Does Digitalisation Increase Economic Growth? Evidence from SADC Countries

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The fourth industrial revolution has contributed significantly towards the growing global technological transfers that enhance productivity, employment and standard of living. The outbreak of the COVID-19 pandemic has undeniably disrupted lives globally; however, it enhanced technological transformation by causing an abrupt shift towards digital technology usage. The development and diffusion of digitalisation is expected to drive economic growth as we move towards the 2030 Sustainable Development Agenda. This study examines the impact of digitalisation on economic growth for 14 Southern African Development Community (SADC) countries from 2000 to 2020 employing the Fixed Effects model. Results reveal that all digitalisation indicators employed tend to have a positive impact on economic growth. A percentage change in individual usage of information communication technologies (ICTs), fixed broadband subscriptions, and mobile cellular subscriptions leads to a 0.17%, 0.11% and 0.12% increase in GDP per capita, respectively. Therefore, usage of and access to digital technologies stimulate economic growth in the SADC region. Public policies should seek to stimulate private sector investments in technological infrastructure and liberalise the telecommunications and innovation market. This accelerates digitalisation and consequently leads to higher economic growth and development in the SADC region.

Key Words: digitalisation, economic growth, fixed effects model, SADC
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Introduction

The world economy has experienced a transition in respect to the social, economic and business landscape due to increased usage of digital technology. To adapt to these dynamic lifestyles and business operations, individuals and businesses are now facing a lot of pressure to utilise digital technology. The use of and access to digital technology has smoothed the way in which businesses interact with their customers, thereby strengthening customer relationships. According to Hagberg, Sundstrom, and Egels-Zandén (2016), digitalisation is defined as the transformation from 'analogue' to 'digital' and to the facilitation of new forms of value creation, while Srai and Lorentz (2019) defined it as the way many domains of social life are restructured around digital communication and media infrastructures.

Evangelista, Guerrieri, and Meliciani (2014), Batuo (2015), Traore (2014), Mirgorodskaya, Rustamova, and Grachev (2020), and Fernández-Portillo, Almodóvar-González, and Hernández-Mogollón (2020) have shown that the development of and access to technological infrastructure drives economic growth. A lot of people are increasingly making use of digital technology for social, business, educational and other activities in these modern days. It is this technological usage by people that is pushing businesses and governments to adopt new technologies to meet the changing needs of their consumers. However, despite the increased usage and development of digital technology, not all people are able to fully utilise technologies due to some costs involved. The investment in technological equipment and usage, especially in developing countries, is costly and has aggravated online inequalities within countries. Developing countries, particularly in Africa, are still lagging with regard to digitalising their economies. According to the United Nations (2021b), extreme poverty is mainly a rural phenomenon, reflecting that most of the poverty-stricken population in developing countries are living in rural areas. In Africa, using the example of Zimbabwe, many of its rural areas have poor internet connectivity, limited devices and limited internet coverage resulting in low internet usage (World Bank 2021). In urban areas where there is better coverage, the cost associated with accessing the Internet may also be an obstacle towards technological usage. To reduce online inequalities and increase growth, governments should improve access to and use of digital technology. Arsić (2020) shows that technical innovations increase productivity, which enables enormous growth in the world and an increase in the standard of living due to the increase of the quantity of product per worker and therefore fewer working hours.

According to International Telecommunication Union (n.d.), over the last four years, the African region has seen continued, albeit slow, growth in most areas of ICT infrastructure, access and use. This slower diffusion of digital technology could be inducing low growth and high poverty levels. Meanwhile, in most developed countries, digitalisation has become one of the main drivers of economic growth. According to Duarte (2021), for Africa to generate economic growth that leads to sustainable development, it must shift its focus to retaining and creating wealth to reboot the continent's economic structures and catch up technologically with the rest of the world. Innovation, and the digital information technology that accompanies it, has become a necessary component of any effort to address growth and poverty challenges. Adequate technological diffusion leads to economic development by enhancing the efficiency with which all the factors of production are utilised in the economy, and this reduces poverty incidence (United Nations 2010). The production frontier is enhanced by the efficient use of technology (Ekekwe 2011). The slow spread of internet technology makes it difficult for the continent to leapfrog obstacles to sustainable development. To generate transformative growth, digitalisation cannot be left mainly to civil society and the private sector. There exists scant empirical research aimed at investigating the effect of digitalisation on the economic growth of Southern African Development Community (SADC) countries. This paper fills the gap by using available data from SADC countries to examine the impact of access to and use of digital technology on economic growth.

The rest of this article is organised as follows: dynamics of economic growth and digital technology development in Africa, literature review, estimation method and model specification, results and discussion, and lastly the conclusions and implications.

The Dynamics of Economic Growth and Digital Technology Development in Africa

To promote peace and prosperity for people and the planet, the United Nations (UN), in 2015, set up a group of 17 global goals. One salient feature of these goals highlights the importance of access to digital technology, development, and diffusion of digitalisation. The United Nations (2018) explain that Sustainable Development Goal (SDG) 9 seeks to promote industrial innovation and infrastructure development to support domestic technology development and innovation in developing countries as well as significantly increase access to information and communication technology and to provide universal and affordable access to the Internet in the least developed cfountries. Furthermore, related to this goal is SDG 17, which seeks to improve access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, promote the development, transfer, dissemination, and diffusion of ecologically sound technologies to developing countries and fully operationalise the technology and innovation capacity-building mechanism for least developed countries, and enhance the use of enabling technology in ICTs (United Nations 2018).

Although progress towards Agenda 2030[1] for Sustainable Development was moving in the right direction, the outbreak of the COVID-19 pandemic has reversed this trend (United Nations 2021a). As of 2019, just over half of the world's population was online, with a large digital divide observed among regions. The United Nations (2021a) further show that during this time, while 85 per cent of the population in Europe and Northern America had internet access, only 20 per cent were connected in the least developed countries. Additionally, while fixed-broadband subscriptions continued to increase, growth in subscriptions slowed to 2.7 per cent in 2020. In developed countries, there were more than 33 subscriptions per 100 inhabitants, representing a high penetration rate, while the number in developing countries stood at 11.5 per 100 inhabitants. In the least developed countries, fixed networks are almost completely absent, with only 1.3 subscriptions per 100 inhabitants. The United Nations (2021a) also reported that in 2018, the share of medium- and high-technology manufacturing in total manufacturing was 49 per cent in developed regions and 41.4 per cent in developing regions, compared to only 8.9 per cent in the least developed countries. The roll-out of mobile broadband networks slowed in 2020. Almost 85 per cent of the global population was covered by a 4G network at the end of 2020, following a twofold increase in coverage since 2015. However, annual growth has been slowing gradually since 2017, with the result that coverage in 2020 was only 1.3 percentage points higher than in 2019.

