The Impact of Digital Technology Usage on Economic Growth in Africa

Abstract 100 Words:

This study analyses the impact of the use of digital technology on economic growth for 39 African countries from 2012-2016. This analysis applies a system GMM estimator to understand the extent to which the usage of digital technology facilitates growth using a measure of digitalisation from the Networked Readiness Index. Unlike previous research, we distinguish between the impact of individual, business, and government ICT usage on growth and show that only individual usage has a positive impact. Furthermore, a disaggregated analysis of the types of usage reveals that two indicators, social media and the importance of ICTs to government vision, are significant for growth.

1.0 *Introduction*

There is a well-documented contention that digitalisation creates economic growth (Bukht & Heeks, 2017). Digitalisation is enabled through information and communication technology, which is defined by Kabongo and Okpara (2014, p. 315) as "any communication device or application, including radio, television, mobiles phones, computers, network hardware and software and satellite systems…and any associated applications." From e-commerce to business process outsourcing, digital technology has transformed how firms operate globally (Lacity et al., 2016; Liu & Aron, 2014). Furthermore, it has revolutionised how people communicate (e.g., social media) and how governments engage with citizens through e-government platforms (Zhao et al., 2015). The implications of successful implementation of digital technologies are substantial (Tong & Wohlmuth, 2019). In 2017, the digital economy constituted 6.9% of the US GDP or USD $1.4 trillion.[1] Technological advances have afforded new opportunities for generativity, which Zittrain (1974, p. 1981) defined as the technology's "overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences", which creates synergies across different tasks. Digital technologies have also facilitated "datafication" and "virtualisation" (Bukht & Heeks, 2017). In fact, the importance of digital technology has rarely been greater understood than during the 2020 global economic shutdown as a result of the COVID-19 pandemic (De' et al., 2020). Around the world, governments mandated social distance measures to slow the spread of the virus, catalysing the use of digital technology for the virtual delivery of school classes and for remote working (Brynjolfson et al., 2020; Prasad et al., 2020; Willcocks, 2020).

Generally, studies have shown a positive relationship between ICTs and economic growth (Jorgenson & Vu, 2016; Niebel, 2018; Romer, 1990). In Africa, the economic liberalisation policies of the 1980s, egged on by international financial institutions (Babb & Kentikelenis, 2018; van.Klyton et al., 2019), coincided with the start of ICT investments and internet infrastructure, resulting in the widespread diffusion of ICT products and services on the continent (Chavula, 2013; Evans, 2019; Ojong, 2016). These efforts included the privatisation of telecommunication lines (Warf, 2010) and the consolidation of various ICT services under a single ministry (Holden & van.Klyton, 2016). In addition, Africa experienced a significant increase in the number of mobile phone subscribers, rising from 247 million from 1998-2008 to 367 million subscribers by 2015. This has been accompanied by an increase in broadband internet penetration rates from zero to 19 million between 2000 and 2010 (Ojong, 2016).

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[1] Source: https://www.bea.gov/docs/special-topics/infographic-how-big-is-the-digital-economy; accessed December 1, 2018.

Despite investment efforts, African countries have faltered in reaping the expected economic prosperity associated with digitalisation because of a persistent digital divide, including digital skills shortages, deficits in ICT infrastructure, and high-cost structures (Banga & Velde, 2018; Melia, 2020; Yoon, 2020). For example, Counted and Arawole (2016) showed how internet inequality in Africa created major challenges for millennial digital entrepreneurs. In fact, African-based businesses are often subjected to restrictions in using certain global e-payment and web hosting services simply because "they are operating from certain African countries" (UNIGF 2017, Meeting Archives).[2] Finally, digitalisation has brought with it some negative consequences, including structural unemployment (Bührer & Hagist, 2017; Rifkin, 2015; UNCTAD, 2017; Valenduc & Vendramin, 2017). Hence, nation-states must align their national workforce in accordance with the demands of a new digital landscape.

There are three lacunae in the literature that this study aims to fill regarding the relationship between digitalisation and economic growth. First, the preponderance of qualitative digitalisation studies (e.g., Dewa et al., 2018; Grunig, 2009) may not fully enable the causal effects of digitalisation on productivity to be established. Second, despite the established link between digital infrastructure and productivity in several studies (Baquero Forero, 2013; Castellacci, 2011; Evangelista et al., 2014), there is a deficit of knowledge about this relationship for African countries, particularly regarding the impact of the usage of digital technology on economic growth, employment, and trade (Myovella et al., 2020). In fact, Wamboye et al. (2015) called for more research to be conducted on these relationships in an African context due to the rapid growth in ICT and the use of cellular technology in the expansion of digital financial transactions.

Finally, previous studies such as Evangelista et al. (2014) and Counted and Arawole (2016) have suggested that ICT usage rather than access is what matters for economic growth without distinguishing between the impacts of individual, business and government ICT usage in a comparative context.[3] This leads to the following research question: *which type of ICT usage constitutes a robust determinant of economic growth?* To answer this question, we conducted a quantitative, empirical analysis on a panel of 39 African countries using a System Generalised Methods of Moment (SYSGMM) estimator from 2012-2016. The measure of digitalisation employed here is represented by the Networked Readiness Index (NRI), a broad measure that captures access to, readiness for, and usage of digital technology. We restrict our analysis to the usage sub-index of the NRI and its fundamental pillars. Although the NRI has existed for 16 years, to the best of our knowledge, no studies have comparatively analysed individual, business, and government usages to estimate the impact of disaggregated forms of usage on economic growth. Therefore, the contribution of this study is in distinguishing and assessing the individual impacts of three types of ICT usage (individual, business, and government usage) on economic growth.

Our main finding is that individual usage of digital technology, rather than business or government usage, yields a significant impact on economic growth for African countries. In addition, we further disaggregate the usage sub-index to show that social media and the importance of ICTs to government vision are positively associated with economic growth. However, no statistically significant relationship exists between government usage and economic growth. The article proceeds with a review of the literature on the relationship between ICT and economic growth. After which, we discuss the methodology and data sources. The findings are then presented and discussed, followed by final remarks and policy recommendations.

[2] friendsoftheigf.org/session/1591; accessed on September 19, 2018.

[3] Jorgenson and Vu (2016) combined the three types of ICT usage in their study without distinguishing among them.

2.0 Related Literature

The traditional, neoclassical view of ICT is that it increases economic growth through capital deepening (i.e., investment in ICT) due to falling prices of ICTs (van Ark et al., 2008). However, the non-traditional view is that ICT spurs innovation by facilitating business-to-business transactions, production spillovers and network externalities (Cardona et al., 2013; Paunov & Rollo, 2016; Stiroh, 2002).

