EFFECTS OF DIGITALIZATION ON ECONOMIC GROWTH IN SADC: A COMPARATIVE ANALYSIS OF UPPER- AND LOWER-INCOME COUNTRIES

MASTER OF ARTS (ECONOMICS) THESIS

KUMBUKANI FELIX MAULIDI

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EFFECTS OF DIGITALIZATION ON ECONOMIC GROWTH IN SADC: A COMPARATIVE ANALYSIS OF UPPER- AND LOWER-INCOME COUNTRIES

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By

KUMBUKANI FELIX MAULIDI
B.Soc.Sc. (Economics)- CUNIMA

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DECLARATION

I, the undersigned, hereby declare that this dissertation is my own original work, and it has never been submitted for similar purposes to this or any other university or institution of higher learning. Where other people's work has been used, acknowledgments have been made. All errors contained herein are the author's sole responsibility.

KUMBUKANI FELIX MAULIDI

_____

Full Legal Name

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Date

CERTIFICATE OF APPROVAL

The undersigned certifies that this thesis represents the student's own work and effort. The thesis makes acknowledgments where other sources of information are used, and it is submitted with my approval.

Signature**:** _____ Date**:** _____

Spy Munthali, Ph.D. (Associate Professor)

Supervisor

DEDICATION

In loving memory of our aunt, Phalyce Salapa

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First, I would like to give all the praise, and honour to the Lord God Almighty for making all this possible for me. I would also like to thank my family for the unconditional love and support not only through this study but in my entire life in general. I can't thank you enough.

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ABSTRACT

The 21st century has witnessed a transformative surge in digitalization, the integration of digital technologies into all facets of society. This phenomenon has fundamentally reshaped traditional production processes and birthed entirely new business models. This study investigates the impact of digitalization, measured by information and communication technology (ICT) use, on economic growth in Southern African Development Community (SADC) countries. A central question is whether the benefits of ICT investments differ between upper income and lower income member states. Employing data from SADC countries for the period 1999-2022, the analysis utilizes the Bias-Corrected Method of Moments (BCMM) estimator to assess the magnitude and direction of the relationship between digitalization and economic growth. The findings reveal a positive overall impact of digitalization on economic growth within the SADC region. Mobile phone subscriptions and international bandwidth usage emerge as key drivers of this growth. However, the significance of international bandwidth is limited to upper income countries, with a relatively weak positive effect. Mobile phone subscriptions stand out as a significant factor in both income groups, exhibiting a comparatively stronger positive impact on economic growth in lower income countries. The study recommends that concerted efforts must be directed towards harnessing the inherent benefits of digitalization which include expanding mobile network coverage, increasing the affordability of mobile data plans, actively promoting the adoption of mobile money services and so forth.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

4G	Fourth Generation
AI	Artificial Intelligence
AIC	Akaike Information Criterion
CIPS	Cross-sectionally Augmented Im-Pesaran-Shin
CIS	Commonwealth of Independent States
CSD	Cross Sectional Dependence
CT	Communication Technology
DOLS	Dynamic Ordinary Least Squares
DRC	Democratic Republic of Congo
EU	European Union
FDI	Foreign Direct Investment
FE	Fixed Effects
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
GMM	Generalized Method of Moments
GSMA	Global System for Mobile Communication
ICT	Information Communication Technology
IT	Information Technology
ITU	International Telecommunication Union
IV	Instrumental Variables
Mbit/s	Megabytes per Second
NGT	New Growth Theory
OECD	Organisation for Economic Cooperation and Development
PC	Personal Computer
PSTN	Public Switched Telephone Network
R&D	Research and Development
RE	Random Effects
SACU	Southern Africa Customs Union
SADC	Southern Africa Development Community
SME	Small and Medium-sized Enterprises
SSA	Sub Saharan Africa

USD	United States Dollar
WB	World Bank

CHAPTER ONE

INTRODUCTION

1.1 Background

The 21st century has been characterized by a global phenomenon: the rise of digitalization. Defined as the application of digital technologies (computers, internet, software, communication networks) to various aspects of life (WB, 2021), digitalization has fundamentally transformed how we live, work, and interact with the world. It is enabled by information and communication Technology (ICT), and its influence extends to individual lives, institutional service delivery, and economic activity. From agricultural mechanization and transportation optimization to enhanced communication, education, and public sector administration, digitalization's positive societal impact is undeniable (Loubier, 2021).

The importance of digital technology has rarely been greater understood than during the 2020 global economic shutdown because 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 ((Brynjolfsson et al., 2020), ((Prasad, 2020:); (Willcocks, 2020)).The traditional, neoclassical view of digitalization 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) and it also reshapes ways of transacting via electronic commerce and online business, facilitating flexibility in banking operations, and improved communications(Bojnec & Fertő, 2012). On the other hand, 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).

1.1.1 Status of Digitalization

The digital revolution began with early computers in World War II, but their high cost and complexity limited their use to large institutions. The invention of personal

computers (PCs) in the mid-1970s, with improved performance and lower prices, sparked wider adoption in businesses and homes during the 1980s. The 1990s witnessed the internet and telecommunication boom, enabling rapid and affordable data transfer, ushering in the initial wave of digitalization (Arsić, 2020). As of 2023 approximately sixty-seven per cent of the world's population, or 5.4 billion people, were online representing a growth of 4.7 percent since 2022, and an increase from the 3.5 percent that was recorded from 2021 to 2022. Concurrently the number of people offline in 2023 decreased to an estimated 2.6 billion people, representing 33 percent of the global population (ITU, 2023). In Europe, the Commonwealth of Independent States (CIS) and the Americas, between 87 and 91 percent of the population used the Internet, which approached universal use (defined for practical purposes as an Internet penetration rate of at least 95 per cent). Approximately two-thirds of the population in the Arab states and Asia-Pacific regions (69 and 66 per cent, respectively) used the Internet, in line with the global average, while the average for Africa was just 37 per cent of the population (ITU, 2023). The stark divide in fixed broadband penetration between richer and poorer countries has widened as the COVID-19 pandemic boosted penetration in high-income and middle-income countries but less so in low-income countries. Fixed broadband subscriptions per 100 persons were above 30 in high-income and upper-middle-income countries, but only 4.4 in lower-middle-income countries and 0.5 in low-income countries in 2022(World Bank, 2023).

The economic liberalization policies implemented across Africa in the 1980s, encouraged by international financial institutions (Babb & Kentikelenis, 2018);(van Klyton et al., 2020), coincided with the initial stages of ICT investment and internet infrastructure development. This convergence of policy and technological advancements facilitated the widespread diffusion of ICT products and services across the continent(Chavula, 2013). 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 to 2008 to 367 million subscribers by 2015. This was accompanied by an increase in broadband internet penetration rates from zero to 19 million between 2000 and 2010 (Ojong, 2016).

In southern Africa, formation of the economic bloc Southern Africa Development Community (SADC) in 1992 led to the promotion of the Information and Communications Technology Declaration Act in 2001 intended to promote regional ICT policy and strategy. The treaty aimed to promote sustainable economic development, technology, and the closing of the digital divide between the area and the rest of the world (Olamide et al., 2022). These efforts have yielded tangible results. Since 2012, SADC countries have adopted 29 different initiatives related to ICT regulation and the region has experienced a significant growth in digitalization. The increase in the percentage of the population with a mobile phone, rising from 24.3% in 2013 to 52.7% by 2018, making mobile services a vital tool for communication, financial inclusion, and access to information. This has been accompanied by an increase in broadband internet penetration rates from 32.8% of the population in 2015 to 80.4% by 2020 (“GSMA,” 2024).

However, Southern Africa’s journey towards unlocking the economic potential of digitalization presents itself as a tale of two speeds. Within the region, a distinct digital divide arises between the countries categorized as High Income (Seychelles), Upper-middle Income (South Africa, Namibia, Botswana and Mauritius) countries and the Lower-middle income (Angola, Comoros, Eswatini, Lesotho, Tanzania, Zambia and Zimbabwe), Low Income (Malawi, Mozambique, Madagascar and Democratic Republic of Congo (DRC)) countries. For the sake of simplification, the high and upper middle-income economies will be referred to as Upper Income economies and the lower middle and low simply as Lower income economies.

Upper-income economies within SADC boast a more advanced digital landscape, with Mauritius leading the regional transformation (Dutta & Lanvin, 2023). These countries have witnessed significant progress in fostering greater accessibility and reaping the benefits of digital integration. This progress is largely driven by substantial investments in communication infrastructure. Upper-income economies prioritize first-mile infrastructure, the backbone that connects them to the global internet through a network of submarine cables and terrestrial links. South Africa exemplifies this commitment, boasting six operational submarine connections with plans for further expansion (Browdie, 2020).

