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The impact of digital transformation on economic growth in South Africa

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Supervisor: Sylvester Horvey

A research proposal submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in the field of Digital Business

Johannesburg, 2025

ABSTRACT

The African continent experiences varying economic growth rates by region and multiple factors contribute to this effect. The nuance of how digital transformation impacts economic growth on a country level is of interest due to limited literature and potential insight that can be employed to eliminate socioeconomic disparities. This paper empirically reviews the impact of digital transformation on economic growth in South Africa using secondary data from the World Bank's World Development Indicators database between 1990 and 2022. The study measures digital transformation using proxies of fixed telephone, fixed broadband, mobile cellular and internet users into an index using principal component analysis (CPA) while using real GDP per capita as a proxy for economic growth. The common literature indicates that technology impacts economic growth positively with some mixed results in other economies. The study reveals that technology as a standalone, cannot solve socioeconomic challenges if other important factors are not considered. This study employed multiple statistical techniques including regression, Augmented Dickey-Fuller (ADF) to test time series stationarity, Bound Cointegration test and Autoregressive Distributed Lag (ARDL) for further analysis. This study presents that digital transformation has a positive correlation with economic growth by reducing transaction costs, providing access and increasing productivity. However, the results indicate a short-run relationship between digital transformation and economic growth in South Africa. Due to rapid technological advancements in all sectors, the study recommends public-private partnerships and regulatory sandboxes to fast-track policy frameworks implementation.

KEYWORDS

Digital transformation, Economic growth

DECLARATION

I, Mthunzi Sikhakhane, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the field of Digital Business at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Mthunzi Sikhakhane Signature: M Sikhakhane

Signed at …Fourways……

On the ……21…….. day of …….January…… 2025…..

DEDICATION

This research is dedicated to everyone who has contributed to its development, whether through direct support or inspiration. To the friends and family who encouraged me, and the countless individuals whose work laid the foundation for this study, this is for you. Thank you for being part of this journey.

"It always seems impossible until it's done" Nelson Mandela

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LIST OF ACRONYMS

Acronyms	Definition
DTI	Digital Transformation Index
FBD	Fixed broadband subscriptions
FTS	Fixed telephone subscriptions
GDP	Gross domestic product
ICT	Information and Communication Technology
lnE	Adjusted savings: education expenditure
lnGFC	Gross fixed capital formation
lnIF	Inflation
lnIQ	Institutional Quality
lnLR	Labor force participation rate
lnTR	Trade rate
IU	Individuals using the Internet
MCS	Mobile cellular subscriptions
MENA	Middle East and North Africa
PCA	Principal Component Analysis
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
WDI	World Development Indicators

CHAPTER 1. INTRODUCTION

1.1. Statement of Purpose

The purpose of this quantitative study is to explore how digital transformation has contributed to economic growth in South Africa.

1.2. Background of the study

The proliferation of technology has been accelerated in the twenty-first century by the need to create new business models, improve efficiency, advance innovation and more. The adoption of technology to drive the policy framework has transformed countries like Singapore which was previously classified as a poor country in the 1960's but has become the world's most digitally connected (Behera et al., 2024). Kraus et al. (2021) defines digital transformation as "the use of information and communication technology, not when trivial automation is performed, but in the case where fundamentally new capabilities are created in business, public government, and in the lives of people and society". The need for digital transformation has been recently exacerbated by the COVID-19 pandemic which forced all industries to adopt digital platforms for remote work, learning and social media (Dhobha & Madondo, 2024; Mwananziche et al., 2023). Technological disruptions are not isolated to specific industries in the private or public sector; they exist everywhere, directly or indirectly.