Several studies have examined the impact of ICT on economic growth. Chowdhury (2006) used firm-level survey data from Kenya and Tanzania between November 1999 and May 2000 to argue that ICTs create a "vector of network externalities" that aids the spread of information (such as prices) between firms, suppliers, and consumers within or across sectors. However, he found that investment in ICTs had a negative impact on labour productivity in small and medium enterprises (SME), owing to a lagged effect between ICT usage and productivity increases (alluded to by Evangelista et al., 2014). Another explanation given for this negative relationship was that usage requires a skilled labour force and a learning curve to integrate the new technology, resulting in potential technology and skills mismatch.

In contrast, Cardona et al. (2013) conducted a survey of 150 studies from 1990 to 2007 to find that ICT had a small but positive effect on economic growth with an elasticity estimate of 0.05. They argued that ICT is a general-purpose technology that leads to further innovations (i.e., generativity), thus contributing to economic growth. Furthermore, they asserted that ICT gives rise to both horizontal and vertical spillovers between technology-producing and technology-using sectors. However, they found no direct empirical evidence to support this assertion. Similarly, Castellacci (2011) applied Arellano-Bond GMM techniques to a panel of 131 countries from 1985-2004 to show that measures of innovation, along with human capital and technological infrastructure, promoted growth in income per capita. In their model, economic growth depended on the stock of knowledge developed through innovation and knowledge imitation with both affected by the levels of human capital and technological infrastructure (i.e., ICT).

ICTs have been found to have a transformative effect on socio-economic development. Palvia et al. (2018) used a capabilities approach to find that, for developing countries, ICTs lowered the cost of doing business by facilitating access to both information and consumers through the internet, thereby reducing the need for a physical store. Access to ICTs was also instrumental in facilitating communication and connectivity that enabled the firms to sustain a long-term relationship with customers. Moreover, they found that ICTs empowered citizens by enabling access to free online educational material and news and by enhancing the "voice" of the people through online forums.

The effects of ICTs on economic growth has not been homogeneous across countries. Watanabe et al. (2015) found that bi-polarisation existed in GDP growth rates between "ICT-growing economies" and "ICT-advanced economies." They found that ICT advancement had a positive effect on innovation and economic modernisation in ICT-growing economies, but not for ICT-advanced economies. They attributed this to the greater access and normalisation of ICT technology afforded by the rapid economic advances in ICT-growing economies that, in some sense, are levelling the playing field.

Ishida (2015) cautioned against overestimating the relationship between ICT and economic growth. Using an autoregressive distributed lag bounds testing approach, he found that although ICT reduced energy consumption in Japan, it did not have a significant effect on real GDP in the short or long run after controlling for the effects of labour and capital stock. In like fashion, Wissner (2011) used a growth accounting method and found that ICT investment's contribution to value-added and average labour productivity had fallen over time in the German energy industry. He reasoned that market liberalisation and increased regulation of the sector caused capital deepening to fall from 49% for the years 1996-2000 to 19% between 2001-2005.[4]

In an attempt to move away from the narrow "supply-side/infrastructural" conceptualisation of ICTs, Evangelista et al. (2014) empirically examined the economic effects of digitalisation for a panel of 27 European Union countries from 2004-2008 using the Arellano-Bond GMM estimates. They found that of the three dimensions of the digitalisation process, ICT usage and digital empowerment, rather than ICT access, was essential for growth in labour productivity and employment.

2.1 Individual Usage of ICT

A number of studies have examined the contribution of individual use of ICT on economic growth. For example, Donou-Adonsou (2018) examined the relationship between technology, education, and economic growth based on data from 45 Sub-Saharan African (SSA) countries from 1993 to 2015. Using a generalised method of moments estimator, he found that for every one-percentage-point increase in internet access, economic growth increased by 0.224 percentage points, but only in countries where the gross primary enrolment was higher than 92.53%. Hence, the level of education was an essential factor for the internet to foster economic growth. Evans (2019) applied the Fully Modified OLS (FMOLS), Dynamic Ordinary Least Squares (DOLS) estimators and panel Granger causality tests to panel data from 45 Sub-Saharan African (SSA) countries from 1995 to 2015. He found a bi-directional causal link between internet usage and economic well-being (proxied by GDP per capita). Ponelis and Holmner (2015, p. 166) argued that the individual usage of ICTs among high school pupils in Africa has afforded new learning opportunities and access to more diverse content. In fact, integrating ICT access and usage into education programmes were seen as effective ways of fostering development in African countries.

Using the SYSGMM in a panel of 43 SSA countries from 1975 to 2010, Wamboye et al. (2015) found that a higher volume of mobile phone subscriptions contributed to economic growth by increasing information sharing across sectors. Mobile phones provide a means of connecting people, particularly in remote regions where education levels tend to be lower. Farmers use mobile phones to access information about the market and weather conditions and as a tool to receive government subsidies (Donou-Adonsou & Lim, 2018).[5]

Chavula (2013) found that fixed telephone main lines and mobile telephony, rather than internet usage, had significant effects on the long-term growth of per capita income in Africa from 1991 to 2007. The significance of fixed main telephone lines and mobile telephony was attributed to Africa's late entrance into the digital economy. In contrast, using cross-sectional data in 2013, Njoh (2018) established a link between mobile phone subscriptions and internet access for economic development in Africa as measured by the Human Development Index (HDI). However, no such evidence was found regarding fixed phone and broadband subscriptions, thus illustrating that not all types of ICT matter for economic progress.

Social media is another application of individual ICT usage. It can be defined as "internet-based applications that carry consumer-generated content" (Xiang & Gretzel, 2010). Many firms use social media for servicing consumers and building industry networks (Grewal & Levy, 2016). There is an

[4] For more on capital deepening, see Acemoglu and Guerrieri (2008).

[5] The positive effects of internet access and mobile phone usage on economic growth in SSA countries was also observed by Haftu (2019).

increasing amount of literature on the relationship between social media and economic growth. In developing countries, social media has become an indirect factor of growth, with new businesses created through social media platforms (Khajeheian, 2013). Tajvidi and Kamari (2017) examined the impact of online and offline social media on branding and innovation as mediators for firm performance in the hotel sector using structural equation modelling. They found that the relationship between social media use and firm performance was positive and significant. Other literature focused on the use of social media marketing by entrepreneurs. Ukpere et al. (2014) used qualitative methods to find that female entrepreneurs in South Africa embraced social media to balance their personal and professional lives. In fact, SMEs are set to benefit from social media. Using qualitative methods, Jones et al. (2015) found that social media afforded SMEs greater visibility in the market, a broader market reach, and enhanced engagement with customers. Social media usage among younger Africans, in particular, has facilitated the growth of e-commerce and social media marketing. Duffett (2017) surveyed more than 13,000 South African millennials regarding the influence of social media marketing on consumer attitudes and found a positive and significant effect on both the cognitive and affective attitudes of respondents. However, Dell'Anno et al. (2016) found a significant adverse effect on firm performance using social media membership data from a cross-section of 83 countries. The main reasons were attributed to increased search costs, decreased productivity and/or a "greater consumption of nonmonetary content" (Dell'Anno et al., 2016, p. 636).

