulong, Z. (2017). The linear and non-linear impacts of ICT on economic growth, of disaggregate income groups within SSA region. Telecommunications Policy, Volume 41, Issues 7–8, pp. 555-572

Andrianaivo, M and Kpodar, KR (2011). ICT, Financial Inclusion, and Growth: Evidence from African Countries. IMF Working Papers. Volume 2011: Issue 073. https://doi.org/10.5089/9781455227068.001.

Ani, W., Mary, IO and David, U. (2013). Telecommunication Development and Regional Economic Growth: Evidence from ITU ICT Development Index (IDI) Top Five Countries for African Region. *African Journal of Business and Economic Research (AJBER)*, Volume 8, Issue 2&3, pp 85-100.

Appiah-Otoo, I and Song, N. (2021). The impact of ICT on economic growth-Comparing rich and poor countries. *Telecommunications Policy*, Volume 45, Issue 2, March 2021, 102082.

Arellano M and Bover O (1995). Another look at the instrumental-variable estimation of error components models. *Journal of Econometrics* 68: 29 –52.

Asongu SA and De Moor L (2017). Financial globalisation dynamic thresholds for financial development: evidence from Africa. *European Journal of Development Research* 29(1): 192–212.

Asongu, S.A., Diop, S. and Addis, A.K. (2020). Governance, Inequality and Inclusive Education in Sub-Saharan Africa, Forum for Social Economics, https://doi.org/10.1080/07360932.2020.1856166.

Asongu SA and Nwachukwu JC (2016). The mobile phone in the diffusion of knowledge for institutional quality in sub-Saharan Africa. *World Development* 86 (October): 133-147.

Asongu, S. A, Orim, S.I. and Nting, R.T. (2019). Inequality, information technology and inclusive education in sub-Saharan Africa, *Technological Forecasting and Social Change*146, pp. 380-389.

Asongu, S. A. and Odhiambo, N. M., (2018). ICT, financial access and gender inclusion in the formal economic sector: evidence from Africa, *African Finance Journal*, Vol. 20 (2), pp. 45-65.

Asongu, SA. and Odhiambo, NM. (2019). Governance, capital fight and industrialisation in Africa. Journal of Economic Structures 8:36. https://doi.org/10.1186/s40008-019-0170-2.

Asongu, S. A. and Odhiambo, N. M. (2020a). Foreign direct investment, information technology and economic growth dynamics in Sub-Saharan Africa, *Telecommunications Policy*. DOI: 10.1016/j.telpol.2019.101838.

Asongu, S. A. and Odhiambo, N. M., (2020b). Foreign Direct Investment, Information Technology and Total Factor Productivity Dynamics in Sub-Saharan Africa, African Governance and Development Institute, Yaoundé.

Asongu, S. A. and Odhiambo, N. M., (2020c). Inequality and gender inclusion: Minimum ICT policy thresholds for promoting female employment in Sub-Saharan Africa, *Telecommunications Policy*, Vol. 44(4), https://doi.org/10.1016/j.telpol.2019.101900.

Asongu, S. A. and Odhiambo, N. M., (2020d). The green economy and inequality in Sub-Saharan Africa: Avoidable thresholds and thresholds for complementary policies, Energy Exploration &Exploitation, https://journals.sagepub.com/doi/pdf/10.1177/0144598720984226.

Asongu, SA. and Odhiambo, NM. (2020e) Inequality thresholds, governance and gender economic inclusion in sub-Saharan Africa, International Review of Applied Economics, 34:1, 94-114, DOI: 10.1080/02692171.2019.1645817.

Asongu, SA. and Odhiambo, NM (2021). Inequality, finance and renewable energy consumption in Sub-Saharan Africa. Renewable Energy, Elsevier, vol. 165(P1), pages 678-688.

Atems, B. and Jones, J. (2015), "Income inequality and economic growth: a panel var approach", Empirical Economics, Vol. 48 No. 4, pp. 1541-1561.

Avgerou, C. (2003). The link between ICT and economic growth in the discourse of development in: Korpela, Mikko; Montealegre, Ramiro and Poulymenakou, Angeliki (eds): *Organizational information systems in the context of globalization*. New York, USA: Springer, pp. 373-386.