The continuous exponential technological disruptions provide unprecedented efficiencies for companies, allowing them to access untapped markets with quality-improved products and enable economies of scale, ultimately increasing economic growth as per findings in some Indian states (Pradhan et al., 2021). The high speed of innovations directly associated with technological advancements has led to new business models and new economic sectors with job creation, thus eliminating socioeconomic disparities within Indian communities (Pradhan et al., 2021). The same ascension remains an under-researched topic from South Africa's perspective. The importance of technology cannot be ignored due to the benefits it provides for all types of industries and individuals however, it must be mentioned that challenges

can hinder the realisation of the benefits, one of them being the digital divide, especially in the South African context (Gaglio et al., 2022). Research conducted in different sectors in South Africa indicates that 27 percent regard their services as digitalised with a realised increase in revenue and reduction of production cost however, manufacturing which has been defined as the bedrock for employment and sustainable economic growth in the country, has seen a decline over the decade due to the slow adoption of the fourth industrial revolution technologies such as robotics, artificial intelligence and Internet of Thing (IoT) (Ndou et al., 2020). The digital adoption of technologies like IoT in manufacturing can enable the industry to operate optimally and efficiently through its capability of connecting devices to the internet while collecting big data for analysis, producing intelligence and actionable insights for globally competitive products (Ndou et al., 2020).

The recent COVID-19 pandemic has unearthed the extent of the digital divide in South Africa with 76 percent of the population using the internet in 2022 and it demonstrated that even though broadband infrastructure exists it does not serve everyone in the country (Hadzic, 2024). The pandemic also accelerated the adoption of digital technologies like e-commerce and digital payment for small and medium-sized enterprises (SMEs) as they were compelled to shift operations online to remain in business and subsequently increase productivity and efficiencies (Obokoh et al., 2024). Similarly, the micro and small enterprises (MSEs) play a key role in contributing to the economy by using technology to create new products and solutions and ultimately eliminating poverty through job creation (Dhobha & Madondo, 2024; Gaglio et al., 2022). It has been stated that one of the key economic growth drivers for any country is access to financial products for everyone to participate in economic activities actively and the use of technology to enable digital financial services has been successfully deployed to achieve such and to drive financial inclusion which is deemed to be the main factor in achieving 7 of the 17 United Nation’s Sustainable Goals (Boukhatem & Ben Moussa, 2023; Mabkhot et al., 2021).

Scholars have cautioned that, inasmuch as there are great benefits driven by technology, it cannot solely resolve all the societal and institutional issues; other factors should be considered (Ejemeyovwi et al., 2021). Such sentiments were also echoed that developed and emerging countries have benefited more from

technology than developing economies (Behera et al., 2024). The extent to which technology impacted economic growth in South Africa must be studied with other influencing factors. It has also been argued that poor institutional quality in emerging countries weakens the ambitions of economic development (Boukhatem & Ben Moussa, 2023). For an economy to grow, it requires a strong and stable government with high institutional quality, zero tolerance for the wastage of public resources (Evans, 2023).

Digital transformation is directly driven by the advancement of Information and Communication Technology (ICT), providing the underpinning infrastructure for the fourth industrial revolution technologies. Multiple studies have found that ICT does contribute positively to economic growth by reducing transaction costs, providing access and increasing productivity (Awad & Albaity, 2022; Behera et al., 2024; Boukhatem & Ben Moussa, 2023; Dhobha & Madondo, 2024; Ejemeyovwi et al., 2021; Zhang et al., 2022). Many studies have focused on how ICT has impacted communities from an economic growth perspective and also indicated that an increase in ICT expansion can improve the productivity of an economy (Awad & Albaity, 2022; Dhobha & Madondo, 2024). Despite more attention given to ICT's impact on economic growth, the extent of this impact has not been explored enough specifically in the context of South Africa. This is consistent with other studies however, the different approach for this study will be adopted and fully defined in the later sections. Addressing South Africa's socio-economic challenges requires a systemic approach by understanding relevant aspects for research. This study seeks to contribute to the body of knowledge and future studies focusing on digital transformation and economic development from the South African context. It is an attempt to determine the possible relationships between these aspects.

1.2.1. Digital Transformation South Africa Context

South Africa presents great opportunities in most sectors for boosting its economic growth through job creation driven by digital transformation. However, the rate of digital transformation in Africa has been hindered by underdeveloped digital infrastructure, the cost of connectivity, limited access, lack of digital skills and inadequate regulatory framework to facilitate the development (WorldBank, 2024a).