2.2. Business usage of ICT

Business usage of ICT has been found to increase labour productivity (Evangelista et al., 2014) and increase competitive advantage, productivity, and efficiency, thus becoming a stimulus for business growth (Ongori & Migiro, 2010). Tchamyou (2017) found that, in African economies, ICTs reduce the time it takes to launch a business and decrease the costs of starting one, thereby increasing the number of businesses. It has been argued that ICT serves as a catalyst for innovation, such as the development of applications that improve living standards (Jung et al., 2001). Mobile phones are said to enhance supply chain management and open opportunities for employment in the ICT sector, thereby catalysing growth in the telephony sector. They also increase the efficiency of other sectors, such as health, education and finance (Njoh, 2018). Furthermore, the use of e-commerce in business operations has the potential to spur economic development for both small and large enterprises (Carbonara, 2005). Wanyoike et al. (2012) argued that the adoption of e-commerce by businesses in Africa is imperative for them to compete more effectively. Foster and Graham (2016) found that the use of digital technology had improved the management and efficiency of the tea sector in Rwanda, such as in the digital monitoring and exchange of goods.

Kabongo and Okpara (2014) argued that the adoption of ICT by SMEs in the Congo had the potential to increase the competitiveness and growth of agribusiness. They also reported that mobile phones and emails were the main ICT tools for businesses in a survey of 85 Congolese SME owners. In contrast, less than 1% had a dedicated fax line, and none had a fixed phone line.

Apulu and Ige (2011) analysed survey data collected from 180 Nigerian entrepreneurs and found that a lack of electricity (81.7%) and infrastructure deficiencies (71.7%) were the main hindrances to business ICT usage, followed by inadequate service provision (67.2%) and a lack of education (61.7%).[6] These

[6] For a comprehensive discussion of the impact of electricity costs on firm productivity, see Abdisa (2018).

factors are in line with the technology acceptance model that emphasises the relevance of facilitating conditions as a determinant of ICT usage (Davis et al., 1989).

2.3 Government usage of ICT

Much of the literature on government usage of ICT revolves around the implementation of e-government and other civic technologies that facilitate e-participation from citizens (Bimber, 2000; McNutt et al., 2016). E-government 2.0 applications and collaborative platforms are said to improve efficiency within public policy decision making and management (Adam, 2020; Ansell & Gash, 2017), improve the interaction between the government and citizens (Falco & Kleinhans, 2018; Rhongo et al., 2019), and between the government and businesses such as in private-public partnerships (Heeks & Mathisen, 2012; Palaco et al., 2019; Sandoval-Almazan & Gil-Garcia, 2012; Warner & Fargher, 2019). E-government has been shown to transform the administrative operations of the state and facilitate the delivery of services to citizens (Bannister & Connolly, 2014; Twizeyimana & Andersson, 2019). In this context, ICT both enables new practices that would otherwise not be present in government services, and it embeds "new values into systems" (Bannister & Connolly, 2014, p. 120). There are also a number of studies that examine e-government in African economies (Bakunzibake et al., 2018; Choudrie et al., 2017); however, their focus is on transparency, corruption, and efficiency.

Although e-government is well researched in the literature, less is known about the impact of government usage of ICT on economic growth. Current literature positions the state as a facilitator of access to technology for individuals and businesses and thus acts as a secondary driver of economic growth (Ghosh, 2017; Zhao et al., 2015). For example, Albiman and Sulong (2016) found that the implementation of ICT by the government served to remove bottlenecks, contributing to economic growth. In a different context, Machova and Lnēcička (2015) pointed out that government procurement of advanced technologies enabled the rapid diffusion of ICT innovations across public institutions, harkening the traditional remit of governments in providing infrastructure. However, Pick and Sarkar (2015, p. 277) pointed out that the laws relating to ICT were a salient predictor of ICT usage in Africa, with positive and significant effects on internet usage, fixed broadband internet subscriptions, mobile subscriptions, fixed telephone subscriptions and the use of virtual social networks (see also Maiorano & Stern, 2007).

Many African governments have prioritised knowledge sharing and procurement of digital technologies as key in achieving sustainable development (Banga & Velde, 2018). However, some have placed limits on ICT access under the guise of protecting the country from cyber-based attacks (Bidemi, 2017). Internet shutdowns have been employed as a means to "control and monitor their population in ways that decrease democratic freedoms" (Ayalew, 2019; Bimbe et al., 2015, p. 5; see also Denardis, 2014). Furthermore, shutdowns undermine economic growth and interfere with start-up ecosystems (Kathuria et al., 2018; Parks & Thompson, 2020; West, 2016), which is particularly problematic for the myriad of technology-enabled start-up enterprises and innovation hubs on the African continent (Friederici, 2016). Counted and Arawole (2016) concluded that in Africa, usage of ICTs was greatly affected by state-imposed restrictions and limited access to online platforms and services.

2.4 Conclusion

A growing body of the literature has examined the impact of digital technologies on economic growth and offered mixed results in explaining this relationship. Nevertheless, the literature has suggested that usage of these technologies stimulates the economy by facilitating communication, empowering individuals, creating employment, and spurring innovation. The literature has also revealed the critical role of the state in providing an enabling environment for technology access and usage. The state bears responsibility for enabling the acquisition or production of advanced technologies and creating and sustaining a legal framework that promotes the use of ICT.

Despite the emphasis on ICT usage rather than ICT access for growth, many studies have failed to consider the impact of different types of usage of digital technology on growth, especially with respect to government usage. Therefore, this study contributes to the emerging literature in this field by distinguishing between the impact of individual, business, and government usages of ICT on economic growth in African countries.

3.0 METHODOLOGY

3.1 The Networked Readiness Index (NRI)

We use the NRI as an indicator of digitalisation. It measures the "degree to which economies across the world leverage ICT to increase their competitiveness" (Milenkovic et al., 2016, p. 1121) and captures the ICT regulatory environment, access, usage, and diffusion of technology in society. Milenkovic et al. (2016) argued that the NRI was created to address critical gaps in our understanding of ICT development, particularly in developing countries. The NRI is an accepted indicator for assessing a country's development toward becoming a knowledge society (Gremm et al., 2018; Pratipatti & Gomaa, 2019). Degerli et al. (2015) used the NRI to illustrate that early adopters of technology fair far better than laggard users of technology, illustrating the synergistic effects of individual usage of technology. This argument is in alignment with the diffusion of technology theory (Rogers, 2003).