Balcilar,M., Gupta,R., Ma, W. and Makena, P. (2021). Income inequality and economic growth: A re-examination of theory and evidence. Review of Development Economics, Volume 25, Issue 2, pp. 515-1103.

Bartak, J., & Jabłoński, Ł. (2019). Inequality and growth: What comes from the different inequality measures? Bulletin of Economic Research. doi:10.1111/boer.12220

Brueckner, M. and Lederman, D. (2015), "Effects of income inequality on aggregate output", Policy research working paper 7317, World Bank Group.

Brueckner,M. and Lederman, D. (2018). Inequality and economic growth: the role of initial income. Journal of Economic Growth, volume 23, pp. 341–366

Caraballo, M. Á., Dabús, C., & Delbianco, F. (2017). Income Inequality and Economic Growth Revisited. A Note. Journal of International Development, 29(7), 1025–1029. doi:10.1002/jid.3300

Cardona, M., T. Kretschmer, and T. Strobel (2013). "ICT and Productivity: Conclusions from the Empirical Literature". Information Economics and Policy 25(3), pp. 109–125.

Cingano, F. (2014), "Trends in Income Inequality and its Impact on Economic Growth", OECD Social, Employment and Migration Working Papers, No. 163, OECD Publishing. http://dx.doi.org/10.1787/5jxrjncwxv6j-en.

Colecchia, A and Schreyer, P. (2002). ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries. *Review of Economic Dynamics*, Volume 5, pp. 408-442.

Das, A., Chowdhury, M and Seaborn, S. (2018). ICT Diffusion, Financial Development and Economic Growth: New Evidence from Low and Lower Middle-Income Countries. *Journal of the Knowledge Economy*, Volume 9, pp. 928-947.

Dalyop, GT (2019), "Political instability and economic growth in Africa", *International Journal of Economic Policy Studies, Volume* 13, pp. 217–257. https://doi.org/10.1007/s42495-018-0008-1

David, OO and Grobler, W. (2020). Information and communication technology penetration level as an impetus for economic growth and development in Africa. *Economic Research-EkonomskaIstraživanja*, Volume 33, Issue 1, pp. 1394-1418.

Dewan S and Ramaprasad J (2014) Social media, traditional media and music sales. *MIS Quarterly* 38(1): 101-128.

Fayissa, B., & Nsiah, C. (2010). The impact of remittances on economic growth and development in Africa. The American Economist, 55(2), 92–103

Fernández-Portillo, A., Almod´ovar-Gonz´alez, M and Hernández-Mogollón, R. (2020). Impact of ICT development on economic growth. A study of OECD European union countries. *Technology in Society*, Volume 63, 101420.

Forbes, K. J. (2000). A reassessment of the relationship between inequality and growth. American Economic Review, 90(4), 869–887. https://doi.org/10.1257/aer.90.4.869.

Galor, O. and Zeira, J. (1993), "Income distribution and macroeconomics", The Review of Economic Studies, Vol. 60 No. 1, pp. 35-52.

Haftu, GG. (2010). Information communications technology and economic growth in Sub-Saharan Africa: A panel data approach. Telecommunications Policy, Volume 43, Issue 1, pp. 88-99

Hwang, WS and Shin, JS. (2017). ICT-specific technological change and economic growth in Korea. *Telecommunications Policy*, Volume 41, Issue 4, pp. 282-294.

Iqbal, K., Peng, H., Hafeez, M and Khurshaid. (2020). Analyzing the Effect of ICT on Migration and Economic Growth in Belt and Road (BRI) Countries. *Journal of International Migration and Integration*, Volume 21, pp. 307-318.

Ishida, H. (2015). The effect of ICT development on economic growth and energy consumption in Japan. *Telematics and Informatics*, Volume 32, Issue 1, pp. 79-88.

Jalava, J and Pohjola, M. (2008). The roles of electricity and ICT in economic growth: Case Finland. *Explorations in Economic History*, Volume 45, Issue 3, pp. 270-287.

Jaouadi, S., Arfaoui, L. and Ziedi, A. (2014), "Political instability and growth: case of the developing countries", International Journal of Social Science Research, Vol. 2 No. 1, pp. 19-28.