Investments extend beyond this initial connection. Middle-mile infrastructure, which expands access to intermediary and large population centres, has also seen significant development. The fibre-optic network covers an impressive 71% of the population in intermediary cities (between 10,000 and 500,000 inhabitants) across southern Africa, with upper-income economies leading the way. This represents the highest rate on the continent, highlighting the commitment to a robust digital infrastructure (OECD, 2021).

Additionally, the last-mile infrastructure connecting the internet to end-users has expanded in the past decade, largely due to the expansion of high-speed mobile internet: The fourth generation (4G) network covered 71% of the population in Southern African countries in 2019, up from only 5.1% in 2012 and above Africa's average of 60%. That said, the share of the population with internet access in Upper income countries is considerably higher than the share in Lower income countries. Similarly, the 4G mobile network has a higher coverage in Upper income countries than in lower income countries ("GSMA," 2024).

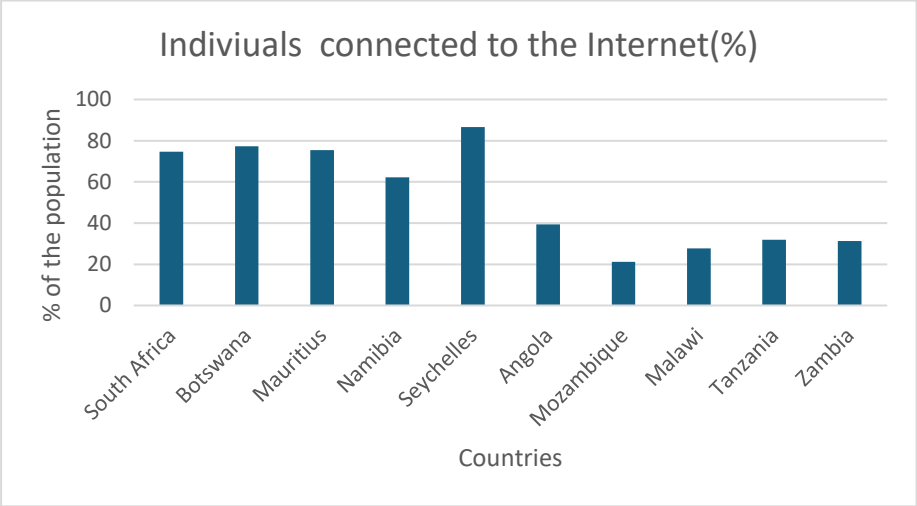

Figure 1: Internet access in selected Southern African countries, 2018

Source: Author's illustration using data from International Telecommunication Union (ITU)

In contrast, the Lower income economies lag behind, grappling with early stages of digitalization. Weak infrastructure and low educational attainments pose challenges to the digital transformation in these countries. A stark figure paints the picture: on average only 25% of their populations had internet access, far below the Upper Income countries' coverage which reached almost 50% of the population, and Africa's average

of 34% (OECD, 2021). Worse yet, in Angola, despite relatively good coverage, mobile penetration has been declining since 2014 due to the combined effects of an economic slowdown and the lack of competition in the telecom market.

1.1.2 The digital sector driving economic growth

The digital economy inform of IT services segment was the most vibrant and fastest-growing segment of the global economy over the past two decades. The compound annual growth rate of global value added and employment for IT services reached 8 percent and 6.7 percent, respectively, during 2000–22, far outstripping the 5.1 percent and 1.2 percent economic growth of the global economy. IT services were increasingly used as intermediate inputs in other sectors. From 2000 to 2020, IT services contributed to a much larger share of total intermediate inputs across all sectors. The input intensity of IT services almost doubled in high-income and upper-middle-income countries during 2000–20 but did not grow at all in lower-middle-income countries (World Bank, 2023).

Most countries experienced robust job creation in IT services. Global employment in IT services quadrupled from 8 million in 2000 to 32 million in 2022. China, Israel, Malaysia, Nigeria, the Philippines, Viet Nam, and several Central and Eastern Europe countries (Hungary, Poland, and Romania) had the fastest employment growth thanks to the burgeoning local IT services industry and roaring exports. On top of that women made up 29 percent of total employment in the male-dominated IT services industry in 2020, up from 23 percent in 2010. Albania, Bangladesh, Brunei Darussalam, Cyprus, the Arab Republic of Egypt, Iceland, the Islamic Republic of Iran, the Kyrgyz Republic, Tanzania, and Uganda achieved significant progress in bringing more women into the IT services workforce (World Bank, 2023).

Diversification of the global value chain and surging demand in IT and IT-enabled services have created new opportunities for countries to pursue export-led growth. The IT services segment was the most dynamic category of international trade for the past decade, creating an export-led growth pathway for countries to expand and diversify their economies. During 2010–22, IT services grew by 12 percent annually, surpassing all other service categories. By 2022, it was the third largest category of service exports, right after transport and travel.

The impact of digitalization has also been evident in Africa. The continent boasts several headline successes and dynamic ecosystems. The mobile money revolution is a well-known example: with 300 million accounts (the highest number in the world) mobile money has begun transforming Africa's job markets, expanding financial services to the underserved and unlocking innovative business models for local small and medium-sized enterprises (SMEs)(OECD, 2021). Africa's telecom industry, which forms the core of the digital transformation, has shown a robust growth in subscribers, revenues, and capital expenditures. To date, more than 500 African companies provide technology-enabled innovation in financial services (fintech). Johannesburg and Cape Town in South Africa, Nairobi in Kenya and Lagos in Nigeria rank among the top 100 cities for fintech ecosystems worldwide. Entrepreneurial and digitally savvy Africans are turning digital technologies and Africa's specific needs to their advantage to deploy fast-growing business models. Some African start-ups' valuations now exceed USD 1 billion. Over 640 tech hubs and incubators are active across the continent, up from 314 in 2016(OECD, 2021).

This has also been the case in Southern Africa. The region's digital trade activities are on the rise. Its annual e-commerce sales rose from USD 93.7 during the 2005-09 period to USD 155.3 million during the 2014-18 period, equivalent to an average of 3-5% of merchandise export values. Similarly, between 2005 and 2018, the value of the region's digitally enabled services exports (e.g. insurance pensions, financial services) grew from USD 2.5 billion to USD 4.6 billion (OECD, 2021) of which was dominated by countries in the Southern African Customs Union (SACU). South Africa provides the core of a dynamic digital economy in the region. The country is home to 700-1200 active start-ups in multiple sectors. Start-ups in South Africa not only dominate in number, but they are also often more advanced in terms of size and funding compared to their peers in the rest of southern Africa (OECD,2021).

1.2 Problem Statement

Despite advancements in digitalization and investment efforts, African countries have faltered in gaining the expected economic prosperity associated with digitalization because of persistent digital divide, including digital skills shortages, deficits in ICT infrastructure, and high-cost structures (Melia, 2020);(Yoon, 2020). This has also been

the case with the Southern African Development Community (SADC) that faces an overall unsettling economic reality. Since the global financial crisis of 2007-2009, the region's GDP growth rate has been steadily declining. From a promising 6.8% in 2007, growth plummeted to a mere 1.2% by 2018. The COVID-19 pandemic further exacerbated this negative trend, leading to a contraction of -4.8% in 2020. Sustained recovery remains uncertain.

A striking pattern emerges when examining the economic landscape and digital development within the SADC region. Upper-income SADC economies consistently exhibit higher average economic growth. Intriguingly, these same economies also demonstrate significantly higher levels of digital advancement, with progress accelerating over time. This observation stands in stark contrast to the situation in lower-income SADC countries. These nations face the double burden of stagnating or slow economic growth coupled with limited progress in digitalization**.**

This divide perpetuates income disparities. limits innovation, and stifles economic diversification in lower-income SADC countries. A better understanding of the relationship between digitalization and economic growth is needed to formulate policies that can address these gaps.

This compelling correlation begs a crucial question: Does digitalization hold an unexplored key to unlocking economic growth, particularly for lower-income economies in the SADC region? Could strategic investments in digital infrastructure, skills development, and e-government solutions act as a catalyst for economic prosperity in these countries?

The observed pattern in SADC suggests a potential causal connection between digitalization and economic growth. Further research is necessary to explore this possibility. By delving deeper into the experiences of upper-income economies and identifying the specific digitalization gaps in lower-income countries, valuable insights could be gained. This research could shed light on whether a targeted focus on digitalization can be a powerful tool for promoting economic convergence and narrowing the growth divide within the SADC region.

1.3 Significance of the Study

The study intends to add on the existing Digitalization literature however predominance 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 and therefore a quantitative analysis fills in such a gap. 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 Southern African countries, particularly regarding the impact of digitalisation on economic growth (Myovella et al., 2020).

1.4. Objectives

The main objective of the study is to assess the effects of digitalisation on economic growth in the Upper-Income and Lower income economies in Southern Africa/ SADC.