Since 2002, the World Economic Forum has produced the NRI as part of its Global Information Technology Report (GITR) series. Since its inception, it increased coverage of African countries from three (Kirkman et al., 2002) to 40 countries. The index's latest revision was in 2012 and comprised four sub-indices (environment, readiness, usage, and impact), ten pillars, and 53 individual indicators (Dutta & Bilbao-Osorio, 2012). The NRI is computed as an average of the four sub-indices. To ensure consistency in the measurement of the NRI, this study uses data from 2012–2016 (see also Pratipatti & Gomaa, 2019).[7] Each sub-index is measured on a scale of 1-7 (best). The environment sub-index consists of indicators which measure the degree to which the legal, political, and business environments enable ICT to thrive. The readiness sub-index measures the extent to which individuals, businesses, and governments are 'ready' to use ICT technology by measuring the availability of physical and ICT infrastructure, quality of education, and affordability of ICT. The usage sub-index measures the adoption of ICT by individuals, businesses, and the government and includes the proportion of households with internet access, use of social networks, the capacity for innovation and the government online service index. The impact sub-index captures the economic and social effects of ICT.

This study's focus on African economies presents some challenges in terms of data collection and availability. The NRI presents a unique opportunity to analyse the impact of digitalisation for African countries because of its comprehensiveness and its inclusion of 40 African countries. This makes the index advantageous over alternatives such as the digitalisation index by Katz et al. (2014), which includes only a handful of African countries.

One potential drawback of using the NRI index in its aggregate form is the broadness that arises from combining 53 indicators, which complicates efforts to isolate the impact of the different dimensions of digitalisation on growth. The literature emphasises that it is the usage of ICT that matters for growth

[7] The computation of the NRI before 2012 was substantially different. It consisted of only 3 sub-indices.

(Evangelista et al., 2014) but is silent on the type of ICT usage (i.e., by households, businesses, or the government). Therefore, this study examines the usage subcomponent of the NRI and the sixth, seventh, and eighth pillars that constitute it. The sixth pillar measures individual usage and consists of seven indicators: mobile phone subscriptions (per hundred), percentage of individuals using the internet, households with personal computers, households with internet access, fixed broadband internet subscriptions, mobile broadband subscriptions, and use of virtual social networks. The seventh pillar measures business usage and includes the following six indicators: firm-level technology absorption, capacity for innovation, PCT patents, ICT use for business-to-business transactions, business-to-consumer internet use, and the extent of staff training. The eighth pillar measures government usage and consists of three indicators: the importance of ICTs to government vision, a government service online index, and the government's success in ICT promotion.

3.2 Empirical Model

To model the impact of digitalisation on economic growth, we begin with a Cobb-Douglas production function for country i and time t[8] :

$$Y_{it} = A_i L_{it}^{\beta_1} K_{it}^{\beta_2} C_{it}^{\beta_3} e^{\sigma it} \dots (1)$$

where Y is output, L is labour (i.e. total employment), K is physical capital stock, C is ICT capital, and A is a country-specific multiplicative constant that could denote country-specific technological capability. The β coefficients denote the factor shares of the corresponding factor inputs, and σ is a country-specific efficiency parameter.

Taking natural logs and first differencing gives:

$$\Delta lnY_{it} = \beta_1 \Delta lnL_{it} + \beta_2 \Delta lnK_{it} + \beta_3 \Delta lnC_{it} + \Delta\sigma_{it} \dots (2)$$

where ΔlnY, ΔlnL, ΔlnK and ΔlnC refer to growth in output, labour, physical capital and ICT capital, respectively. The parameters β_1, β_2 and β_3 denote output elasticities with respect to the corresponding factor inputs. As in Stiroh (2002), we do not impose constant returns to scale. Following the approach of Lokshin et al. (2008), we assume that the country-specific efficiency parameter ($\Delta\sigma_{it}$) is a function of past productivity (Y_{it-1}) to allow for conditional convergence among countries (Barro, 1991; Bond et al., 2001); that is, the hypothesis that poorer countries grow faster than richer ones, conditional on other variables in the model. For example, Murthy and Ukpolo (1999) and Asongu and Odhiambo (2020) find strong evidence of conditional convergence in African countries.

$$\Delta\sigma_{it} = a_1 lnY_{it-1} + e_{it} \dots (3)$$

The error term in equation 3 (e_{it}) consists of a country-specific fixed effect, a_i, that measures unobserved permanent differences in output across countries, a time-specific effect (λt) that captures disembodied technical change (Ugur et al., 2016), and an idiosyncratic error term (u_{it}).

$$e_{it} = a_i + \lambda t + u_{it} \dots (4)$$

The ICT capital (C) can be approximated using penetration rates such as broadband or computers per workers (Cardona et al., 2013). Therefore, we proxy for ICT capital using the three pillars of the usage sub-component of the NRI indicator: IND is the individual usage pillar (sixth pillar), BUS is the

[8] Our version of the Cobb-Douglas function is from Lokshin et al. (2008).

business usage pillar (seventh pillar), and GOV is the government usage pillar (eighth pillar). These indicators capture penetration rates of ICT-enabled technology by the household, business, and government sectors. Taking into account our proxies for ICT capital and combining equations 2, 3, and 4 yields the following dynamic specification:

$$\Delta lnY_{it} = a_1 lnY_{it-1} + \beta_1 \Delta lnL_{it} + \beta_2 \Delta lnK_{it} + \beta_3 \Delta lnIND_{it} + \beta_4 \Delta lnBUS_{it} + \beta_5 \Delta lnGOV_{it} + a_i + \lambda t + u_{it} \dots (5)$$

Finally, we include three control variables to allow for differences in production technology across countries (Niebel, 2018): laws relating to ICT (*ICTLAW*), tertiary education gross enrolment rate (*TER*), and inward FDI (*FDIGDP*).

With respect to laws relating to ICT, Nkohkwo and Islam (2013) pointed out that in developing countries, there is a lack of laws that address digital activities such as freedom of information, cybercrime, and intellectual property rights. If a government is to foster an enabling digital environment, then the legal framework must reflect the new realities brought on by engagement with digital technology (Lefophane & Kalaba, 2020). Furthermore, Pick and Sarkar (2015, p. 277) asserted that ICT-related laws are a "dominant predictor" of all forms of ICT in Africa. The second control variable, tertiary education gross enrolment rate, proxies for human capital. Human capital has a positive effect on economic growth because a skilled workforce facilitates the productive use of both physical capital and ICT, the generation and sharing of ideas (C. Jones & Romer, 2010; Murphy & Siedschlag, 2013), and serves as an essential agent in the diffusion of technology.