Joshi, R. (2017). Assessing the Impact of Income Inequality on Economic Growth. The Indian Economic Journal, 65(1-4), 1–26. doi:10.1177/0019466217727811

Jaouadi, S., Arfaoui, L. and Ziedi, A. (2014), "Political instability and growth: case of the developing countries", International Journal of Social Science Research, Vol. 2 No. 1, pp. 19-28.

Kallal, R., Haddaji, A and Ftit, Z. (2021). ICT diffusion and economic growth: Evidence from the sectorial analysis of a periphery country. *Technological Forecasting and Social Change*, Volume 162, 120403.

Kuppusamy, M., Raman, M and Lee, G. (2009). Whose ICT Investment Matters to Economic Growth: Private or Public? The Malaysian Perspective. *The Electronic Journal of Information Systems in Developing Countries*, Volume 37, Issue 1, pp. 1-19.

Kurniawati, MA. (2020). ICT infrastructure, innovation development and economic growth: a comparative evidence between two decades in OECD countries. *International Journal of Social Economics*, Volume 48 Issue 1, pp. 141-158.

Kurniawati, MA. (2020). The role of ICT infrastructure, innovation and globalization on economic growth in OECD countries, 1996-2017. *Journal of Science and Technology Policy Management*, Volume 11, Issue 2, pp. 193-215.

Lee, JW and Brahmasrene, T. (2014). ICT, CO2 Emissions and Economic Growth: Evidence from a Panel of ASEAN. *Global Economic Review*, Volume 43, Issue 2, pp. 93-109.

Li, H., & Zou, H. (1998). Income inequality is not harmful for growth: Theory and evidence. Review of Development Economics, 2(3), 318–334. https://doi.org/10.1111/1467-9361.00045.

Litschig, S. and Lombardi, M. (2019), "Which tail matters? Inequality and growth in Brazil", Journal of Economic Growth, Vol. 24 No. 2, pp. 155-187.

Love I and Zicchino L (2006). Financial development and dynamic investment behavior: Evidence from panel VAR. The *Quarterly Review of Economic Finance* 46(2):190–210.

Lucas, RE (1988). On the mechanics of economic development, *Journal of Monetary Economics* 22, pp. 3–42.

Lucas, RE (1993). Making a miracle, *Econometrica* 61, 251–272.

Makun, K and Devi, S. (2019). The effect of information and communication technology on economic output: An empirical study of the Republic of Fiji Islands. *International Journal of Development Issues*, Volume 18, issue 2, pp. 229-242.

Melia, E. (2019), The Impact of Information and Communication Technologies on Jobs in Africa: A Literature Review, Discussion Paper 3/2019, German Development Institute. https://www.die-gdi.de/uploads/media/DP__3.2019_01.pdf.

Meniago C and Asongu SA (2018). Revisiting the finance-inequality nexus in a panel of African countries. *Research in International Business and Finance*46 (December): 399- 419.

Myovella, G., Karacuka, M. and Haucap, J. (2020). Digitalization and economic growth: A comparative analysis of Sub-Saharan Africa and OECD economies. Telecommunications Policy Volume 44, Issue 2.

Nasab, EH and Aghaei, M. (2009). The Effect of ICT on Economic Growth: Further Evidence. *International Bulletin of Business Administration*, Issue 5, pp. 46-56.
OECD (2010). ICTs for Development: Improving Policy Coherence: OECD: Paris, France, 2010.

Niebel, T. (2014). ICT and economic growth: Comparing developing, emerging and developed countries, ZEW Discussion Papers, No. 14-117, ZentrumfürEuropäischeWirtschaftsforschung (ZEW), Mannheim,http://nbn-resolving.de/urn:nbn:de:bsz:180-madoc-374884.

Niebel, T. (2018). ICT and economic growth – Comparing developing, emerging and developed countries. *World Development*, Volume 104, pp. 197-211.

Nair, M., Pradhan, RP and Arvin, MB. (2020). Endogenous dynamics between R&D, ICT and economic growth: Empirical evidence from the OECD countries. *Technology in Society*, Volume 62, 101315

Odhiambo, NM (2020). Financial development, income inequality and carbon emissions in Sub-Saharan African countries: a panel data analysis, *Energy Exploration & Exploitation*, Vol. 38 (5), pp. 1914-1931.