1.4.1 Specific Objectives

a) The following are specific objectives of the study.
b) To examine the effects of level of technological advancement on GDP growth
c) To examine the effects of ICT usage on GDP growth
d) To examine the effects of ICT access on GDP growth

1.5. Study Hypothesis

The following are the study hypotheses.

a) There is no statistically significant relationship between the level of technological advancement and GDP growth.
b) There is no statistically significant relationship between ICT usage and GDP growth.
c) There is no statistically significant relationship between ICT access and GDP growth

1.6. Chapter Summary

This chapter lays the groundwork for the study by exploring the concept of digitalization within a global and regional context. It provides a broad overview of the digital economy's current state, both worldwide and across the SADC region. This

analysis reveals a critical issue: a significant digital divide exists within SADC, characterized by disparities in digital access and infrastructure between upper-income and lower-income countries. This observation forms the foundation of the study's central research question: Does digitalization have a positive impact on economic growth within the SADC region?

1.7. Organization of the Study

The rest of the paper is organized as follows: Chapter 2 gives a summary of the theoretical and empirical literature on the subject. Chapter 3 explains the methodology that will be used, Chapter 4 will give the empirical results and finally Chapter 5 provides the conclusion and policy recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This chapter reviews the existing literature on the relationship between digitalization and economic growth, focusing on two key themes: (1) the theoretical mechanisms through which digitalization can impact economic growth, and (2) empirical evidence of the relationship between different dimensions of digitalization (e.g., ICT access, usage, and technological advancement) and economic growth.

2.2. Theoretical Literature

This section explores the theories that have been the foundation of most studies on digitalisation and economic growth.

2.2.1 Solow-Swan Neoclassical Growth model

The Solow growth model (Solow, 1955), also known as the Solow-Swan neoclassical growth model, has been a cornerstone for understanding the determinants of long-run economic growth. It emphasizes the role of capital accumulation, labour force growth, and technological progress. In the context of digitalization, the model can be adapted to reflect how digital technologies impact these factors and, consequently, economic growth. The equation is given as

$$Y_t = K_t^{\alpha}(A_t L_t)^{(1-\alpha)} \qquad (1)$$

Where output is produced using two factors of production, labour (L) and capital (K). *t* denotes time, $0< \alpha <1$ is the elasticity of output with respect to capital, and Y_t represents total production. A refers to labour-augmenting technology or knowledge, thus *AL* represents effective labour.

Capital Accumulation: Digitalization affects capital accumulation by changing the nature of capital itself. Traditional physical capital is complemented by digital capital,

such as software and digital platforms, which can enhance productivity. Investments in digital infrastructure can lead to higher output levels, as seen in the research by Sun and Guo, which explores the impact of enterprise digital transformation on green innovation (Sun & Guo, 2022).

Labor Force Growth: Digital technologies can influence labour force growth by altering the demand for different skill sets. Automation and artificial intelligence can replace routine tasks, shifting the demand towards more complex and creative jobs. This transition requires a workforce that is adaptable and skilled in digital competencies.

Technological Progress: Digitalization is a key driver of technological progress. The diffusion of digital technologies can lead to new business models, processes, and products, fostering innovation. However, the Solow productivity paradox, which posits that increased investment in information technology does not necessarily lead to productivity growth, remains a concern. The paradox suggests that the benefits of digitalization may not be immediately apparent in productivity statistics, as noted in the study on digital transformation and green innovation(Sun & Guo, 2022).

Economic Growth: The literature suggests that digitalization has a positive impact on economic growth, but the extent and nature of this impact can vary. For instance, an econometric model with balanced panel data over a 22-year period found that digitalization generates a positive and significant impact on economic growth (Mura & Donath, 2023). However, the net effect on employment and productivity growth is still debated, with some researchers suggesting that explosive growth in productivity is unlikely, and the net effect on employment may be negative (Arsić, 2020).
However, the Solow model assumes diminishing returns to capital accumulation. This means that eventually, the positive impact of additional capital investment starts to decline. Additionally, the model treats technological progress as exogenous (external to the model).

2.2.2 The New Growth Theory (NGT)

This theory offers an alternative to the Solow model, it emphasizes the role of endogenous technological progress driven by research and development (R&D) and

knowledge spillovers. Digitalization can facilitate knowledge creation and diffusion, potentially accelerating growth (Romer, 1994). The theories key mechanisms and how they relate to digitalisation:

Research & Development Investments: Firms and governments invest in research and development activities to create new knowledge and innovations. Digital technologies like artificial intelligence (AI) and big data can accelerate R&D processes by facilitating data analysis, simulations, and automation of tasks.

Knowledge Spillovers: New knowledge can spill over to other firms and sectors, leading to broader productivity gains and economic growth. Digital tools like online platforms and communication networks can speed up the sharing and dissemination of knowledge between researchers, firms, and across sectors.

Human Capital Development: A more skilled workforce can better utilize and contribute to technological advancements. Digital technologies can revolutionize education and training, providing more efficient and personalized learning experiences. This can lead to a more skilled and adaptable workforce capable of innovation in the digital age.

The New Growth Theory breaks the diminishing returns barrier**,** unlike the Solow model, NGT allows for sustained growth through continuous innovation fuelled by R&D investments. Digitalization can further enhance this by accelerating the innovation cycle. It also allows for creation of increasing returns to scale, as more digital technologies are developed, they can complement each other, leading to even greater productivity gains and economic growth. (This concept is sometimes referred to as "synergy" or "network effects".)

In summary, digitalization has the potential to significantly affect economic growth through its impact on capital accumulation, labour force growth, and technological progress. The Solow growth model provides a theoretical basis to analyse these effects, although the real-world implications are complex and multifaceted. Further empirical research is needed to fully understand the relationship between digitalization and economic growth.

2.3. Empirical Literature

Studies on the interaction between digitalization and economic growth remain of little quantity. However, of the studies conducted varying results are found on the relationship. Some studies have found a positive or negative relationship whilst others have found no relationship.

Chowdhury (2006) in his paper Investments in ICT-capital and economic performance of small and medium scale enterprises in East Africa focused on whether investments in ICTs could cause any increases in a firm's performance. The study 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.

Several micro-level studies have shed light on the impact of Communication Technologies (CT) and Information and Communication Technologies (ICT) on productivity in developing and emerging countries. A key example is the work of Aker & Mbiti, (2010) who examined the (potential) economic consequences of the rapid rise in mobile phone usage across Sub-Saharan Africa over the past decade.

Beyond this broader focus on CT/ICT, other research has delved deeper into the specific impact of mobile phones on small and micro-enterprises in developing contexts. Jensen (2007), using data from India, highlights how mobile phones can improve welfare for both consumers and producers. Similarly, Muto and Yamano (2009) find that improved mobile phone coverage in remote areas of Uganda increased market participation for farmers dealing with perishable goods. However, the impact of mobile phone access isn't always clear-cut. Tadesse and Bahiigwa (2015) found minimal significant effects on the marketing decisions of Ethiopian farmers. These mixed findings from the micro-level studies on mobile phone subscriptions further emphasize the need to include this

variable in our own research to gain a more comprehensive understanding of its potential role in driving economic growth.

Farhadi et al., (2012) in their study on Information and communication Technology use and economic growth. Examined the impact of ICT use on economic growth using the Generalized Method of Moments (GMM) estimator within the framework of a dynamic panel data approach and applied it to 159 countries over the period 2000 to 2009. The results indicated that there was a positive relationship between growth rate of real GDP per capita and ICT use index (as measured by the number of internet users, fixed broadband internet subscribers and the number of mobile subscriptions per 100 inhabitants). They also found that the effect of ICT use on economic growth was higher in high income group rather than other groups. This implied that if countries seek to enhance their economic growth, they needed to implement specific policies that facilitate ICT use.

Ishida (2015) cautioned against overestimating the relationship between ICT and economic growth in his study "The effect of ICT development on economic growth and energy consumption in Japan". 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. From these findings the study intends to control for labour and capital and use a long run model to analyse if digitalization independently influences economic growth in SADC.

In addition Albiman & Sulong (2016) examined the long run impact of information and communication technology (ICT) on economic growth in the Sub Saharan African (SSA) region using the System generalized method of moments (GMM) from panel data collected for the years 1990-2014 from 45 countries. The findings were as follows; for the direct impact analysis, mobile phone and internet were found to have triggered economic growth. However, for nonlinear effect analysis, mass penetration of ICT

proxies seemed to slow economic growth. The threshold analysis showed a penetration rate threshold of 4.5 percent for both mobile phone and internet, and 5 percent for fixed telephone lines before economic growth gets triggered. The findings on mobile phone subscriptions encourage the use of the variable in this study.

Another strand of research explores the varying responses of economic growth to digitalization. Niebel (2018) examines the impact of ICT on economic growth across a diverse sample of 59 developing, emerging, and developed countries from 1995 to 2010. This study employs various regression models, including Fixed Effects and Instrumental Variables estimators, to analyse the data. The findings suggest that the full potential of digitalization may not be fully realized due to insufficient adoption of Artificial Intelligence (AI) and other IT innovations, particularly in developing and emerging economies. Additionally, these economies might experience lower returns on investments in ICT compared to more developed countries. These observations regarding the moderating effect of ICT investment highlight the importance of including this variable in our own study. By investigating ICT investment levels within the SADC region, we can gain a deeper understanding of its influence on economic growth.