There is no consensus on what constitutes human capital; however, we follow the work of Siddiqui and Rehman (2017) and Ogundari and Awokuse (2018) in using tertiary education as a proxy for human capital. We prioritise tertiary education over primary and secondary education because in Africa university graduates are far more likely to have the skills that are required to work in the knowledge economy than those with secondary education. Furthermore, Pick and Sarkar (2015) show that tertiary education is significantly related to the usage of ICT-enabled devices at the 1% level. Our final control variable is inward FDI which has been shown by several studies (Kokko, 1994; Okechukwu et al., 2018; Wang & Blomström, 1992) to stimulate growth by increasing the amount of capital in the host country. Inward FDI aids the transfer of technology spillovers from foreign to domestic firms in a number of ways, including forward and backward linkages with domestic firms, the movement of workers from foreign firms to domestic firms, an increase in exports, and the stimulation of competition.

Equation 5, therefore, becomes:

$$\Delta lnY_{it} = a_1 lnY_{it-1} + \beta_1 \Delta lnL_{it} + \beta_2 \Delta lnK_{it} + \beta_3 \Delta lnIND_{it} + \beta_4 \Delta lnBUS_{it} + \beta_5 \Delta lnGOV_{it} + a_6 ICTLAW_{it} + a_7 TER_{it} + a_8 lnFDIGDP_{it} + a_i + \lambda t + u_{it} \dots (6)$$

To examine the impact of digitalisation on economic growth, we estimate equation 6 for a sample of 39 countries from 2012 to 2016. Our proxies for digitalisation are the three pillars of the usage sub-component of the NRI indicator, $\Delta lnIND$, $\Delta lnBUS$ and $\Delta lnGOV$, which are our main variables of interest.

3.3 Study Hypothesis

We postulate that individual usage of ICT is growth-enhancing in several ways. First, it serves as a platform through which individuals can access and disseminate knowledge, which can empower them to be more productive. Individual usage creates network externalities: as more people engage with digital technologies such as mobile phones or social media, the value of such products increases for others. An increase in individual usage of digital technologies raises the demand for ICT-enabled goods and services, which leads to the growth in the telecommunications sector. Finally, individual usage facilitates digital communication, which increases awareness of the availability of goods and services on the market, leading to higher demand for goods and services through word-of-mouth marketing (Trusov et al., 2009; Viljoen et al., 2016). Hence, we state our first hypothesis as follows:

$H_0: \beta_3 = 0$ (The individual usage of ICT has no impact on GDP growth)
$H_1: \beta_3 > 0$ (The individual usage of ICT has a positive impact on GDP growth)

We assert that business usage of ICT increases economic growth by boosting business competitiveness, efficiency, and productivity. Also, access to ICTs enhances innovation and affords benefits that spillover from the telecommunications sector to other sectors of the economy (Counted & Arawole, 2016). This leads to our second hypothesis.

Hypothesis 2: Business usage of ICT has a positive impact on economic growth.

$H_0: \beta_4 = 0$ (Business usage of ICT has no impact on GDP growth)
$H_1: \beta_4 > 0$ (Business usage of ICT has a positive impact on GDP growth)

We propose that government usage of ICT is beneficial for economic growth by improving efficiency and transparency in government departments and strengthening collaborations between the public and private sectors. This leads to hypothesis 3.

Hypothesis 3: The impact of government usage of ICT on growth is positive.

$H_0: \beta_5 = 0$ (Government usage of ICT has no impact on GDP growth)
$H_1: \beta_5 > 0$ (Government usage of ICT has a positive impact on GDP growth)

3.4 Empirical Strategy

The inclusion of the lagged dependent variable in the specification makes equation 6 a dynamic panel data model. In such models, the pooled ordinary least squares (POLS) and fixed effects (FE) estimators are biased and inconsistent arising from a correlation between the lagged dependent variable and the error term. This results in y_{t-1} being upwardly biased with a POLS estimator and downwardly biased with a fixed-effects estimator. The GMM estimator of Arellano and Bond (1991), otherwise known as the first differenced estimator, was proposed as one way of correcting the bias. Its implementation involves the first differencing of all variables and instrumenting the first differenced series using appropriate lags of each variable. However, in short dynamic panels that are persistent, the lags can be weak instruments for the first differenced series, thus leading to bias (see Bond et al., 2001). To mitigate the weak instrument problem of the Arellano and Bond (1991) estimator, Arellano and Bover (1995) and Blundell and Bond (1998) developed the SYSGMM estimator. This estimator consists of the first differenced series augmented with the lagged levels of each variable plus the original (level) series instrumented with the lagged first differences of each variable.

We estimate equation 4 using the SYSGMM estimator for a panel of 39 countries from 2012 to 2016. Apart from being suitable for short dynamic panels as described above, the SYSGMM also has the advantage of controlling for unobserved heterogeneity and correcting for endogeneity arising from all variables in the model (see Blundell & Bond, 1998; Bond et al., 2001; Roodman, 2009b). Three conditions must be met for the SYSGMM to be valid. First, there should be no serial correlation in the error term. Second, the instruments must be exogenous (i.e., uncorrelated) with the error term. Third, the extra instruments used in the SYSGMM compared with first differenced estimator must be valid. These conditions can be tested using appropriate specification tests.

For the first condition to hold, the first differenced residuals must be negatively correlated, but there must be no second-order serial correlation. The second condition can be tested using the Hansen test of over-identifying restrictions (Bowsher, 2002; Parente & Santos Silva, 2012). Here, the extra instruments must be uncorrelated with the error term. Finally, the third condition can be tested using the Difference-in-Hansen test (Roodman, 2009b), which tests for the validity of the extra instruments. In other words, the extra instrument set in the SYSGMM must be uncorrelated with the error term. One drawback of the SYSGMM estimator is that the number of instruments can expand very quickly, which can lead to bias and a severe weakening of the specification test (Roodman, 2009a). Consequently, Roodman (2009b) advocated collapsing the instrument set so as to restrict the instrument count. Finally, GMM estimators can be implemented using either a one-step procedure or a more efficient two-step procedure. However, the estimated standard errors of the two-step GMM estimator was found to be downwardly biased in small samples, so a correction term was proposed by Windmeijer (2005). This study makes use of the two-step SYSGMM with the Windmeijer (2005) correction and a collapsed instrument set.