Persson, T., & Tabellini, G. (1994). Is inequality harmful for growth? American Economic Review, 84, 600–621. https://doi.org/10.3386/w3599.

Pilat, D. (2004). The ICT productivity paradox: Insights from micro data. *OECD Economic Studies*, 2004(1), 37–65.

Pradhan, G., Upadhyay, M., & Upadhyaya, K. (2008). Remittances and economic growth in developing countries. The European journal of development research, 20(3), 497–506.

Pradhan, RP., Mallik, G and Bagchi, TP. (2018). Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. *IIMB Management Review*, Volume 30, Issue 1, pp. 91-103.

Radu, M., 2015. Political Stability - A Condition for Sustainable Growth in Romania?, Procedia Economics and Finance, 30, pp.751-757.

Raheem, ID., Tiwari, AK and Balsalobre-Lorente, D. (2020). The role of ICT and financial development in CO2 emissions and economic growth. *Environmental Science and Pollution Research*, Volume 27, pp. 1912-1922.

Romer, PM (1986). Increasing returns and long-run growth, *Journal of Political Economy*, Vol. 94, Issue 5, 1002-1037.

Romer, PM (1990). Endogenous technological change, *Journal of Political Economy* 98, S71–S102.

Roodman D (2009a) A note on the theme of too many instruments. *Oxford Bulletin of Economics and Statistics* 71(1): 135-158.

Roodman D (2009b) How to do xtabond2: An introduction to difference and system GMM in Stata. *Stata Journal* 9(1): 86-136.

Saidi, K., Hassen, LB and Hammami, MS. (2015). Econometric Analysis of the Relationship Between ICT and Economic Growth in Tunisia. *Journal of the Knowledge Economy*, Volume 6, pp. 1191-1206.

Shin, I. (2012). Income inequality and economic growth. Economic Modelling, Volume 29, Issue 5, pp. 2049-2057.

Sinha, M and Sengupta, PP. (2019). FDI Inflow, ICT Expansion and Economic Growth: An Empirical Study on Asia-Pacific Developing Countries. *Global Business Review*, pp. 1-18. https://doi.org/10.1177/0972150919873839

Sassi, S and Goaied, M. (2013). Financial development, ICT diffusion and economic growth: Lessons from MENA region. *Telecommunications Policy*, Volume 37, Issues 4–5, pp. 252-261.

Solow, R.A. (1956). Contribution to the theory of economic growth, *The Quarterly Journal of Economics*, Vol. 70, No. 1, pp. 65-94

Sutradhar, SR (2020). The impact of remittances on economic growth in Bangladesh, India, Pakistan and Sri Lanka. International Journal of Economic Policy Studies (2020) 14:275–295

Swan, TW (1956). Economic growth and capital accumulation, *The Economic Record*, Vol. 32, issue 2, 334-361

Stanley, TD., Doucouliagos, H and Steel, P. (2018). Does ICT Generate Economic Growth? A Meta-Regression Analysis. *Journal of Economic Surveys*, Volume 32, Issue 3, pp. 705-726.

Steinmueller, W. E. (2001). ICTs and the possibilities for leapfrogging by developing countries. *International Labour Review*, Vol. 140(2), pp. 193–210.

Stiroh, K. J. (2002). Are ICT spillovers driving the new economy*? Review of Income and Wealth*, 48(1), 33–57.

Stiroh, K. J. (2005). "Reassessing the Impact of IT in the Production Function: A Meta-Analysis and Sensitivity Tests". Annales d'Economie et de Statistique 79/80, pp. 529–561.

Sutradhar, SR (2020), The impact of remittances on economic growth in Bangladesh, India, Pakistan and Sri Lanka", *International Journal of Economic Policy Studies*, Volume 14, pp. 275–295

Tchamyou VS (2020) Education, lifelong learning, inequality and financial access: Evidence from African countries. *Contemporary Social Science* 15(1):7-25.

Tchamyou VS and Asongu SA (2017) Information sharing and financial sector development in Africa. *Journal of African Business* 18(7):24-49.

Tchamyou VS, Erreygers G and Cassimon D (2019a) Inequality, ICT and financial access in Africa. *Technological Forecasting and Social Change* 139 (February):169-184.