The COVID–19 pandemic negatively affected several development indicators in developing economies, with no exception in technological development. According to the Organisation for Economic Co-operation and Development statistics (OECD n.d.), Africa's real GDP growth

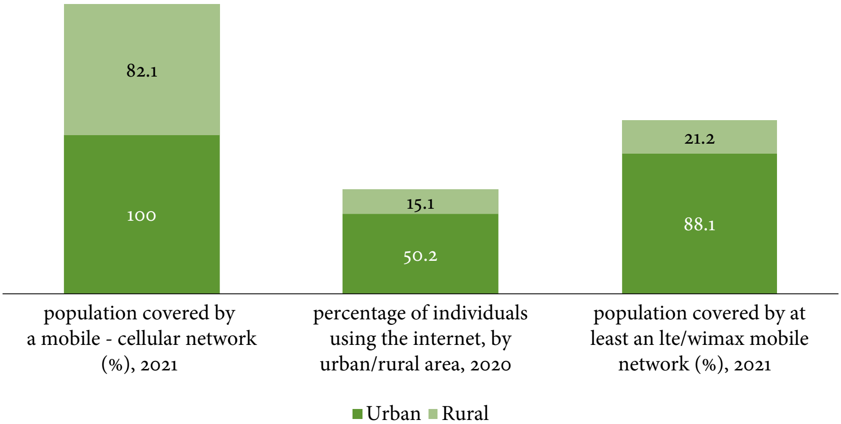

FIGURE 1 ICT Penetration Rates in Africa (based on data from International Telecommunication Union n.d.)

was –1.6% in 2020, while in 2019 the African economy grew by 3.3%. The most affected region in Africa in 2020 was the Southern region, with real GDP growth of –5.7%. Countries that recorded a very high negative growth are Botswana (Southern Africa), Mauritius and Seychelles from East Africa, Libya and Tunisia in North Africa, and Cabo Verde in West Africa. The OECD (n.d.) report shows that gross domestic product in Africa decreased in 41 countries in 2020, compared to 11 countries in 2009 when the global financial crisis occurred. In terms of digitalisation progress in Africa, the International Telecommunication Union statistics shows that Africa had the lowest subscriptions both fixed telephone and broadband subscriptions than other ITU regions by 2021 (International Telecommunication Union n.d.). Although Africa has a better number of mobile-cellular telephone subscriptions and active mobile broadband subscriptions than Arab States, the Commonwealth of Independent States (CIS), and Europe, the subscriptions were still relatively low in 2021. Additionally, the population covered by at least an LTE/WiMAX mobile network or by a mobile cellular network at a 3G mobile network, although greater than Asia Pacific and CIS regions, was still relatively low in 2021. The international bandwidth in 2021 remained very small compared to the majority of other ITU regions. The penetration rates in Africa are still very low in rural areas as compared to urban areas, as illustrated in figure 1. Figure 1 also depicts that by 2020, only 15% of individuals in rural areas were using the Internet, while 50% of the urban population were using internet. Additionally, by 2021 only 21% of the rural population was covered by at least an LTE/WiMAX mobile network, while 88% of the urban population is covered (International Telecommunication Union n.d.). Consequently, ICT penetration rates in rural areas of Africa remained very low in spite of a greater number of the population being covered by a mobile cellular network.

To achieve UN SDG 9.c, SDG 17.6 and SDG 17.8, as well as kick-start a new growth cycle in the aftermath of the COVID-19 crisis, Africa has an opportunity to boom its digital sector. Digitalisation is one of the most powerful tools for implementing the 2030 Agenda for Sustainable Development and Africa's Agenda 2063. Figure 2 depicts a bivariate analysis of average growth in GDP per capita and average individual usage of the Internet, average fixed broadband subscriptions and average mobile cellular subscriptions for the period 2000-2020. The plots show a positive correlation between growth and all the digitalisation variables, in line with findings from Solomon and van Klyton (2020). The correlation is strongest between average GDP per capita and mobile broadband subscriptions.

Literature Review

THEORETICAL LITERATURE

The mixed performance of neoclassical theories such as Solow's (1956) neoclassical growth model in explaining long-term economic growth led to discontentment with traditional growth theory. The models predict that economies of both developed and developing countries will eventually converge to zero economic growth if there are no external technological shocks or changes. Therefore, Solow (1956) perceived increasing per capita gross national income (GNI) as a short-run occurrence emanating from technological changes or a situation where the economy is self-adjusting in order to reach its long-run equilibrium point. It is this failure by the neoclassical theories to account for sustained economic growth and ascribing it to exogenous technological shocks that led to the emergence of the endogenous growth models (Todaro and Smith 2015).

Romer (1986; 1989), and Lucas (1990) postulated alternative growth models known as Endogenous or New Growth models, where long-run growth depended on intentional investment decisions as opposed to Solow's exogenous technological innovation. These models differ from the neoclassical Solow Growth Model in that they account for sustained economic growth by disregarding the assumption of diminishing returns to capital and treating the accumulation of knowledge as deliberate