3.5. Data Measurement and Discussion

The sample used in this study consists of a panel of 39 African countries from 2012 to 2016, based on the availability of data across all three databases: the NRI, the World Bank Development Indicators, and the Penn World Tables. Table 1 summarises the list of variables with their descriptions and sources.

Table 1: Description of Variables (The World Bank Development Indicators, 2016)

Variable	**Description**	**Source**
ΔlnY	Growth in output-side real GDP at chained PPPs (in mil. 2011 US$)	Penn World Tables 9.1 (Feenstra et al., 2015)
ΔlnL	Growth in the number of persons engaged in employment (in millions)	Penn World Tables 9.1 (Feenstra et al., 2015)
ΔlnK	Growth in capital stock at constant 2011 national prices (in mil. 2011US$)	Penn World Tables 9.1 (Feenstra et al., 2015)
$\Delta lnIND$	Growth in individual usage (Sixth pillar of the Networked Readiness Index) (1- 7)	The World Economic Forum (2012-2016)
$\Delta lnBUS$	Growth in business usage (Seventh pillar of the Networked Readiness Index) (1- 7)	The World Economic Forum (2012-2016)

$\Delta lnGOV$	Growth in government usage (Eighth pillar of the Networked Readiness Index)) (1- 7)	The World Economic Forum (2012-2016)
$ICTLAW$	Laws relating to ICT (1-7, best)	The World Economic Forum (2012-2016)
TER	Tertiary education gross enrolment rate (%)	The World Economic Forum (2012-2016)
$lnFDIGDP$	Log of Net inward FDI as a percentage of GDP)	World Bank Development Indicators, November 2016

4.0 Estimation Results

Table 2 presents the summary statistics for the full sample of 39 African countries from 2012 to 2016. Table 3 provides statistics on the NRI index for each year across the countries, indicating a slight increase in levels of digitalisation by about 2% over the period. The coefficient of variation, a rough measure of the digital divide among countries in Africa, increased from 14% to 16% showing a slight worsening of the digital divide, which contradicts Brännström's (2012) findings that the digital divide in Africa had decreased.

Table 2: Summary Statistics

	Mean	**SD**	**Min**	**Max**	**Between country variation**	**Within country variation**	**No. of obs.**
Growth in GDP (ΔlnY)	0.034	0.057	-0.227	0.189	0.035	0.045	156
Growth in Employment (ΔlnL)	0.028	0.015	-0.051	0.063	0.010	0.011	156
Growth in capital stock (ΔlnK)	0.057	0.042	0.0003	0.242	0.037	0.019	156
Growth in NRI-Sixth Pillar: Individual Usage ($\Delta lnIND$)	0.044	0.070	-0.123	0.253	0.039	0.060	141
Growth in NRI-Seventh Pillar: Business Usage ($\Delta lnBUS$)	0.009	0.046	-0.190	0.140	0.032	0.041	141

NRI- Eighth Pillar: Government Usage ($\Delta lnGOV$)	-0.006	0.073	-0.157	0.205	0.040	0.066	141
Laws Relating to ICT ($ICTLAW$)	3.287	0.690	1.91	5.047	0.654	0.234	185
Tertiary Gross Enrolment Rate (TER)	11.285	11.128	0.510	60.877	11.767	2.298	180
Log of Net inward FDI as a percentage of GDP)	1.090	1.277	-6.280	4.441	0.955	0.847	190

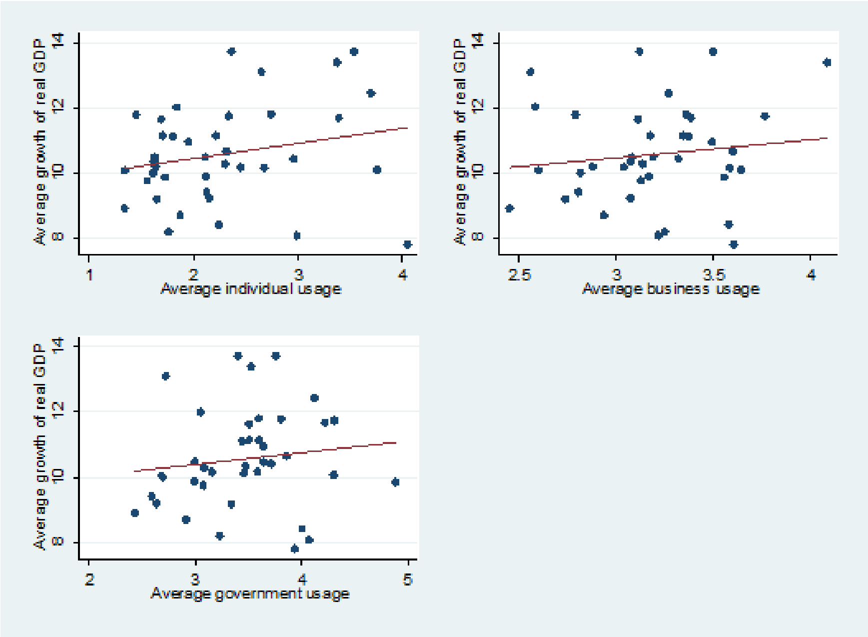
Table 3: Summary statistics of the Networked Readiness Index for African countries by year[9]

Year	Mean	Coefficient of Variation (%)	Minimum	Median	Maximum
2012	3.176328	14.07	2.49088	3.051449	4.116491
2013	3.133443	14.36	2.304824	2.984504	4.123937
2014	3.170183	15.27	2.223768	3.086978	4.314352
2015	3.202971	16.19	2.297946	3.086647	4.485026
2016	3.246427	16.16	2.197698	3.178475	4.379175

Figure 1 shows the average growth of real GDP on the average individual, business, and government usage pillars by country. Although there are positive correlations between growth and each pillar, the strongest correlation is between individual usage and growth.

Figure 1: Scatter Graphs of Average Growth in GDP and Average Individual, Business, and Government Usages in 2016

[9] To put the NRI values in context, in 2015, Singapore and Finland had the highest NRI index globally with scores of 6.02. In the same year, the median NRI score was 3.086647 for all countries.



Turning to the main results, Table 4 presents estimates of the impact of digitalisation on economic growth using the system GMM estimator (SYSGMM), with the pooled OLS (POLS) and fixed effects (FE) estimators also presented for comparison. In columns 1 to 3, the individual, business, and government usage pillars are used as indicators of digitalisation, with the usage sub-index[10] in column 4 for comparison. The specification tests show the validity of the SYSGMM. The p-values of the AR(1) test and AR(2) test indicate a significant correlation in the first differences of the error term but no second-order correlation, showing the absence of serial correlation. Next, the p-values of the Hansen test (p-value > 0.10) show that the over-identified instruments are uncorrelated with the error term. Finally, the p-values of the Difference-in-Hansen test (p-value > 0.10) indicate the validity of the extra instruments used in the SYSGMM. As a final check of the trustworthiness of the SYSGMM, the coefficient of the lagged GDP variable is expected to lie between the POLS and FE estimators due to the upward bias of the POLS and the downward bias of the FE (Bond et al., 2001). Table 4 shows this to be the case, which indicates that the lagged GDP has been consistently estimated by the SYSGMM.