In addition, Solomon & Van Klyton (2020) analyses the impact of the use of digital technology on economic growth for 39 African countries from 2012 to 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. The results indicated that individual usage of ICT was positively associated with growth and that in its disaggregated form, social media usage, and the importance of ICTs to government vision emerged as significant for economic growth. This encouraged the use of the internet usage variable in the study.

In contrast, Remeikiene et al (2021) in a study on the role of ICT development in boosting economic growth in transition economies aimed to address the role of ICT development in enhancing the economic growth of 11 EU transition economies over the period 2000 to 2019. The study used the linear regression analysis. These transitional economies are former command economies characterised by relatively low standards of living, poor infrastructure and continuous changes in economy structure

and regulatory framework. The obtained results suggest that ICT development has a positive impact on economic growth in the countries under consideration. However, only the link between the number of internet users and economic growth was statistically significant. The study relates to the current study as countries with similar characteristics are analysed and this specific finding regarding internet use is particularly relevant to our own focus on this variable as a potential driver of economic growth in SADC countries.

On top of that, a study by Kim et al (2021) on the influence of mobile Information and Communication Technology (ICT) on national productivity in developing and developed countries investigated how the quality of wired ICT and mobile ICT using internet speed differently influences national productivity between the countries. A sample of 32 countries, 18 developed and 14 developing from the period 2011 to 2016 was used. The study found that mobile ICT played an important role in increasing national productivity in developing countries; however, found no significant impact of wired ICT for either developed or developing countries and cautioned on the combination of the two measures. In line with these findings this study employed two separate variables to measure usage, fixed broadband subscriptions for wired ICT and mobile phone subscriptions.

2.4. Chapter Summary

The chapter laid the theoretical and empirical groundwork for the study. It began by reviewing relevant economic growth theories, including the Solow-Swan model and new growth theories. These theories provided a framework for understanding the potential influence of technological advancement on economic growth. The chapter then turned to the existing empirical literature on this relationship. While a significant portion of this research was qualitative in nature, the quantitative studies identified did not specifically address the SADC region. However, this review offered valuable insights that informed the selection of both the digitalization variables and the control variables utilized in our own research.

CHAPTER THREE

METHODOLOGY

3.1. Introduction

This chapter outlines the methodology used to carry out the analysis. Section 3.2 presents the conceptual framework. Section 3.3 explains the empirical model while Section 3.4 describes all variables considered in the model, their sources and measurement. Section 3.5 presents the diagnostic tests for model robustness. The chapter ends with Section 3.6 as a chapter summary.

3.2. Conceptual Framework

This framework explores how different aspects of digitalization contribute to economic growth in an economy. It focuses on the role of mobile subscriptions, internet access, fixed broadband subscriptions, and international bandwidth usage, highlighting their potential impact on financial inclusion, international trade, and foreign direct investment (FDI) and ultimately economic growth.

Mobile Subscriptions: Increased mobile phone penetration allows for increased access to information and financial inclusion; mobile money platforms can provide access to financial services for unbanked populations giving them the chance to expand their trading capacities. This aligns with research showing the positive impact of mobile money on financial inclusion, particularly in developing economies (Beck et al., 2009). Mobile phones also facilitate access to information, which can empower individuals and small businesses (Aker & Mbiti, 2010).

Internet usage and access facilitates Fintech businesses which are innovative financial technology companies offering new financial products and services. On top of that, local businesses through the internet can reach wider audience through online marketing and e-commerce platforms potentially influencing international trade. This is supported by research showing the positive relationship between internet penetration

and trade such as Freund & Weinhold, (2004) and the growth of Fintech in driving financial innovation (Gomber et al., 2017).

Fixed Broadband subscription and international bandwidth usage: High levels of these indicators indicate widespread internet use by organisations and institutions like banks, governments etc. Consequently, this attracts FDI through seeking favourable environments, skilled labour forces and improved market access. Studies like Latif et al (2018) have shown that better ICT infrastructure, including broadband and international bandwidth, is a significant determinant of FDI inflows.

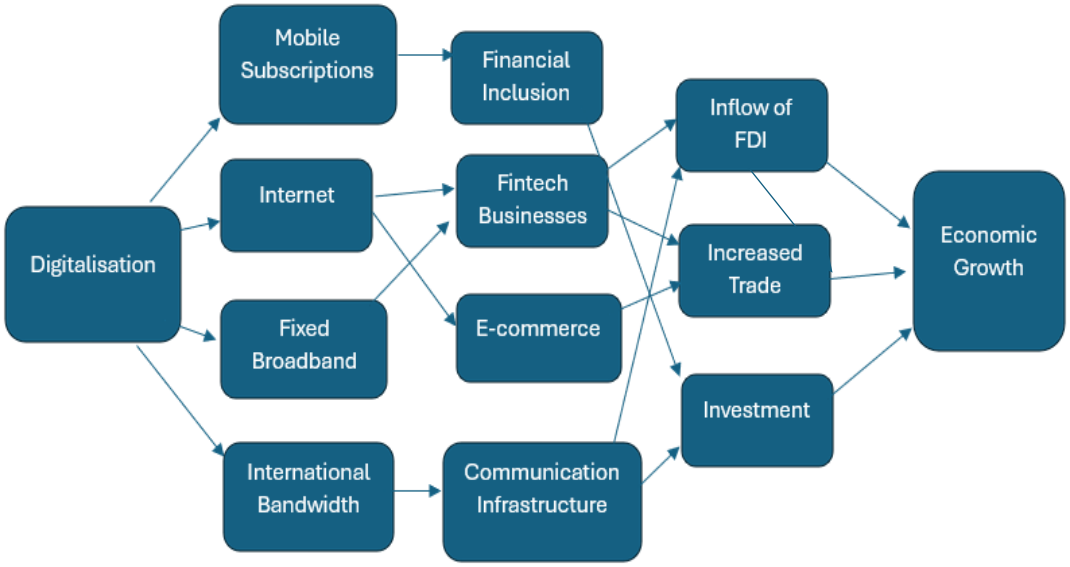

Figure 2: Conceptual framework for the model

3.3 Empirical Model

To achieve the research aim, the study employed a dynamic panel data model. Most economic relationships are dynamic in nature and one of the advantages of panel data is that they allow researchers to better understand the dynamics of adjustment (Baltagi, 2008). These Dynamic relationships are characterized by the presence of a lagged dependent variable among the regressors. In the case of the study, digitalization is a process that unfolds over time and its influence on economic growth likely wouldn't be instantaneous. A dynamic model allows to track how past levels of digitalization (lagged variables) would affect current economic growth and how past levels of economic growth would influence the pace of digitalization.

To model the impact of digitalisation on economic growth, the study employed a Cobb-Douglas production function and a model specification by Albiman & Sulong (2016) was adapted. It was then modified to suit the needs of this paper. The main model of interest in this study was specified as below:

$$lnY_{it} = \beta_0 + \beta_1 lnY_{it-1} + \beta_2 lnL_{it} + \beta_3 lnK_{it} + \beta_4 lnICT_{it} + \eta_i + \varepsilon_{it} \quad (2)$$

Where *i* implies observations which represent a country and *t* is the time index. *InY* is output, (GDP per capita), L is labour (i.e. total employment), K is physical capital stock, ICT is ICT capital, η_i is the individual country effects term, and ε_{it} is the error term. The parameters $\beta 1$, $\beta 2$, $\beta 3$ and $\beta 4$ denote output elasticities with respect to the corresponding factor inputs. For easy description of the variables, the entire variables were changed into logarithms. $lnY(-1)_{it}$ is the lagged output (GDP per capita) or past productivity 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.

Estimating dynamic panel data models presents unique challenges due to the presence of a lagged dependent variable, which introduces endogeneity by correlating with the error term. This endogeneity renders standard estimators like Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE) biased and inconsistent (Baltagi, 2008). Therefore, alternative estimation techniques are required.

Instrumental variables (IV) and Generalized Method of Moments (GMM) estimators have been widely used in dynamic panel data analysis since the work of Anderson and Hsiao (1981). However, the traditional difference GMM estimator proposed by Arellano and Bond (1991) and Holtz-Eakin et al. (1988) is known to suffer from the "weak instrument" problem, especially when the data exhibits strong persistence (Blundell & Bond, 1998). While Blundell and Bond (1998) introduced system GMM, which uses lagged levels as instruments for first differences and lagged first differences as instruments for levels, mitigating some of these issues, it can still be susceptible to weak instruments when the variance of the individual-specific effects is large relative

to the variance of the idiosyncratic errors (Breitung et al., 2022; Bun & Windmeijer, 2010).