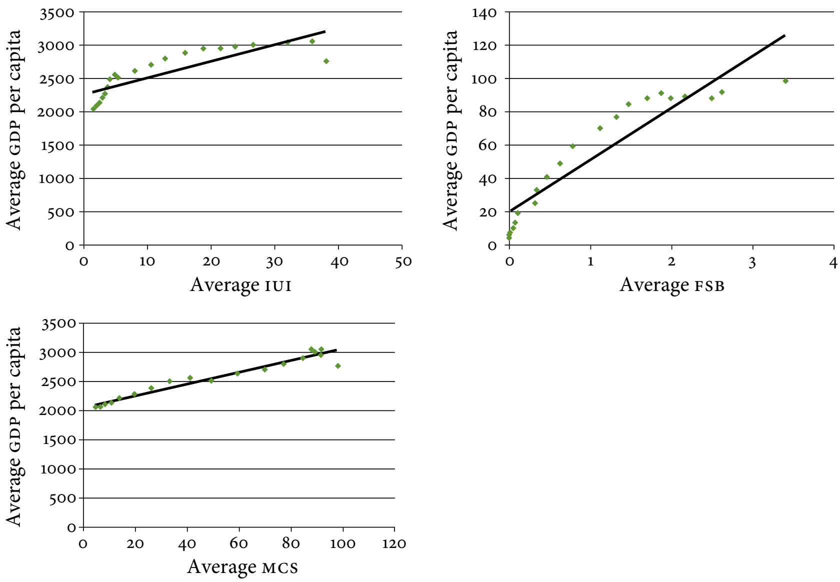

FIGURE 2 Average Growth in GDP Per Capita and Average Individual Usage of Internet (IUI), Fixed Broadband Subscriptions (FBS) and Mobile Cellular Subscriptions (MCS) for the Period 2000-2020 in Africa

decisions by profit-maximizing firms (Todaro and Smith 2015; Snowdon and Vane 2005). In the endogenous growth models, technological innovations by individual firms are partially excludable, which allows other firms to imitate the technologies and benefit the larger economy, because of these positive externalities from technological innovations. While an individual firm's production function is subject to diminishing returns, the production function of the economy is subject to increasing returns to scale owing to the positive technological spill overs (Myovella, Karacuka, and Haucap 2020). In this way, the endogenous growth models can explain the divergent long-term growth patterns among countries.

Dissimilar to the Solow model, new growth theory accounts for technological change as an endogenous outcome of public and private investments in human capital and knowledge-intensive industries. According to Todaro and Smith (2015), the endogenous growth models emphasise the need for public policy to be geared towards investments in human capital formation and the stimulation of 'foreign private investment in knowledge-intensive industries such as computer software and telecommunications'. The effects of digitalisation on economic growth can, therefore, be explained within the framework of the endogenous growth theory (Aghaei and Rezagholizadeh 2017; Myovella, Karacuka, and Haucap 2020).

Defined as the 'incorporation of data and the Internet into production processes and products, new forms of household and government consumption, fixed-capital formation, cross-border flows, and finance' (International Monetary Fund 2018), digitalisation is enabled by the advent of Information and Communication Technologies (ICT). Myovella, Karacuka, and Haucap (2020) explained that specific ICTs, namely internet and mobile phone technologies, necessitate the creation of 'new products and processes, new market channels and organizational complexities, along with technological advancement'. Thus, ICT improves allocative efficiency both in resource and goods markets, reduces production costs, and promotes demand and investment in all sectors of the economy. Digitalisation has, among other things, revolutionised how businesses operate (e.g. e-commerce and electronic payments systems), how people communicate (e.g. social media and videoconferencing) and how governments provide services to the public (e.g. e-government portals). In this way, technological changes have brought efficiencies that have become the engines of growth for both developing and developed countries.

EMPIRICAL REVIEW

There is a bountiful amount of research detailing the impact of digitalisation on economic growth. The empirical efforts examining the digitalisation effects on growth appear to be more extensive in developing and emerging countries in comparison to other world regions. There is basically a consensus that digitalisation drives economic growth for both developing and developed countries. For the sake of brevity and relevance, we restrict our review to studies which focus on the digital technology usage and digital technology infrastructure contribution to growth. These studies can be conveniently divided into 3 strands of empirical works namely: i) Studies inclusive of developing countries, ii) Studies inclusive of developed countries, and iii) Methodology used in these studies.

The first cluster of studies includes all reviewed studies covering developing countries with their results. In this group, we include the works of Solomon and van Klyton (2020) on 39 African countries, distinguishing between the impact of individual, business and government ICT usage on growth and showing that only individual usage, social media usage and government ICT have a positive impact. Batuo (2015) presents empirical evidence on how telecommunication infrastructure is related to growth in a panel data set covering 44 African countries and suggests that telecommunication infrastructure contributes in a major way to economic development of the continent. Bahrini and Qaffas (2019) evaluate the impact of ICT on growth for selected countries in the Middle East and North Africa region and Sub-Saharan region and shows that except for fixed telephone subscriptions, other information and communication technologies such as mobile cellular subscriptions, Internet usage, and broadband adoption are the main drivers of growth. Traore (2014) studies the effects of telecommunications infrastructure on economic development and growth in 33 Sub-Saharan African countries and shows that the implementation of mobile phone technology contributes in a major way to the economic development of the continent. Onyeji and Karner (2008) prove that the contribution of mobile subscribers to economic growth is positive and significant in the case of Africa and Central East European countries. Donou-Adonsou (2019) shows some different results, where the Internet contributes to economic growth, but only in countries with better access to education, with no strong evidence on how mobile phones promote growth in 45 Sub Saharan African countries. Salahuddin and Gow (2016) investigate the relationship among internet use, economic growth and financial development and results indicate that internet use stimulates economic growth. Sridhar and Sridhar (2007) use 63 developing countries to examine the relationship between telecommunications infrastructure on economic growth and find a positive impact of mobile and landline phones on national output. Shodiev, Turayey, and Shodiyev (2021) reveal that ICT affects GDP per capita positively and significantly in emerging countries of Central Asia. Usman et al. (2021) investigate the effect of ICT on economic growth in South Asian economies and reveal that in the long run, ICT significantly and positively contributed towards the economic growth of India only.