Table 4: Effects of the Use of Digital Technology on Economic Growth

	(1)	**(2)**	**(3)**	**(4)**
	Pooled OLS	Fixed Effects	System GMM	System GMM
Lag of Log GDP ($\ln Y_{it-1}$)	-0.00767** (-2.06)	-0.308*** (-3.70)	-0.0141 (-1.02)	-0.0129 (-0.70)
Δ Log Employment (ΔlnL_{it})	0.100 (0.31)	0.101 (0.29)	-1.086 (-1.10)	-0.00285 (-0.00)
Δ Log of Physical Capital Stock (ΔlnK_{it})	0.598*** (5.99)	0.406* (1.76)	0.806** (2.46)	0.885** (2.18)

[10] Usage sub-index computed as the average of the three pillars.

ΔLog of Individual Usage ($\Delta lnIND_{it}$)	-0.0197 (-0.28)	0.0370 (0.68)	0.250* (1.74)	
Δ Log of Business Usage ($\Delta lnBUS_{it}$)	-0.0837 (-0.51)	-0.0745 (-0.62)	0.192 (0.77)	
Δ Log of Government Usage ($\Delta lnGOV_{it}$)	0.0897** (2.16)	0.0795* (1.75)	0.115 (1.12)	
Δ Log of Usage Sub-index				0.487 (1.17)
Laws Relating to ICT ($ICTLAW_{it}$)	0.0133* (1.89)	0.0288 (1.63)	0.00733 (0.40)	-0.00388 (-0.17)
Tertiary Gross Enrolment Rate (TER_{it})	0.000647 (1.31)	0.00148* (1.87)	0.00134 (0.52)	0.00192 (0.69)
Log of Inflows of FDI as a percentage of GDP ($\ln FDIGDP_{it}$)	-0.00406 (-0.87)	0.00189 (0.62)	-0.00645 (-0.51)	-0.00223 (-0.09)
Observations	132	132	132	132
Countries	39	39	39	39
AR (1): p-value			0.056*	0.059*
AR (2): p-value			0.455	0.635
Hansen test: p-value			0.550	0.181
Diff-Hansen test: p-value			0.728	0.460

(i) The dependent variable is growth in GDP proxied by the first difference of the log of GDP (ΔlnY); (ii) t-statistics are in parentheses; (iii) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$; (iv) All estimations include a constant and unreported time dummies; (v) All estimations were conducted using Stata 14.2; (vi) Columns 3 and 4 are two-step system GMM estimations with the Windmeijer (2005) correction; (vii) A collapsed instrument set is used in the SYSGMM estimation with up to 4 lags for each variable. (viii) AR(1) refers to the Arellano-Bond test of serial correlation in the first differences of the error term. AR(2) refers to the Arellano-Bond test of serial correlation in the second differences of the error term. The Hansen test tests for the validity of the instruments and the Diff-Hansen test is the Difference-in-Hansen test for the validity of the extra instruments in the SYSGMM estimator.

Focusing on the results from column 3, we find that the lagged GDP coefficient is negative but insignificant. This shows that there is no evidence that poorer African countries grow faster than richer ones, showing a lack of convergence between the poorer and richer African countries. The physical capital stock coefficient is positive and significant, where a 1% increase in the growth of physical capital stock is predicted to increase GDP growth by about 0.81%. However, employment has an insignificant effect on growth.

The findings show that of the three pillars, only individual usage has a significant impact on growth at the 10% level, in support of hypothesis 1. A 1% increase in the growth of the individual usage index is predicted to increase GDP growth by about 0.25% on average. Individual usage of ICT is growth-enhancing because it fosters human capital, reduces the cost of purchasing goods and services, and increases the productivity of labour and capital (Evangelista et al., 2014). This is also in line with the findings of Wamboye et al. (2015). The coefficients for both business and government usages of ICT are insignificant, which do not support our second and third hypotheses. The insignificance of the business and government usages of ICT could be due to the aggregation of the indicators that make up the seventh and eighth pillars. The usage sub-index (column 4) coefficient is insignificant, which shows the importance of using more disaggregated measures of digitalisation to isolate which components are essential for growth.

The findings show that all the control variables-laws relating to ICT, tertiary education, and FDI- are insignificant. The lack of significance of tertiary education on growth can be attributed to a lack of appropriate training for African university staff to meet the rapid demands of ICT-related growth occurring across the continent, which limits the ability to produce locally-trained, advanced human capital (Ewusi-Mensah, 2012). Furthermore, Ewusi-Mensah (2012) recommended frequent retraining of IT professionals in Africa to better align their capabilities with rapid technological advancements. The lack of significance of laws relating to ICT on GDP growth is in contrast with the findings of Pick and Sarkar (2015) and Nkohkwo and Islam (2013) who showed that the legal environment is a critical enabler of both the development and adoption of ICT in African countries. However, the results might reflect the fact that the legal and policy development process around ICT laws in Africa has not caught up with the rapidly changing environment of the digital economy and technology (Lefophane & Kalaba, 2020).

Table 5: Effects of the Individual Usage, Business Usage and Government Usage of Digital Technology on Economic Growth. (System GMM Results)

	(1) Individual Usage components	(2) Business Usage components	(3) Government Usage components
ΔLog of Mobile phone subscriptions (per 100 population)	0.162 (1.56)		
ΔLog of Fixed broadband Internet subscriptions (per 100 population)	-0.00692 (-0.57)		
ΔLog of Use of virtual social networks (1- 7(best))	0.260* (1.77)		
ΔLog of Capacity for innovation (1- 7(best))		-0.0922 (-0.53)	
ΔLog of ICT use for business-to-business transactions (1- 7(best))		0.116 (0.38)	

ΔLog of Importance of ICTs to gov't vision (1- 7(best))			0.235** (2.30)
ΔLog of Government Online Service Index (0- 1(best))			0.0239 (1.42)
Number of Observations	131	99	129
Number of Countries	38	39	38
AR (1): p-value	0.035**	0.032**	0.032**
AR (2): p-value	0.799	.	0.608
Hansen test: p-value	0.697	0.417	0.565
Diff-Hansen test: p-value	0.472	0.343	0.726