Given these limitations of standard GMM approaches, alternative bias-corrected estimators were considered. Baltagi (2008) and Judson and Owen (1999) highlighted the bias-corrected within-group (FE) estimator proposed by Kiviet (1995), which performed well in simulations. However, Kiviet's (1995) estimator relies on a higher-order expansion of the bias term and requires consistent initial estimates of unknown parameters, which can introduce further complications.

Therefore, this study employs the Bias-Corrected Method of Moments Fixed Effects (BCMM-FE) estimator developed by Breitung et al. (2022). This estimator builds upon the strengths of Kiviet (1995) while addressing its limitations by providing a more robust bias correction. Furthermore, as discussed by Bun et al. (2017), BCMM-FE offers improvements over maximum likelihood estimators (Bai, 2013; Hsiao et al., 2002). Crucially, BCMM-FE is well-suited for this study because it accommodates individual-specific heteroskedasticity in a large-N, fixed-T framework and allows for cluster-robust/panel-corrected standard errors to account for potential cross-sectional dependence, which is a concern in regional panel data, where economic shocks can affect multiple countries simultaneously.

While BCMM-FE offers significant advantages, it is important to acknowledge a potential limitation. Like other panel data techniques, its performance can be affected by small T dimensions. Although our dataset spans 23 years, it is recognized that with smaller T, the precision of the estimates could be reduced.

For control of small sample sizes, the study also employed the Fully Modified Ordinary Least Squares (FMOLS) estimation technique. This estimation technique was chosen based on its ability to handle small sample fragilities and to provide much more precise estimates in small sample environments (Mark & Sul, 2003). In situations where the time periods are greater than the number of observations (T>N), economic relationships can be analysed through long run cointegration estimation models, and such include the Fully Modified Ordinary Least Squares (FMOLS) proposed by Phillips and Hansen (1990) and the Dynamic Ordinary Least Squares (DOLS) model proposed by Stock and

Watson (1994) (Tembo, 2018). It must be noted, however, that scholars are indifferent to the choice between FMOLS and DOLS. Esposito et al (2019) noted that both FMOLS and DOLS control for endogeneity and produce efficient results. Therefore, the FMOLS in this study is best suited to establish the existence of a statistically significant long-run relationship due to its focus on the overall model significance.

3.4. Description of Variables and Data

The study primarily used panel secondary for SADC countries for the period of 1999 to 2022. This period coincides with the evolution of ICT and the fourth economic revolution that was characterized by the digital explosion. Data was collected from the International Telecommunication Union (ITU) and World Bank Development Indicators. Data on digitalisation variables, particularly fixed broadband usage, may have gaps or inconsistencies across countries especially in earlier years. This could affect the robustness of the results for lower-income countries where infrastructure is less developed.

3.4.1 Dependent Variable

Economic growth proxied by the GDP per capita, which is largely used in the literature as a statistical tool to measure a country's overall level of economic performance and welfare. GDP per capita is computed as the ratio of the GDP to the average population quantified in purchasing power standards (PPS, EU-28—2020). It is measured at constant 2015 US$ by the World Banks measurement of economic growth.

3.4.2 Independent Variables

The variable of interest (i.e., digitalisation) is proxied by mobile subscriptions, internet users, fixed broadband subscriptions and international bandwidth usage, which serve as prerequisites for digitalisation and as potential levers for economic growth (Myovella et al., 2020). **Access** was proxied by two indicators, mobile cellular subscription and fixed broadband subscription, Technological Advancement was proxied by International Bandwidth Usage and Usage was proxied by total number of individuals using the internet. Data collected on these indicators was annual from 1999 to 2022. ICT regulatory environment was dropped due to lack of data.

Mobile-cellular telephone subscriptions refer to the number of subscriptions to a public mobile-telephone service that provides access to the PSTN (public switched telephone network) using cellular technology.

Internet users refer to the proportion of individuals who used the Internet from any location in the last three months. Access can be via a fixed or mobile network, following a survey addressed to national households. It is measured as a percentage of the total population of a country.

Fixed-broadband subscriptions refer to fixed subscriptions to high-speed access to the public internet; they include both residential as well as organisational subscriptions, calculated as fixed broadband subscribers/population.

International Bandwidth Usage refers to average usage of all international links including Fiber-optic cables, radio links and traffic processed by satellite ground stations and teleports to orbital satellites (expressed in Mbit/s).

To overcome omitted variable bias in the model, as well as to isolate the reaction of the interest variables and allow for differences in production technology across countries (Niebel, 2018): a set of control variables is considered for economic growth, as follows: Foreign direct investment (FDI) refers to the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP.

Trade openness is quantified as the percentage of imports and exports of goods and services in the GDP. Trade openness impacts growth by increasing income per capita by boosting productivity through competition. Openness supports technological transfer across borders and, hence, a more efficient organisation of the economy. Trade Openness is a significant factor given the high level of economic integration within the Southern Africa region, which justifies its inclusion as an additional variable for

consideration in economic analyses. Consequently, a positive sign for this variable is expected.

The model equation, therefore, becomes:

$$lnY_{it} = \beta_0 + \beta_1 lnY_{it-1} + \beta_2 lnL_{it} + \beta_3 lnK_{it} + \beta_4 lnMOB_{it} + \beta_5 lnINTERNET_{it} + \beta_6 lnFXDBB_{it} + \beta_7 lnINTRBB_{it} + a_7 lnFDIGDP_{it} + a_8 lnOP_{it} + \eta_i + \varepsilon_{it} \quad (3)$$

Table 1: Description of variables and their expected sign

Variables	Explanation	u. m.	Source	Expected sign
Economic growth	GDP per capita	PPS	World Bank database	+
Interest variables (Digitalisation)	Mobile subscriptions Internet Users Fixed broadband Subscriptions International bandwidth usage	%	International Telecommunications Union database	+
Labor	Labor force participation	%	World Bank database	+
Capital	Gross fixed capital formation	%	World Bank database	+
Controls:				
Foreign direct investment (FDI)	Foreign direct investment net inflows	% of GDP	World Bank database	+
Trade openness (TRADE)	The sum of exports and imports of goods and services measured.	% of GDP	International Monetary Fund	+

3.5 Diagnostic Tests

As with most estimation methods, panel analysis relies on specific diagnostic tests to ensure the validity of the results. This study utilized several key tests commonly employed in dynamic panel analysis. For any tests not conducted, justifications are provided to explain their exclusion.

3.5.1 Cross Sectional Dependence Test

In panel data analysis, where we observe data for multiple units (e.g., countries) over time, a crucial concern is cross-sectional dependence. This refers to the situation where the error terms of different units are correlated. Several factors can induce this, such as unobserved common shocks, shared environmental conditions, or centralized policies (Basak & Das, 2018). Ignoring cross-sectional dependence can have severe consequences, leading to inaccurate estimates and unreliable test statistics (Lau et al., 2019). Hence, it's essential to assess its presence before proceeding with the analysis. Fortunately, various tests can help us detect cross-sectional dependence. This study employs a combination of established tests, including the Breusch-Pagan LM (1980), Pesaran scaled LM (2004), Bias-corrected scaled LM (a variant), and the Pesaran CD test (2004). The reported results will provide insights into the potential presence of this dependence within the data.

3.5.2 Stationarity (Unit root) Test

Panel data analysis, like time series analysis, demands stationary variables. Stationarity implies constant mean, variance, and covariance over time (Gujarati & Porter, 2009). Non-stationary data can lead to unreliable analysis results. However, panel data introduces additional challenges - one being cross-sectional dependence (correlated error terms across units). To address this, scholars developed first and second-generation stationarity tests. Second-generation tests account for potential cross-sectional dependence, unlike first-generation tests that assume independence. Given this, this study employs the Peseran CIPS test (suitable for small samples and accommodating potential cross-dependence) (Barbieri, 2009).

3.5.3 Cointegration

Panel data's time series nature necessitates cointegration testing. Two variables are cointegrated if they exhibit a stable, long-term equilibrium relationship (Gujarati,

2009). Cointegration implies that a linear combination of these variables eliminates their individual stochastic trends, leading to co-movement in the long run (Banerjee & Carrion-i-Silvestre, 2006). This study employs cointegration analysis to assess the existence of a long-run relationship between the dependent and independent variables. Panel cointegration tests hold significance for policy formulation, enabling predictions of future economic performance (Kimaro et al., 2017). Given the potential for cross-sectional dependence, the Kao test was chosen for cointegration analysis. This residual-based test examines unit roots in the residuals to infer long-run relationships(Gengenbach et al., 2005).

3.5.4 Heterogeneity

Panel data analysis allows researchers to study how variables change across units (e.g., countries) and over time. However, the effect of interest might not be uniform across all units. This variation in the effect is known as heterogeneity. Heterogeneity tests help us determine whether the estimated relationship between variables holds true for all units or if it differs across them. Ignoring heterogeneity can lead to misleading conclusions. This study used the Pesaran and Yamagata test of heterogeneity. The test has much better size properties and is recommended for T>N cases (Breitung, 2015).