The impact of digitalisation on growth and development has also been widely researched in relation to developed countries. This cluster of studies includes the works of Jiao and Sun (2021) on digital economy development in China, focusing on internet development, digital literacy and industrial efficiency improvement. The study finds that digital economic development in China has a positive effect on urban economic growth, and a heterogeneity effect exists between different cities. Mirgorodskaya, Rustamova, and Grachev (2020) investigated the impact of digitalisation on Russia's economic growth and found a strong correlation between GDP and the digital economy development indicators. Raeskyesa and Lukas (2019) analysed the effect of digitalisation on the economic growth of eight ASEAN middle income countries and found that ICT indicators have a significant positive impact on growth; however, usage and intensity of ICT have a higher impact than access to ICT. Toader et al. (2018) evaluate the effect of using ICT infrastructure on economic growth in the EU countries. Their results indicate a positive and strong effect of using ICT infrastructure on the EU member states' economic growth. According to Pradhan et al. (2019), there are strong interlinkages between ICT infrastructure, economic growth and venture capital in their analysis done using 25 European countries. Shahiduzzaman and Alam (2014) investigate the role of investment in IT on economic output and productivity in Australia. The empirical evidence points to a cointegration relationship between ICT capital and output and implies that ICT capital Granger causes economic output and multifactor productivity, as does non-ICT capital. Different results were found in the case of Japan, where Ishida (2015) estimated the relationship between ICT and economic growth and found that ICT investment does not contribute to an increase in GDP. Fernández-Portillo, Almodóvar-González, and Hernández-Mogollón (2020) investigate the impact of ICT development on economic growth on OECD European union countries. Results suggest that progress in the deployment and use of ICT drives the economic growth of countries that are within the framework of developed European countries.

In terms of economic integrations, Latif et al. (2018) investigated the dynamic relationship between ICT, FDI, and economic growth in BRICS and found that ICT positively contributes to economic growth of BRICS countries. Aghaei and Rezagholizadeh (2017) examine the impact of ICT on economic growth among the Organization of Islamic Conference members and reveals that there is a significant impact of investments in ICT on economic growth in the countries considered. By distinguishing several stages or domains of the digitalisation process, Evangelista, Guerrieri, and Meliciani (2014) evaluated the economic impact of digital technologies in Europe. The findings demonstrated that the usage of ICT, particularly digital empowerment, has a major economic impact, notably on employment and the labour-market involvement of 'disadvantaged' groups. They found that digitisation has the potential to boost productivity and employment development, and that inclusive policies may help close the gap between the most advantaged and disadvantaged portions of the population.

Another interesting group of studies compares the most and the least developed countries to measure which group benefits the most from digitalisation. The results in this group of studies show mixed direction. Myovella, Karacuka, and Haucap (2020) compare the most and the least developed countries to measure the effects of digitalisation on economic growth using 41 SSA and 33 OECD countries. Their results show that digitalisation makes a positive contribution to economic growth in both groups of countries. Majeed and Ayub (2018) use 149 countries to analyse the impact of ICT indicators on economic growth at both global and regional levels. This analysis involves developed, emerging, and developing countries and reveals that emerging and developing countries are gaining more from ICT than developed countries, validating the argument that these economies are 'leapfrogging' through ICT. Niebel (2018) analyses the impact of ICT on economic growth in developing, emerging, and developed countries; however, the study found no statistical evidence that developing and emerging countries are gaining more from ICT than developed economies. Appiah-Otoo and Song (2021) employ a panel of 123 countries, including high-income countries or middle-income and low-income countries. Their results show that ICT increases economic growth in both countries. Additionally, poor countries tend to benefit more than rich countries from the ICT revolution. Albiman and Sulong (2017) examine both linear and nonlinear impacts of ICT on economic growth for lower middle income, lower income, and upper income categories within the SSA region. Results show that lower-middle-income countries have more first-mover advantages when it comes to absorbing benefits from ICT compared to lower-income and upper-income categories. Additionally, the impact of fixed telephone lines are higher compared to mobile phone lines even though the positive impact of the mobile phone is more robust for each income category compared to other technologies.

In further summarising the empirical literature, we can look at estimation techniques to show the trend in development of econometrics techniques used. The econometric techniques used extensively as a method of estimation are the Generalized Method of Moments (GMM), pooled OLS, fixed effects, random effects and ARDL (Bounds test and the PMG/ARDL Models). Jiao and Sun (2021), Bahrini and Qaffas (2019), Traore (2014), Donou-Adonsou (2019), Solomon and van Klyton (2020), Myovella, Karacuka, and Haucap (2020), and Nasab and Aghaei (2009) employed the GMM estimator, while Elding and Morris (2018), Raeskyesa and Lukas (2019), Batuo (2015), Onyeji and Karner (2008), Toader et al. (2018), Niebel (2018), and Aghaei and Rezagholizadeh (2017) employed panel data regression analysis using either one or a combination of the Pooled OLS, Fixed and Random effects. Another widely used technique is the ARDL Model and the PMG/ARDL Model. These models are used in the works of Salahuddin, Alam, and Ozturk (2016), Salahuddin and Gow (2016), Shahiduzzaman and Alam (2014), Ishida (2015), Albiman and Sulong (2017), and Usman et al. (2021). The OLS and VECM have been used, but not more often. Latif et al. (2018) and Shodiev, Turayey, and Shodiyev (2021) employ the OLS, while Fernández-Portillo, Almodóvar-González, and Hernández-Mogollón (2020) employ the Partial Least Squares (PLS) analysis. The VECM was employed in the works of Pradhan et al. (2019) and Saidi and Mongi (2018).

Notably, there is a consensus that ICT usage and infrastructure development have a significant impact on the growth of both developing and developed countries. However, studies focusing on African economies present some challenges in terms of data collection and availability. Additionally, 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 and deficits in ICT infrastructure. This has resulted in Internet inequality (Online inequalities) in Africa, creating major challenges and, hence, the motive to investigate the impact of digitalisation on African countries.

This research contributes to the literature by being the first study to explore the dynamics between economic growth and digitalisation in the SADC region. Existing studies on this subject look at Sub-Saharan Africa as whole or at developing countries without a specific focus on the SADC region. The SADC region is an important bloc because it represents regional integration in the Southern part of Africa. The main objective of the SADC grouping is to 'Achieve development and economic growth, alleviate poverty, enhance the standard and quality of life of the people of Southern Africa and support the socially disadvantaged through regional integration' (Southern African Development Community 1992). This objective seeks to address the chronic socio-economic problems which are common in other regions of the African continent. In its Vision 2050, SADC aims 'to have efficient and effective, technologically-driven cross-border infrastructure services and networks to support and facilitate deeper regional integration' (Southern African Development Community 2020, 6). Therefore, it is important to measure the extent to which the region has managed to exploit advancements in technology to achieve its key objectives, and this is what this study seeks to ascertain.