Tchamyou VS, Asongu SA and Odhiambo NM (2019b) 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):261-274.

Tripathi, M and Inani, SK. (2020). Does information and communications technology affect economic growth? Empirical evidence from SAARC countries. *Information Technology for Development*, Volume 26, Issue 4, pp. 773-787.

Usman, A., Ozturk, I., Hassan, A., Zafar, SM and Ullah, S. (2021). The effect of ICT on energy consumption and economic growth in South Asian economies: An empirical analysis. *Telematics and Informatics,* Volume 58, May 2021, 101537.

Vu, KM. (2013). Information and Communication Technology (ICT) and Singapore's economic growth. *Information Economics and Policy*, Volume 25, Issue 4, pp. 284-300.

World Bank (2012). ICT for Greater Development Impact. http://siteresources.worldbank.org/EXTINFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/Resources/WBG_ICT_Strategy-2012.pdf.

World Economic Forum (2013). The Global Information Technology Report 13, Digitization for Economic Growth and Job Creation. 2013. World Economic Forum and INSEAD.Available online: http://www3.weforum.org/docs/WEF_GITR_Report_2013.pdf.

Yousefi, A. (2011). The impact of information and communication technology on economic growth: evidence from developed and developing countries. *Economics of Innovation and New Technology*, Volume 20, issue 6, pp. 581-596.

Appendices

Appendix 1: Definitions of Variables

Variables	Signs	Definitions of variables (Measurements)	Sources
Economic growth	GDPg	Gross Domestic Product Growth (annual %)	WDI
Mobile Phones	Mobile	Mobile cellular subscriptions (per 100 people)	WDI
Internet	Internet	Internet users (per 100 people)	WDI
Fixed Broadband	BroadB	Fixed broadband subscriptions (per 100 people)	WDI
Gini Index	Gini	"*The Gini index is a measurement of the income distribution of a country's residents*".	GCIP
Atkinson Index	Atkinson	"*The Atkinson index measures inequality bydetermining which end of the distribution contributed most to the observed inequality*".	GCIP
Palma Ratio	Palma	"*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%'s share*".	GCIP
Political Stability	PolS	*"Political stability/no violence (estimate): measured as the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional and violent means, including domestic violence and terrorism*	WGI
Remittance	Remit	Remittance inflows to GDP (%)	WDI

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

Appendix 2: Summary statistics (2004-2014)

	Mean	SD	Minimum	Maximum	Obs
GDP Growth	5.186	4.392	-36.699	33.735	462
Mobile Phone Penetration	45.330	37.282	0.209	171.375	458
Internet Penetration	7.676	10.153	0.031	54.26	453
Fixed Broadband	0.643	1.969	0.000	14.569	369
Gini Coefficient	0.586	0.034	0.488	0.851	461
Atkinson Index	0.705	0.058	0.509	0.834	461
Palma Ratio	6.457	1.477	3.015	14.434	461
Political Stability	-0.471	0.905	-2.687	1.182	462
Remittance	4.313	6.817	0.00003	50.818	416

S.D: Standard Deviation.

Appendix 3: Correlation matrix (uniformsample size: 334)

		ICT variables			Inequality variables			Control variables	
	GDPg	Mobile	Internet	BroadB	Gini	Atkinson	Palma	PolS	Remit
GDPg	1.000								
Mobile	-0.156	1.000							
Internet	-0.108	0.676	1.000						
BroadB	-0.064	0.529	0.687	1.000					
Gini	-0.154	0.152	0.036	-0.015	1.000				
Atkinson	-0.140	0.083	-0.045	-0.049	0.788	1.000			
Palma	-0.142	0.165	0.017	-0.041	0.930	0.919	1.000		
PolS	-0.028	0.300	0.205	0.343	0.280	0.316	0.339	1.000	
Remit	-0.122	-0.069	-0.068	-0.110	0.040	0.242	0.154	0043	1.000

GDPg: Gross Domestic Product growth rate. Mobile: Mobile phone penetration. Internet: Internet penetration. BroadB: Fixed Broadband subscriptions.Gini: the Gin coefficient. Atkinson: the Atkinson index. Palma: the Palma ratio. PolS: Political stability. Remit: Remittance inflows.