3.5.5 Endogeneity Test

While lagged terms can introduce endogeneity (correlated error terms and explanatory variables), other factors like omitted variables or reverse causality can also contribute. Endogeneity bias leads to unreliable estimates and potentially incorrect conclusions (Ullah et al., 2018). Fortunately, the Bias-corrected method of moments estimator and FMOLS method employed in this study inherently control for endogeneity. Therefore, no additional endogeneity tests were necessary.

3.5.6 Optimal Lag Length

In macro panel analysis, choosing the appropriate lag length for explanatory variables is critical before drawing inferences. Dormann and Griffin (2015) highlight that accurate lag selection can significantly improve our understanding of causal relationships. The wrong lag length can lead to missed effects or misleading conclusions. To address this, this study employed the Akaike Information Criterion (AIC) to determine the optimal lag length. AIC is a widely used statistical method for

selecting the best model fit based on a balance between model complexity and goodness-of-fit.

3.6. Chapter Summary

This chapter outlined the methodological framework used in the study. To investigate the potential long-run relationship between digitalization and economic growth in SADC countries, two econometric techniques were selected: the Bias-Corrected Method of Moments (BCMM) and the Fully Modified Ordinary Least Squares (FMOLS). The justifications for these choices, along with detailed descriptions of the variables used in the analysis, were presented based on the theoretical and empirical foundations established in the previous chapter. Finally, the chapter concluded by outlining the intended diagnostic tests that would be conducted to ensure the robustness and reliability of the estimated results.

CHAPTER FOUR

EMPIRICAL RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter explores the key findings from the analyses conducted in this study. We will explore the descriptive statistics of the data, revisit the models and tests discussed in the methodology chapter, and most importantly, unpack the economic and statistical implications of the results.

4.2. Descriptive Statistics

This section presents summary statistics of the variables considered in the study, for the full sample of 16 SADC countries from 1999 to 2022.

The average GDP per capita for the region was USD 3,148, however the between country variations had a greater magnitude than the within country variations revealing the income disparities between the region's economies. The minimum value of GDP per capita was $293.32 (Mozambique 2000) whilst the maximum value was $16,747.36 (Seychelles 2019).

The mean value of trade openness recorded 84.06% of GDP with a maximum 235.82%, representing the inter-connectedness of the region. For example, within SADC exists other trade regions like the Southern African Customs Union (SACU). Inward Foreign Direct Investments varied greatly across the SADC countries, with a minimum of -10% of GDP (Angola 2017) and a maximum of 56% (Seychelles 2012), the negative inward FDI could be associated with repatriation of investment due to unfavourable economic conditions, maturing investments or even data discrepancies.

Table 2: Summary Statistics

Variable	Mean	Std. dev.	Min	Max	Btwn Variations	Within Variations	Obs
Gdp per capita	3148.467	3581.288	293.2319	16747.36	3620.872	708.6872	384
Labor P.rate	67.60901	11.90114	41.954	89.45	12.09633	2.165686	384
Capital	21.76787	9.471003	2.000441	56.4668	7.683172	5.836787	384
Trade Openness	84.06559	41.95361	23.98087	235.8202	39.95302	16.81657	384
FDI	4.137061	6.452226	-10.0384	56.26384	3.956844	5.187949	384
Internet users	16.27882	20.1791	0.001009	86.6654	12.33184	16.30821	384
Fixed Broadband	1.718028	5.068057	0	38.7715	3.484707	3.768594	384
Mobile subs	9444323	1.78E+07	2000	1.00E+08	1.44E+07	1.11E+07	384
International BW	88980.16	396457.7	0.064	3500000	257084	301865.8	384

As of the variables of interest, digitalization proxies, the statistics reflected the glaring digital divide faced within the SADC economies. The average internet users as a percentage of the population were 16.27 whilst the maximum internet users were 86.67 with a between country variation of 12.33 signifying a high difference between countries. Fixed broadband subscription, mobile subscription and international bandwidth usage also unveiled a similar trend. One other notable statistic was that the between variations (1.44E+07) of mobile cellular subscriptions was higher than the within variations (1.11E+07) further depicting the disparities between the region's countries.

4.3. Pre estimation Test Results

In reference to the methodology chapter, several tests were conducted before and after estimation for robust results. However, neither endogeneity nor lag length determination tests were conducted basing on the idea that the estimation models chosen takes care of them.

4.3.1. Cross-sectional Dependence Test

To ensure the most appropriate stationarity test was employed, a cross-sectional dependence test had to first be conducted. This test assesses whether the error terms (unexplained factors) in the data are correlated across different groups (countries, regions, etc.) in the panel. The null hypothesis of the test is that there is no cross-sectional dependence. The test produces four different statistics, each offering insights into potential dependence in the data. Analysing these statistics helped determine the most suitable stationarity test for the panel data analysis. The results of the test are presented in Table 3.

Table 3: Cross-sectional Dependence Tests

Variables	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Gdp Growth	413.0065***	18.91349***	18.56566***	16.12355***
Trade Openness	554.6864***	28.05889***	27.71106***	6.081693***
Foreign Direct Investment	231.2301***	7.179871***	6.832045***	5.198897***
Labor	2200.688***	144.6162***	144.2901***	46.66214***
Capital	401.1833***	18.15031***	17.80248***	1.753742*
Internet connectedness	2508.799***	154.1963***	153.8485***	50.01780***
Mobile Subscription	2705.253***	166.8773***	166.5295***	51.98325***
Fixed Broadband Subs	1995.979***	121.0939***	120.7461***	44.26945***
International Bandwidth	1886.642***	114.0363***	113.6884***	41.63400***

Note: ***, **, * denotes rejection of null hypothesis of no cross-sectional dependence at 1%,5% and 10% level respectively

The test results all indicated statistically significant cross-sectional dependence (CSD) in the data (at varying levels of significance according to the specific tests). To address this, subsequent analyses considered the presence of CSD. However, because the model used was fixed effects it took care of group-specific effects.

4.3.2. Stationarity Test

Since the analysis revealed cross-sectional dependence in the data, a second-generation unit root test was a more appropriate option. This approach is better suited to handle situations where error terms (unexplained factors) are correlated across different groups. For this purpose, the Pesaran CIPS unit root test was employed. The test is split into the CIPS and truncated CIPS, the truncated CIPS is a modified version of the CIPS test that considers a truncated lag-length to potentially account for cross-sectional dependence (CSD) in the data.

The test was conducted against the null hypothesis of unit root (no stationarity) on both the levels and first differences of the pooled series of the variables. The results of this test are presented in the Table 4.

Table 4: Pesaran Truncated CIPS test

Variables	At Levels		First difference	
	Test statistic	P-value	Test statistic	p-value
GDP Growth	-3.60863	<0.01		
Trade Openness	-2.05134	>=0.10	-3.11872	<0.01
Foreign Direct Investment	-2.79796	<0.01		
Labor	-1.22776	>=0.10	-2.37952	<0.05
Capital	-2.45518	<0.05		
Internet connectedness	-2.01545	>=0.10	-3.20273	<0.01
Mobile Subscription	-2.54659	<0.01		
Fixed Broadband Subs	-1.52637	>=0.10	-3.27335	<0.01
International Bandwidth	-0.37851	>=0.10	-2.54724	<0.05

The results show some variables were found to be stationary at levels (at different levels of significance) whilst the others were stationery at first difference.

4.3.3. Heterogeneity Test

Heterogeneity, in the context of panel data analysis, refers to the presence of unobserved differences across the individual units (e.g., countries, firms, individuals) in the panel. The study employed the Pesaran and Yamagata test to investigate whether the sectors exhibit homogeneity (similar behaviour) or heterogeneity (distinct behaviour) across slope coefficients. This test assumes the null hypothesis that the slope coefficients for all sectors are identical. The following results were obtained from the test:

Table 5: Peseran Heterogeneity test

Testing for slope heterogeneity

(Pesaran, Yamagata. 2008. Journal of Econometrics)

H0: slope coefficients are homogenous

	Delta	p-value
	1.119	0.263
adj.	1.552	0.121

Variables partialled out: constant

The Pesaran and Yamagata test results suggest that we cannot reject the null hypothesis of homogenous slope coefficients (p-values not statistically significant). Consequently, this drives the decision of using a pooled FMOLS approach as it is most appropriate in the presence of homogeneity than a grouped FMOLS for estimating the long-run relationship between the dependent and independent variables.

4.3.4. Cointegration Test

The Kao cointegration test was employed to investigate the presence of a long-run equilibrium relationship between the variables in the panel data analysis. This test operates under the null hypothesis that there is no cointegration (no stable long-run relationship) among the variables. Table 6 presents the results from the test.