Estimation Method and Model Specification

To model the impact of digitalisation on economic growth in the SADC region, we begin with a Cobb-Douglas production function for country *i* and time.

$$Y_{it} = A_i L_{it}^{\beta_1} K_{it}^{\beta_2} D_{it}^{\beta_3} e^{\rho it} \tag{1}$$

where Y is output, L is labour (i.e. total employment), K is physical capital stock, D level of digitalisation and A is a country-specific multiplicative constant that could denote country-specific technological capability. The β coefficients denote the factor share of the corresponding factor inputs, and ρ is a country-specific efficiency parameter. Taking natural logs and first differencing gives:

$$\Delta In Y_{it} = \beta_1 \Delta ln L_{it} + \beta_2 \Delta ln K_{it} + \beta_3 \Delta ln D_{it} + \Delta \rho_{it} \tag{2}$$

where ΔlnY, ΔL, ΔK and ΔD refer to growth in output, labour, physical capital, and level of digitalisation, respectively. The parameters β_1, β_2 and β_3 denote output elasticities with respect to the corresponding factor inputs. In line with the endogenous growth model, we do not impose constant returns to scale. Following the approach of Lokshin, Belderbos, and Carree (2008), we assume that the country-specific efficiency parameter ($\Delta\rho_{it}$) is a function of past productivity (Y_{it-1}), to allow for conditional convergence among countries (Barro 1991; Bond, Hoeffler, and Temple 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.

$$\Delta \rho_{it} = \alpha_1 In Y_{it} + e_{it} \tag{3}$$

The error term in equation (3) (e_{it}) consists of a country-specific fixed effect, σ_i, that measures unobserved permanent differences in output across countries, a time-specific effect (τt) that captures disembodied technical change (Lokshin, Belderbos, and Carree 2008), and an idiosyncratic error term (u_{it}).

$$e_{it} = \sigma_i + \tau t + u_{it} \tag{4}$$

The level of digitalisation (D) can be approximated by usage and access (Cardona, Kretschmer, and Strobel 2013). Therefore, the usage aspect of the level of digitalisation will be proxied by *IUI* (individual using the Internet as percentage of the population) while the access aspect will be proxied by *FBS* (fixed broadband subscriptions per 100) and (Mobile-cellular subscriptions per 100 inhabitants) for each SADC country. Based on the existing theoretical and empirical bases of modelling the impact of digitalisation on economic growth reviewed, we specify a simple Cobb-Douglas production in the following specification:

$$\begin{aligned}\Delta Y_{it} = {} & \beta_0 + \beta_1 \Delta \ln L_{it} + \beta_2 \Delta \ln K_{it} + \beta_3 \Delta \ln IUI_{it} \\ & + \beta_4 \Delta \ln FBS_{it} + \beta_5 \Delta \ln MCS_{it} + \beta_6 \Delta \ln POG_{it} \\ & + \beta_7 \Delta \ln TO_{it} + \beta_8 Z_i + u_{it}\end{aligned} \tag{5}$$

where Z_i are unobserved time invariant heterogeneities across the countries $i = 1, 2, \ldots 14$.

The aim is to estimate output elasticities in equation (5) with respect to the corresponding explanatory variables holding constant Z_i. The baseline specification given in this study is a fixed effect (FE) panel regression model controlling for unmeasured cross country differences. In addition, we use the Pooled OLS (POLS) and Random Effect model.[2]

Among other variables, labour, gross capital formation and other variables are anticipated to be endogenous for two salient reasons: omitted variable bias and reverse causality. As a method to reinforce our estimations from equation (5), an approach that has been widely employed to avoid the problems associated with simultaneity is to replace a suspected variable with its lagged values. Examples of studies employing this approach include the works of Buch, Koch, and Koetter (2013), Cornett et al. (2007), Vergara (2010), Hayo, Kutan, and Neuenkirch (2010) and Clemens et al. (2012). As a result, we lagged all explanatory variables by one year. Since after diagnostic the FE model proved to be the most appropriate model, equation (6) is a representation of the Fixed Effects model, letting $\alpha_i = \beta_0 + \beta_9 Z_i$ to obtain:

$$\begin{aligned}\Delta In Y_{it} = {} & \beta_1 \Delta \ln L_{it-1} + \beta_2 \Delta \ln K_{it-1} + \beta_3 \Delta \ln IUI_{it-1} \\ & + \beta_4 \Delta \ln FBS_{it-1} + \beta_5 \Delta \ln MCS_{it-1} + \beta_6 \Delta \ln POG_{it-1} \\ & + \beta_7 \Delta \ln TO_{it-1} + \beta_8 \Delta \ln INF_{it-1} + \alpha_i + u_{it}\end{aligned} \tag{6}$$

with $i=1,\dots 14$ and $t=2000, \dots 2020$, $t-1$ is lag of one year. The α_i are country-specific intercepts that capture heterogeneities across countries.

Estimating the FE model with regressors, taking averages on both sides of equation 4 we obtain:

$$\frac{1}{n}\sum_{i=1}^{n}\ln Y_{it} = \beta_1\frac{1}{n}\sum_{i=1}^{n}\ln L_{it-1} + \beta_2\frac{1}{n}\sum_{i=1}^{n}\ln K_{it-1} + \beta_3\frac{1}{n}\sum_{i=1}^{n}\ln IUI_{it-1} + \beta_4\frac{1}{n}\sum_{i=1}^{n}\ln FBS_{it-1} + \beta_5\frac{1}{n}\sum_{i=1}^{n}\ln MCS_{it-1} + \beta_6\frac{1}{n}\sum_{i=1}^{n}\ln X_{it-1} + \frac{1}{n}\sum_{i=1}^{n}\alpha_i + \frac{1}{n}\sum_{i=1}^{n}\mu_{it} \tag{7}$$

DATA AND DESCRIPTIVE STATISTICS

We estimate equation (7) for a sample of 14 SADC countries from 2000 to 2020. The study used this period because of data availability on all the variables in the study, and although employing an unbalanced panel data, the number of observations is more than 225 in all variables, which is enough to perform regression analysis. Due to data unavailability, Seychelles and Malawi are removed from the sample. Table 1 summarises the list of variables and the respective descriptions.