(i) The dependent variable is growth in GDP, which is proxied by the first difference of the log of GDP (ΔlnY), (ii) t-statistics are in parentheses, (iii) * p < 0.10, ** p < 0.05, *** p < 0.001; (iv) All estimations include a constant and unreported time dummies. All estimations include the lag of log GDP, Δlog employment, Δlog capital stock, laws relating to ICT, tertiary gross enrolment rate, and the log of net inflows of FDI; (v) All estimations were conducted using Stata 14.2; (vi) All estimations apply the two-step system GMM estimations with the Windmeijer (2005) correction. (vii) A collapsed instrument set is used in the SYSGMM estimation with up to 4 lags of each variable. (viii) AR (1) refers to the Arellano-Bond test of serial correlation in the first differences of the error term. AR (2) refers to the Arellano-Bond test of serial correlation in the second differences of the error term. The Hansen test tests for the validity of the instruments and the Diff-Hansen test is the Difference-in-Hansen test for the validity of the extra instruments in the SYSGMM estimator.

To probe these results further, we estimated the impact of the disaggregated indicators that make up each of the pillars on economic growth using the System GMM in Table 5. For the purpose of presentation, only the NRI indicators are displayed.[11] Column 1 displays the components of the individual usage pillar.[12] Of these indicators, only the use of virtual social networks is positive and significant at the 10% level. On the other hand, none of the indicators that constitute the business usage pillar is significant (column 2).[13] Column 3 shows that the importance of ICTs to government vision has a positive and significant effect on GDP growth at the 5% level. It is the only significant indicator associated with the government usage pillar. [14]

[11] Full results which includes the other variables are available upon request to the authors.

[12] We include only 3 out of 7 of the indicators that constitute the individual usage pillar. This is for purposes of parsimony and also because a number of the indicators are highly correlated. The indicators that were dropped were not significant. Results with all 7 indicators are available upon request of the author.

[13] The business usage pillar also includes the business to consumer internet use indicator, but this variable was dropped due to problems of multicollinearity.

[14] The government success in ICT promotion was dropped due to collinearity with the Importance of ICTs to government vision indicator.

The positive contribution of social media usage to economic growth is in line with the literature (e.g., Khajeheian, 2013). Social media has been associated with stimulating entrepreneurship (Ukpere et al., 2014) including among SMEs (N. Jones et al., 2015), firm performance (Tajvidi & Karami, 2017), consumer marketing (Tsitsi Chikandiwa et al., 2013) and coordination among businesses (Diba et al., 2019; Juntunen et al., 2019). The lack of significance of internet usage on growth could be due to low internet penetration, a lack of ICT skills necessary to use the internet (Haftu, 2019), or a lack of local digital content (Holden & van.Klyton, 2016). Furthermore, we found that mobile phone subscriptions are positive but insignificant. This is in line with the recent finding of Donou-Adonsou (2019), who found that mobile phone adoption was insignificant for growth in Africa. He asserted that the level of education of the internet user was the more relevant contributor to economic growth. This finding also lends support to Yoon's (2020) assertion that the majority of Africans still use flip phones (rather than smartphones), thus inhibiting mobile phone subscriptions potential to contribute to growth.

Column 2 of Table 5 shows that neither of the business usage components is statistically significant.[15] The results might suggest the lack of enabling conditions in Africa (such as poor infrastructure, lack of education or poor service from internet service providers)[16] that hinder businesses from reaping the benefits of ICT usage. In particular, the lack of significance of capacity for innovation could be attributed to a skills deficit in Africa, whereby individuals vary in their capacity to convert a "given resource into valuable functionings" (Palvia et al., 2018, p. 4). Therefore, it is a logical assumption that not all business owners in Africa would have the capabilities required to use ICT resources to advance their business. In addition to human capital, innovation requires an enabling environment through effective government policy and investment (Jorgenson & Vu, 2016; Lefophane & Kalaba, 2020; Maiorano & Stern, 2007; Osabutey et al., 2014). In fact, Amanwak et al. (2018, p. 1) showed that in Africa, many governments lag behind in "charting technology and innovation trajectories", which are critical for building the capacity for innovation. Worse still is the evidence that innovation had either regressed or declined throughout most of Africa (Danquah & Amankwah-Amoah, 2017). Hence, governments should see themselves as enablers of ICT-based growth in the economy and support the complementarity between the quality of human capital and the growth effects of ICT, which has also been emphasised in the literature.

Finally, a government with a clear ICT vision reflects an ability for it to convert and utilise ICTs to improve competitiveness. Such governments are more likely to create policy environments that facilitate the use of ICTs across various business sectors and for individual use, which is essential for enhancing economic growth (Ghosh, 2017; Zhao et al., 2015). Effective use of ICT can help to reduce bureaucracy in government processes (Albiman & Sulong, 2016).

5. Conclusion

Empirical research on the impact of digitalisation in African countries is limited. Our research contributes to this field by using available data from 39 African countries from 2012-2016 to examine the impact of digital technology usage on economic growth. Unlike existing research, we distinguish between the impacts of individual, business, and government usage of ICT by analysing data from the

[15] The regression results for the business usage components should be treated with caution because of the smaller sample size compared with the results for the individual and government usage components.
[16] See Apulu and Ige (2011).

sixth, seventh, and eighth pillars of the Networked Readiness Index. Using the SYSGMM estimator, the results indicated that individual usage of ICT was positively associated with growth. When the three pillars were disaggregated into their individual component indicators, social media usage, and the importance of ICTs to government vision emerged as significant for economic growth.

The growth effects of ICT can be maximised through a skilled labour force and an enabling ICT policy environment. The quality of human capital has been emphasised in the literature as a complementary factor in the ICT-growth relationship. Therefore, investment in human capital is an important policy consideration to improve the growth effects of ICT. As such, individual users would become drivers of digitalisation on the continent. This would incentivise firms to increase their use of technology to meet the demands of newly technology conscious consumers across Africa. The government could also implement programmes that increase the availability of mobile phone-based applications, which could facilitate remote learning and other activities. Although our data showed an increasing trend in digitalisation since 2012, African governments should improve both the usage of digital technology and technical capacity through appropriate science, technology, and innovation (STI) policies.

Finally, the NRI has the benefit of being a comprehensive measure of digitalisation that captures several dimensions and provides relatively extensive coverage of African countries. However, it has a drawback of being too broad in its aggregate or even sub-aggregate forms, which makes it challenging to identify the impact of digitalisation on aggregate measures of economic activity. However, using the NRI in its more disaggregated forms (pillars or indicators) is instructive for isolating the effects of different components of digitalisation and could inform other areas of research.

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