Table 6: Kao cointegration test

	Statistic	p-value
Modified Dickey–Fuller t	-7.4213	0.0000
Dickey–Fuller t	-8.5967	0.0000
Augmented Dickey–Fuller t	-5.6030	0.0000
Unadjusted modified Dickey–Fuller t	-11.8077	0.0000
Unadjusted Dickey–Fuller t	-9.6453	0.0000

The test results yielded a statistically significant p-value (less than 0.05), suggesting the presence of a cointegrating relationship between the variables. This implies a stable long-run equilibrium exists, and we can proceed with estimating the long-run relationship using an appropriate technique like FMOLS.

4.4. Estimation Results

To analyse the effects of digitalization on economic growth, two models were employed; the Bias-corrected Method of Moments Fixed Effects (BCMM-FE) and Fully Modified Ordinary Least Squares (FMOLs) estimations based on the justifications outlined in the methodology chapter.

To understand the overall influence of digitalization on the economies of Southern African Development Community (SADC) member states, an initial round of estimations was conducted. The results of this analysis, which consider all SADC countries as a whole, are presented in Table 7.

Table 7: Estimation Results-Full sample

	BCMM-FE		FMOLS	
Variables	Coefficients	p-value	Coefficients	p-value
Gdp growth L1.	0.8792174	0.000		
Capital	0.0012291	0.071	0.001076	0.1501
FDI	-0.0000235	0.925	0.007522	0.0015
Labor	0.0069288	0.053	0.001399	0.8579
Trade Openness	0.0001824	0.442	0.000519	0.0306
Mobile subs	0.0175014	0.004	0.037035	0.0000
International Bandwidth	4.63E-09	0.053	0.049540	0.0000
Internet use	0.0010049	0.301	0.004709	0.0021
Fixed broadband usage	-0.0005706	0.797	-0.205834	0.4961

Results from the BCMM-FE (1) and FMOLS (2) models represent the long run relationship between the variables. The variables mobile subscription and international bandwidth usage were found to have statistical significance on both estimation models whilst variables, capital and labour were significant in the BCMM_FE model. And Foreign Direct Investment, Trade openness and Internet usage were significant in the FMOLS model.

The analysis reveals a statistically significant (at the 1% level) positive relationship between mobile phone subscriptions and economic growth in SADC countries. This suggests that increased mobile phone penetration is associated with higher GDP growth, both in Model 1 and 2. The results in model 1 show that**;** a 1% increase in mobile cellular subscriptions is linked to a 1.75% increase in GDP growth, holding all other factors constant (ceteris paribus). Whilst in model 2: The impact is even stronger, with a 1% increase in mobile subscriptions leading to a 3.7% increase in GDP growth (ceteris paribus). These findings align with the observed rise of mobile phone subscriptions and the subsequent surge in mobile money services across SADC (ITU, 2023). Africa boasts the highest number of mobile money accounts globally, reaching a staggering 300 million("GSMA," 2024). These digital ecosystems have had a transformative effect, creating jobs (both directly and indirectly), modernizing banking systems, expanding financial inclusion for underserved populations, and fostering innovative business models(Beck et al., 2009). The widespread adoption of mobile money services has significantly contributed to financial inclusion in SADC. As highlighted by Fanta et al. (2016), mobile money has addressed liquidity shortages and limited access to hard currency by providing a 24/7 platform for depositing, withdrawing, transferring funds, and paying bills (including utilities) directly from mobile phones. These findings resonate with similar observations made by Albiman & Sulong (2016).

The variable of international Bandwidth usage exhibited positive relationship to economic growth and was found statistically significant with a 10% significance level in Model 1 and a 1% significance in Model 2. The model 2 results show that; A 1% increase in international bandwidth usage is linked to a 4.9% increase in GDP growth (ceteris paribus). Model 1: the magnitude of the impact is small close to zero, with a 1% increase in international bandwidth usage leading to a 0.00000436% increase in GDP growth. The results were expected as international bandwidth usage is associated with development of telecommunication infrastructure, that take several years to completion and therefore in the short run fruition of these developments may not be observed. However, in the long run just as the results depict development of ICT infrastructure leads to increased investment and expenditure thereby boosting GDP growth. The findings are in contradiction to Chowdhury (2006) who found a negative relationship between ICT investments and economic growth.

The analysis also reveals a positive relationship between Individuals using the internet as a percentage of the total population and GDP growth. The relationship was statistically significant at 1% significance level in model 2 only. A 1% increase in individuals using the internet is linked to a 0.4% increase in the growth of GDP. The linkage manifests itself in increased information access, financial inclusion, and innovation driving business efficiency, e-commerce, and human capital development. These findings are similar to a study conducted by Paunov and Rollo (2016) who found evidence of the positive impact of industries' Internet use on firm performance for 50,013 firm observations, covering 117 countries for 2006-2011. These gains which did not depend on firms' own ICT investments but public infrastructure.

The control variables labour and capital were found to have a positive relationship to GDP growth. Both variables were statistically significant at a 10% significance level only in model 1. The positive significance of capital and labour in model 1 aligns with well-established economic theory. These factors are fundamental contributors to economic growth in the long run. Increased capital stock (machinery, equipment, infrastructure) allows for higher production capacity, while a larger and more skilled workforce enables greater output (Solow, 1955). In model 2 control variables FDI and trade openness were found significant, with a 1% and 5% level of significance respectively.

Comparing the contribution of digitalization to growth in Upper-Income and Lower-Income countries in SADC is the main goal of the paper. Therefore, in the next section, the production functions are estimated for each country subgroup individually. Table 8 presents results for the split-sample regressions of the two country subgroups for the period 1999-2022.

Table 8: Estimation Results- Sub samples

	Upper-Income				Lower-Income			
	BCMM-FE		FMOLS		BCMM-FE		FMOLS	
Variables	Coefficients	p-value	Coefficients	p-value	Coefficients	p-value	Coefficients	p-value
GDP growth L1.	0.9334003	0.000			0.8731479	0.000		
Capital	0.0005428	0.492	-0.003924	0.0000	0.0015115	0.145	0.003349	0.0015
FDI	0.0001279	0.707	0.005729	0.0000	-0.000287	0.365	0.008338	0.0146
Labor	0.0076817	0.051	-0.000838	0.6812	0.0023602	0.786	0.002415	0.8311
Trade Openness	0.0005502	0.076	0.000302	0.2637	0.0001241	0.655	0.000618	0.0589
Mobile subs	0.0054048	0.031	0.034123	0.0243	0.0176879	0.004	0.038358	0.0000
International Bandwidth	4.57e-09	0.043	0.050788	0.0000	3.69E-08	0.343	0.048973	0.0000
Internet use	0.0009469	0.440	0.001292	0.1424	0.0013585	0.204	0.006262	0.0043
Fixed broadband usage	-0.0002618	0.895	-0.017886	0.0006	0.0002957	0.992	-0.291265	0.5080

The analysis revealed that in model 1, for the digitalization proxy variables, mobile subscriptions and international bandwidth usage were the only significant variables. Both variables exhibited a positive relationship with GDP growth. Mobile subscription was significant in both subgroups whilst international bandwidth usage was only significant in upper-income countries. The coefficients of the upper-income group on mobile subscriptions represented a 1% increase in mobile subscriptions was linked to a 0.5% increase in GDP growth whilst as for the lower-income group the magnitude was relatively higher, a 1% increase in mobile subscriptions led to a 1.7% increase in GDP growth holding all things constant. The difference was expected as mobile service use such as mobile money are more widespread in the lower-income economies, and these should definitely have an impact on the growth of GDP. The international bandwidth variable though significant the magnitude of its coefficient was small, close to zero. A 1% increase in international bandwidth usage led to a 0.00000457% increase in GDP growth ceteris paribus.

Analysis of model 2 revealed a broader set of significant digitalization variables compared to Model 1. Mobile phone subscriptions and international bandwidth usage remained significant contributors to economic growth across both upper-income and lower-income country subgroups. Interestingly, fixed broadband subscriptions emerged as a significant factor influencing growth only in the upper-income group. In contrast, individual internet usage was a significant driver of growth only in the lower-income group.

Importantly, the magnitude of the coefficients for all significant variables increased in model 2 compared to model 1. For instance, a 1% increase in mobile subscriptions translated to a 3% increase in GDP growth for upper-income countries and a 4% increase for lower-income countries (ceteris paribus). Similarly, a 1% increase in international bandwidth usage led to a substantial 5% increase in GDP growth for both upper-income and lower-income groups. This is in line with the features of the FMOLS model as it shows the overall significance of digitalization to GDP growth.

One unexpected result was the significant negative relationship observed between fixed broadband subscriptions and economic growth in the upper-income group. While the reasons for this require further investigation, reverse causality is a potential explanation. Economic growth might be driving fixed broadband subscriptions, rather than the other

way around. As economies experience growth, businesses and individuals might have more resources to invest in broadband infrastructure. This scenario could lead to a negative coefficient, even though broadband might ultimately contribute to further growth in the long run.