Table 2 shows the within and between summary statistics. The descriptive statistics of the panel data for SADC countries shows that the overall mean GDP per capita was about US$ 2595.26, which fluctuated between $294.65 and $10643.77 over the period.

Trade liberalisation is improving in the SADC region as shown by a high degree of trade openness with an overall mean of 78.60%. The degree of trade openness has not been stable over the period, as indicated by a high standard deviation of 32.41%. The minimum trade openness was 23.98%, recorded in Tanzania in 2000, showing lower trade density in that country, while Eswatini recorded the highest trade density of 175.80% in 2002. In terms of technological diffusion, mobile cellular subscriptions reached an average of 53%, with Comoros having recorded zero subscriptions between the periods 2000-2003 and South Africa having recorded the highest subscriptions of 165% in 2019. The overall mean for the fixed broadband subscriptions was very low over the period, showing lower diffusion of these subscriptions in the region. SADC countries are still struggling when it comes to fixed broadband subscriptions with

TABLE 1 Description of Variables

Variable	Short Description	Source
ΔInY_{it}	Growth in GDP per capita (constant 2015 US$)	World Bank (2022a)
ΔInL_{it}	Growth in Employment to population ratio, 15+, total (%)	World Bank (2022a)
ΔInK_{it}	Growth in Gross capital formation (% of GDP)	World Bank (2022a)
$\Delta InIUI_{it}$	Growth in Individuals using the Internet (% of population)	World Bank (2022a)
$\Delta InFBS_{it}$	Growth in Fixed broadband subscriptions (per 100 people)	World Bank (2022a)
$\Delta InPOG_{it}$	Growth in Population growth (annual %)	World Bank (2022a)
$\Delta InTO_{it}$	Growth in Trade (% of GDP)	World Bank (2022a)
$\Delta InMCS_{it}$	Growth in Mobile-cellular subscriptions per 100 inhabitants	OECD (n.d.)

countries like DRC, Comoros, Lesotho and Zambia having recorded no subscriptions in some parts of the years and the highest subscriptions recorded in Mauritius in 2020. South Africa is the technological giant of the SADC region since it recorded the maximum percentage of individuals using the Internet, reaching 70% in 2020, while the DRC recorded the lowest of 0.01% in 2000 and 2001.

PRE-ESTIMATION DIAGNOSTIC TESTS

Before estimating the model specified in Equation (7), some pre-estimation diagnostics must be carried out, namely, unit root and correlation tests. The results of these tests are presented in tables 3, 4 and 5. Two types of unit root tests were conducted, that is, Im-Pesaran-Shin unit-root test and Fisher-type unit-root test, to confirm stationarity, since these tests accept unbalanced panel data.

Results for unit root tests show that all the variables are stationary in levels (I (0)) except *laglnL, laglnK* and *laglnTO,* which are stationary after first differencing, becoming I(1) variables and represented as *dlaglnL, dlaglnK* and *dlaglnTO.*

A check for multicollinearity among the variables was conducted by computing the correlation matrix and variance inflation factors as shown in table 4 and table 5, respectively. The values on the correlation matrix are very low, indicating that variables are not highly correlated.

This is further supported by the VIFs check for multicollinearity, which looks fine since it is less than 5 using the strict/conservative rule

TABLE 2 Within and Between Descriptive Statistics

Variable		Mean	Std. Dev.	Min	Max	Observations
Y	*overall*	2595.26	2403.96	294.65	10643.77	$N = 294$
	between		2422.74	419.62	7840.12	$n = 14$
	within		556.81	289.11	5398.91	$T = 21$
L	*overall*	60.41	16.86	35.78	86.03	$N = 294$
	between		17.38	38.48	83.94	$n = 14$
	within		1.71	55.66	65.01	$T = 21$
K	*overall*	22.89	9.46	1.53	53.99	$N = 274$
	between		8.06	8.97	35.96	$n = 14$
	within		5.67	6.83	42.49	T *bar* = 19.5714
IUI	*overall*	12.54	15.94	0.01	70.00	$N = 286$
	between		9.55	2.79	32.15	$n = 14$
	within		12.97	−12.33	55.57	$T = 20.4286$
FBS	*overall*	1.38	3.77	0.00	25.41	$N = 225$
	between		2.66	0.01	10.26	$n = 14$
	within		2.57	−8.85	16.54	T bar = 16.0714
POG	*overall*	1.98	1.07	−0.62	3.71	$N = 294$
	between		1.08	0.28	3.47	$n = 14$
	within		0.26	1.09	2.67	$T = 21$
TO	*overall*	78.60	32.41	23.98	175.80	$N = 286$
	between		30.58	37.63	145.88	$n = 14$
	within		16.22	35.77	143.04	T *bar* = 20.4286
MCS	*overall*	53.34	45.56	0.00	165.60	$N = 293$
	between		27.81	23.11	102.89	$n = 14$
	within		36.78	−32.78	117.57	T *bar* = 20.9286

TABLE 3 Panel Unit Root Test

	Unit root test results in levels		Unit root test results after first difference	
Variable	Im-Pesaran-Shin	Fisher-type	Im-Pesaran-Shin	Fisher-type
lagInY	−2.16***	4.34***	--	--
laglnL	−0.98	−2.01	−1.11**	5.84***
laglnK	−0.81	0.21	−7.40***	25.69***
laglnIUI	−1.67**	5.31***	--	--
laglnFBS	−3.13	20.35***	--	--
laglnPOG	−2.47*	20.87***	--	--
laglnTO	−0.68	0.34	−6.94***	23.18***
laglnMCS	−6.81***	64.77***	--	--

NOTE *, ** and *** means statistically significant at 10%, 5% and 1% level, respectively.

of thumb that an individual VIF greater than 5 indicates the presence of severe collinearity.

A value between 1 and 5 indicates moderate correlation between a given explanatory variable and other explanatory variables in the model, but this

TABLE 4 Correlation Matrix

	dlaglnL	*dlaglnK*	*laglnIUI*	*laglnFBS*	*laglnPOG*	*dlaglnTO*	*laglnMCS*
dlaglnL	1.0000						
dlaglnK	0.0675	1.0000					
laglnIUI	−0.1183	−0.0756	1.0000				
laglnFBS	−0.0733	−0.0764	0.7909	1.0000			
laglnPOG	−0.0084	0.0638	−0.3040	−0.3763	1.0000		
dlaglnTO	0.0456	0.1242	−0.1315	−0.1292	0.0775	1.0000	
laglnMCS	−0.0700	−0.0044	0.8039	0.7248	−0.1257	−0.1222	1.0000

TABLE 5 Variance Inflation Factors

Variable		VIF	1/VIF
laglnUIU		3.99	0.250673
LaglnMCS		3.31	0.301995
laglnFBS		3.13	0.319613
laglnPOG		1.27	0.786321
dlaglnTO		1.04	0.965137
dlaglnK		1.03	0.966328
dlaglnL		1.02	0.976961
Mean VIF	2.11		

is often not severe enough to require attention. Therefore, it can be concluded that the variables included in this study's model are not correlated.

Results and Discussion

Three panel regression models, the Pooled OLS (POLS), random effects (RE) and fixed effects (FE) were estimated to explore the relationship between digitalisation and economic growth in the SADC region.

The Breusch and Pagan Lagrangian Multiplier test (the chibar2) is extremely significant, showing that the RE model is better than POLS. Comparison of the consistent fixed-effects model with the random-effects model using the Hausman specification test, rejects the random effect estimator in favour of the fixed effect estimator at the 1% significance level. Therefore, the most appropriate model for this study is the FE panel regression model. With respect to model diagnostics, the variables in this model are normally distributed, as shown by the lack of significance in the Skewness/Kurtosis tests for Normality. The Pesaran's test confirms no cross-sectional dependence, while the Wooldridge test shows no autocorrelation. These diagnostic tests supports that our results are efficient, consistent and unbiased. The results of this model are the focus of this

TABLE 6 Panel Data Modelling Results

Variable	POLS		RE		FE	
	Coeff.	T statistic	Coeff.	z- statistic	Coeff.	t-statistic
dlaglnL	−1.91***(0.16)	−12.32	−1.60***(0.14)	−11.25	−1.22***(0.14)	−8.55
dlaglnK	0.11(0.09)	1.24	0.06 (0.05)	1.13	0.04(0.05)	0.73
laglnIUI	−0.01(0.69)	−0.21)	0.03 (0.03)	0.97	0.17***(0.05)	3.52
laglnFBS	0.29***(0.03)	9.12	0.10***(0.02)	4.89	0.11***(0.02)	5.68
laglnPOG	−0.003 (0.05)	−0.07	−0.08***(0.24)	−3.23	−0.10***(0.02)	−4.35
dlaglnTO	0.37***(0.11)	3.24	0.27***(0.08)	3.33	0.28***(0.08)	3.64
laglnMCS	−0.23***(0.09)	−2.55	−0.06*(0.04)	−1.48	0.12**(0.05)	2.36
Const	12.84***(0.84)	17.62	13.03***(0.76)	17.08	10.23***(0.82)	12.42
F-stat	69.44***		286.85***		13.89***	
R-squared	0.71		0.65		0.78	
Breusch and Pagan Lagrangian multiplier test (chibar2)	617.76 (0.00)***					
Hausman Test (chi2)	37.81 (0.00)***					
Skewness/Kurtosis tests for Normality	3.35 (0.18)					
Pesaran's test of cross sectional independence	3.61 (0.48)					
Average absolute value of the off-diagonal elements	0.51(0.68)					
Wooldridge test for autocorrelation in panel data	82.78 (0.34)					
Modified Wald test for groupwise heteroskedasticity	40.19 (0.12)					

NOTE (***) indicates significance at 1%, (**) indicates significance at 5%, (*) indicates significance at 10%. Number inside brackets represents Std. Error. Breusch and Pagan Lagrangian multiplier test for random effects - choosing between POLS and RE model. Hausman test for fixed/random effect model. Cross-sectional time-series FGLS regression to check for heteroskedacity and correlation.

study's analysis of the relationship between digitalisation and economic growth in SADC.

The model estimation results show that all the digitalisation variables in the model *laglnIUI, laglnFBS* and *laglnMCS* have the expected positive signs and are highly statistically significant at either the 1% or 5% significance level. Therefore, it can be said that the three digitalisation variables Individual Internet Usage (*laglnIUI*), Fixed Broadband Subscriptions (*laglnFBS)* and Mobile Cellular Subscriptions (*laglnMCS*) have a strong positive impact on economic growth in SADC countries. All the control variables included in the model besides *DlaglnTO*, namely *DlaglnL* and *laglnPOG*, have a statistically significant impact on economic growth in SADC countries at the 1% significance level. Of these three significant variables, only *DlaglnTO* bears the expected positive sign.

In line with international trade theory, increasing trade liberalisation in the SADC region, which was the mean calculated to be 78.6%, seems to be paying off as reflected by the positive significant impact of the trade openness (*DlaglnTO*) variable on growth in the region. Counterintuitively, the labour variable (*DlaglnL*) has a highly significant negative effect on growth in the SADC region, which can be attributed to a poorly skilled labour force coupled with low labour productivity within the region (World Bank 2022c). The capital variable (*DlaglnK*) also has a negative but insignificant impact on growth in the region. This could be owing to the low intensity of technology in the capital investments carried out in the region (Apulu and Ige 2011). Population growth has a negative influence on growth in the SADC area, contradicting findings from studies such as Peter and Bakari (2019), who investigated the impact of population expansion on African nations' economic growth from 1980 to 2015 using a panel data technique, and found the relationship to be positive. However, results from this study corroborate results from studies done in Uganda (Klasen and Lawson 2007) and Nigeria (Ukpolo 2002). The negative impact of population increase on economic growth is owing to the fact that children and young people aged 15 to 29 make up the majority of the population in Sub-Saharan Africa, which houses the SADC region (Bello-Schünemann 2017). A young population imposes a variety of economic burdens and risks, including large public expenditures on public health, education, and basic services; high unemployment and poverty rates; and a high risk of social instability (Bello-Schünemann 2017).