4.5. Post estimation Tests Results

Having presented the initial estimation results, the study then turned to a series of post-estimation tests. These tests help assess the reliability and robustness of the findings.

4.5.1. Hansen (1982) overidentification test

The Hansen test, also known as the Sargan-Hansen test, is a statistical test used in instrumental variable (IV) regression to assess the validity of the instruments employed in the model. It specifically focuses on overidentifying restrictions. In IV regression, you use instrumental variables (instruments) that are correlated with the independent variables but not correlated with the error term. These instruments help address issues like endogeneity (correlation between independent variables and the error term). A high p-value (often greater than 0.05) from the Hansen test suggests you fail to reject the null hypothesis. This implies the instruments are likely valid, and the overidentifying restrictions are consistent with no correlation between the instruments and the error term. Results from the test are shown in the Table 9.

Table 9: Hansen overidentification test

Hansen test of the overidentifying restrictions	chi2(6) = 7.3637
H0: overidentifying restrictions are valid	Prob > chi2 = 0.2885

4.5.2 Generalised Hausman (1978) test (Re vs Fe)

The Generalized Hausman test (1978), developed by Jerry Hausman, is a workhorse in panel data econometrics. It helps in deciding whether to use a Fixed Effects (FE) model or a Random Effects (RE) model when analysing panel data. The choice between fixed and random effects lies on the premise that FE model accounts for unobserved unit-specific effects that are constant over time (e.g., country-specific factors). It estimates

the effect of the independent variables on the dependent variable while controlling for these unobserved effects whilst RE model assumes the unobserved effects are random and uncorrelated with the independent variables. Results of the test are depicted in the Table 10.

Table 10: Hausman Test

Generalized Hausman test	chi2(6) = 39.9193
H0: coefficients do not systematically differ	Prob > chi2 = 0.0000

Low p-value (often < 0.05): Rejects the null hypothesis. This indicates potential bias in the RE estimates due to the correlation between unobserved effects and the independent variables. The FE model is the better choice in this scenario.

4.5.3. Arellano and Bond (1991) serial-correlation test

The Arellano-Bond (1991) serial correlation test is a diagnostic tool used in panel data analysis with dynamic models. The test helps assess the presence of serial correlation in the error terms of the model. Serial correlation occurs when the error terms in a regression model are not independent but are correlated across time periods for a particular unit (e.g., country, firm). This can lead to inefficient and biased estimates.

Table 11: Arellano and Bond test

Arellano-Bond test for autocorrelation of the first-differenced residuals

H0: no autocorrelation of order 1:	z =	-2.4542	Prob > |z| =	0.0741
H0: no autocorrelation of order 2:	z =	-1.5818	Prob > |z| =	0.1137

A high p-value (often greater than 0.05) for both the m2 and AR (2) tests suggests you fail to reject the null hypothesis of no serial correlation. This is a good sign, indicating the model might not be plagued by this issue. From the results our model is free from autocorrelation.

4.6. Chapter summary

This chapter explored the impact of digitalization on economic growth in SADC countries. The analysis employed two econometric techniques: the FMOLS and the BCMM. The FMOLS technique, focused on overall model significance, revealed a statistically significant long-run relationship between digitalization and economic growth. Additionally, all digitalization variables exhibited positive significance in both the full sample and the subsamples (upper and lower-income countries). The BCMM estimator, designed to assess the magnitude and direction of the relationships, identified mobile phone subscriptions and international bandwidth usage as positively significant drivers of economic growth in the full sample and the upper-income group. Interestingly, for the lower-income economies, only the mobile phone subscription variable remained statistically significant, also exhibiting a positive association with economic growth.

CHAPTER FIVE

CONCLUSION AND POLICY IMPLICATIONS

5.1. Introduction

This chapter delves into the key takeaways from our analysis of digitalization's impact on economic growth in SADC. This will explore the results, discuss their implications for policymakers, and acknowledge the study's limitations while outlining promising avenues for further research.

5.2. Study Summary

Digitization plays a crucial role in driving global economic growth by enabling improved access to information, increased productivity, reduced transaction costs, and enhanced economies of scale. However, despite the growing adoption of digitization in Southern Africa, the region still faces challenges in fully leveraging digital technology products. Encouragingly, there have been significant increases in the penetration rate of digital products, such as mobile-cellular telephone and mobile-broadband subscriptions. However, this progress has mainly been dominated by the upper-income economies in comparison to the lower income economies. This study addressed the effects of digitization on income levels and economic growth, examining the diverse channels through which digitization can impact these factors.

The study employed the Bias corrected method of moments (BCMM) and the Fully modified Ordinary Least Squares (FMOLS), on a balanced panel data of the 16 Southern African Development Community (SADC) countries from 1999 to 2022. Analysis was done by running several regressions on the sub samples of upper-income and lower-income countries that represented the relationship of digitalization on economic growth in the long run.

The study's long-run model analysis revealed a strong link between digitalization and economic growth in SADC countries. The FMOLS estimation indicated that most digitalization variables were statistically significant across all samples, suggesting digitalization played a key role in long-run economic growth. However, the BCMM

estimator, which delved deeper into specific effects, showed that only mobile phone subscriptions and international bandwidth usage had significant positive impacts. Interestingly, mobile phone subscriptions displayed a much larger effect on growth compared to international bandwidth usage, whose coefficients were closer to zero. This suggests that, at least within the timeframe captured by the models, mobile phone subscriptions might have been a more potent driver of long-run economic growth in SADC countries. Interestingly, a closer look at country subgroups unveiled a disparity in the magnitude of this effect. Lower-income SADC nations experienced a more pronounced benefit, with a 1.7% increase in GDP per capita growth associated with a rise in mobile subscriptions. Conversely, upper-income economies within the bloc saw a more modest 0.5% gain. This suggests that mobile phone penetration may act as a stronger catalyst for economic growth in less developed countries**.** This finding departs from the work of Niebel(2018), who did not identify a clear advantage for developing economies in terms of ICT investment returns compared to developed nations.

5.3. Policy Recommendations

The findings of this study offer valuable insights for policymakers and stakeholders, highlighting the pivotal role of digitization in driving economic growth in Southern Africa and shedding light on the various transmission mechanisms through which digitization can positively influence income levels. One key transmission mechanism identified is mobile phone subscriptions. This variable consistently emerged as significant across all estimation results, with an even larger coefficient in lower-income countries. This suggests that policies fostering mobile subscription growth can significantly influence economic development in the SADC region. Below are some potential policy directions to consider:

a) Expanding Mobile Network Coverage:

Infrastructure Investment: Governments and regulatory bodies can prioritize infrastructure development to expand mobile network coverage, particularly in remote areas. This could involve supporting network operators in building new cell towers, providing incentives for rural infrastructure development, or encouraging public-private partnerships.

b) Promoting Mobile Broadband Adoption:

Affordability Initiatives: Governments can implement policies that make mobile data plans more affordable for individuals and businesses. This could include reducing taxes on mobile data services or promoting competition among operators.

c) Encouraging Mobile Money Services:

Financial Inclusion Initiatives: Governments can partner with mobile network operators and financial institutions to expand the reach of mobile money services, particularly in underserved areas. This could involve offering incentives for mobile money registration and usage or promoting its use for government services like social safety net payments.

d) Strengthening the Digital Ecosystem:

Cybersecurity Measures: Implementing robust cybersecurity measures can build trust in the digital environment and encourage wider adoption of mobile technology for economic activities.

Regarding the findings on the other significant variable, international bandwidth usage, upper-income SADC governments should focus on enhancing international bandwidth capacity and promoting competition among service providers to support advanced digital services and innovation. Simultaneously, lower-income governments should prioritize expanding basic broadband access and digital literacy initiatives to bridge the digital divide and enable broader participation in the digital economy.

By understanding these dynamics, policymakers can craft strategies to maximize the benefits of digitization and foster sustainable economic development in the region.

5.4. Limitations of the study

This study, while illuminating the link between digitalization and growth in SADC, has limitations.

Data Availability: Expanding the analysis to include additional digitalization variables, such as ICT governance and the adoption of specific technological advancements like Artificial Intelligence (AI), could have provided a more comprehensive picture. However, data availability for these aspects presented challenges:

- Limited Scope: Data collection for some variables, like AI, was in its early stages, leading to limited information across SADC countries.

- Short Time Series: For other variables, like ICT governance, data existed but only covered short periods, making it difficult to establish robust long-run relationships. Additionally, the study's focus on long-run relationships provided valuable insights. However, it is important to acknowledge the influence of digitalization on economic growth might also have short-run dynamics that weren't captured in this long-run analysis.

5.5. Areas of Further research

While economic growth is a crucial indicator of progress, it doesn't always translate directly to poverty reduction, a significant challenge faced by many SADC countries. To gain a more comprehensive understanding of the impact of digitalization, it's vital to explore how it can specifically contribute to poverty alleviation in the region. Additionally, examining various regions can offer a more comprehensive understanding of how digitalization fosters economic growth.

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