The coefficient value of the usage variable (*laglnIUI*) is 0.17, which means that a one percent increase in the number of individuals using the Internet generates an increase in GDP per capita of 0.17% in the SADC region. This result, showing a positive effect of individual internet usage on growth, corroborates results from studies by scholars such as Solomon and van Klyton (2020), Bahrini and Qaffas (2019) and Albiman and Sulong (2017), who also evaluated the impact of internet usage on growth in the African countries. Access to ICT technology as measured by the *laglnFBS* and *laglnMCS* variables have coefficients of 0.11 and 0.12, respectively. This means that a one percent increase in fixed broadband subscriptions and in mobile cellular subscriptions leads to a 0.11% and 0.12% increase in GDP per capita in the SADC region, respectively. Onyeji and Karner (2008) and Sridhar and Sridhar (2007) found similar results in their study on developing countries and Central East European countries, respectively. However, Donou-Adonsou (2019) could not find strong evidence on how mobile phone subscriptions promote growth in 45 Sub Saharan African countries.

The above results demonstrate that access to and usage of ICTs have generated a wide array of opportunities 'for economic growth, improved health, better service delivery, learning through distance education, and social and cultural advances' (World Bank 2022b) in the SADC region. Using technological devices such as smartphones and tablets, individuals can access the Internet and process a lot of information for use in learning, communication, business, and health. Access to and usage of digital technology may promote economic development by impacting both the supply and demand sides of an economy. For example, digital connection may have a direct impact on the productivity of enterprises, workers, and other inputs in the manufacturing process (Hjort and Poulsen 2019). On the demand side, an internet connection may affect the ability of sellers and buyers to access marketplaces, as well as the availability and quality of information on the items and services being sold (Donou-Adonsou 2019).

Although the access variables were significant in this study, developing countries like those in the SADC region are confronted with challenges which inhibit them from full utilisation of the Fourth Industrial Revolution (4IR) technologies, as shown by statistics released by International Telecommunication Union (n.d.). African countries are still battling low access rates to digital technologies like the Internet due to the high costs, which makes technology unaffordable for greater sections of the population, especially the poverty-stricken living in the rural areas

(International Telecommunication Union n.d.). Furthermore, data from the World Bank also showed that least developed countries like the ones in the SADC region only had 20% of their populations accessing the Internet, while in Europe and other developed regions the rate was about 85%.

Although the COVID-19 pandemic was largely disruptive, the UN's Sustainable Development Goals Report of 2022 spotlighted the importance of industrialisation, technological innovation, and resilient infrastructure in helping nations to achieve the 2030 Agenda (United Nations 2022). The report demonstrated that countries with a diversified industrial sector and strong infrastructure such as transport, internet connectivity and utility services experienced less economic misfortune during the pandemic and are recovering faster than those countries which are less diversified and less digitalised. Considering that usage of the Internet has a positive effect on growth in SADC, there is a need to leverage on technological advancements of the 21st century and further increase the impact of usage on economic growth and development. The access aspect can be improved through intensive investments in infrastructure, with respect to power and telecommunication technologies, especially in the rural areas of SADC countries. Due to their mobility, ease of use, adaptable deployment, and comparatively low and decreasing rollout costs, wireless technologies can be exploited to reach the rural populace (World Bank 2022b), and the resulting increase in access and usage of digital technologies (thus a reduction in online inequalities) will further accelerate economic development in SADC.

Conclusions and Implications

The SADC region, like the rest of Africa, has witnessed a revolution in ICT technology as seen by growing numbers of people who are able to access and use the Internet and the growth in the number of both fixed broadband and mobile subscriptions. The outbreak of the COVID-19 pandemic has intensified the use of internet and other technologies. However, there is a glaring lack of empirical research investigating the effect of digitalisation on the economic growth of SADC countries. This research paper fills that gap by using available data from 14 SADC countries from 2000 to 2020 to examine the impact of digitalisation on economic growth. Results from the Fixed Effects Model showed that the usage and access aspects of technology both have a significant positive impact on growth. Specifically, the variables individuals using the Internet (*lagInIUI*), fixed broadband subscriptions (*lagInFBS*), and mobile cellular subscriptions (*lagInMCS*) have a positive effect on the economic growth of the SADC region.

Given the significant positive impact of digitalisation in the SADC region revealed in this study, the growth effects of digitalisation can be maximised by ensuring that the labour force is adequately skilled through education and a regulatory environment that facilitates digital innovations. The relevant skills are necessary to meet the changing technical needs. Governments in SADC need to embark on programmes that are aimed at increasing access to and usage of the Internet by their people. There is a greater need for advancement in the use of digital technologies and improvement in the technical abilities of SADC countries through implementation of prudent science, technology, and innovation policies to promote the realisation of SDG 9 and SDG 17 in the SADC region. Favourable innovation policies are paramount to attract private sector investments, considering that government expenditure alone is insufficient to provide the necessary 4IR-friendly infrastructure which stimulates growth. Policies that liberalise the telecommunications and innovation market, attract private sector investments and encourage competition will reduce costs for investors while improving the quality, access, and usage of digital technologies in the SADC economies.

This way, the SADC region stands to reap the benefits of digitalisation because rapid developments of the Internet, ICTs and mobile technologies have become the new engines of economic growth and development. The technological advancements are accelerating globalisation and promoting efficiency, transparency, and effectiveness in both the private and public sector, and the SADC region should not lag.

Future studies on the digitalisation-economic growth nexus in SADC should explore the transmission mechanism of digitalisation on economic growth, exploring the role of variables such as ICT policies, infrastructural development, and investments in research and development (R&D). Such research will further provide useful information that can be incorporated in policy making regarding digitalisation and will increase the ability of SADC to exploit the benefits of digitalisation.

Notes

1 The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which

are an urgent call for action by all countries–developed and developing–in a global partnership. They recognise that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.

2 The time period selected and members of SADC included in this investigation depends on data availability. Having mentioned this, the final sample used resulted in the number of countries (N) being less than time period (T). Therefore, in such models, the pooled ordinary least squares (POLS), Random Effect (RE) and Fixed Effects (FE) estimators would be more appropriate than any other estimators.

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