The African Union's Digital Transformation Strategy for Africa suggest that South Africa is one of the top four countries with an e-government development index above the global average indicating a progressive prospect for ICT in the country (AfricanUnion, 2020).

The youthful population on the African continent promise more agility towards digital aspirations of the continent to address the challenges of poverty, inequality and economic growth (AfricanUnion, 2020). The Sub-Saharan African region has experienced a significant increase in internet users at 115 percent between 2016 and 2021 with South Africa seeing an 18 percent increase for the same period (WorldBank, 2024a). This increase is mainly driven by mobile internet users as fibre cable or cable broadband remains part of the challenge with an estimated 300 million people living at least 50 km away from such infrastructure in Africa (AfricanUnion, 2020). Digital payment is the main driver of mobile access in the region estimated by the World Bank to be at 119 million payments (WorldBank, 2024a). With all the efforts of the population to innovate using digital tools, the role of government remains paramount on the continent, providing infrastructure that enables affordability and accessibility. Policymakers are also mandated to create policies that provide a conducive environment for private investors to supplement government digital initiatives. The South African government has embarked on a journey to modernise the public sector through policy development involving multiple departments, the initial policy being Electronic Government: The Digital Future in 2001 and subsequent updates (Willem et al., 2024).

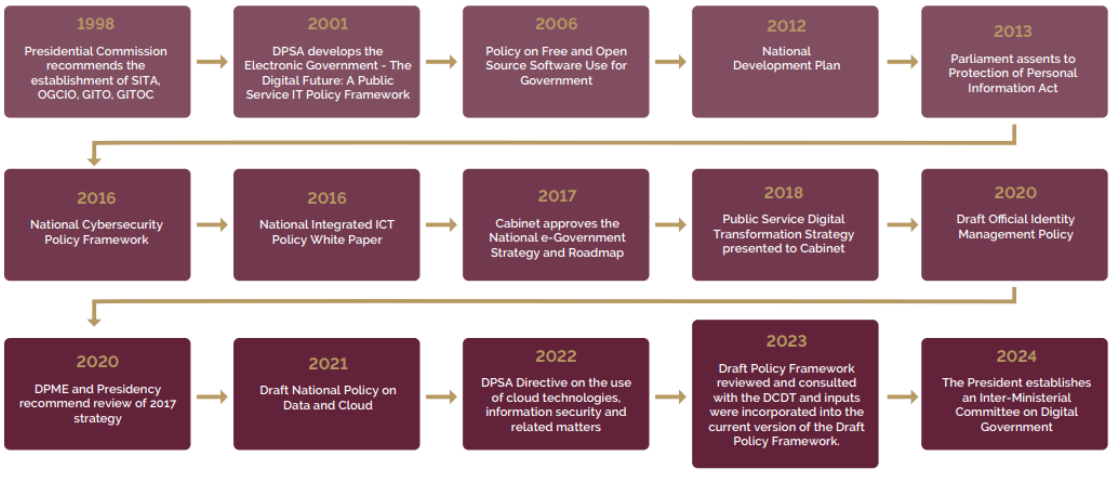

Figure 1: Key policy developments related to digital transformation in South Africa (Willem et al., 2024)

Willem et al. (2024), summarised all the initiatives and timelines in **Figure 1**. The South African government has initiated these policy frameworks to stimulate job creation and curb the challenges of poverty, inequality, and unemployment using technology, which are part of the UN's Sustainable Development Goals (AfricanUnion, 2020). However, given all the above-mentioned positive trajectories on ICT policy development and governance framework, the country has performed poorly from the implementation perspective which led to a slow uptake of digital skills and awareness (Hadzic, 2024; Manda & Backhouse, 2018). The slow implementation is partly driven by the lack of clear policy direction on whether the State Information Technology Agency (SITA) or another government agency should drive the digital transformation initiatives, as indicated in the Draft Digital Government Policy Framework (DPSA, 2024). The issues also stem from the capacity of SITA to execute its mandate due to internal instability within top leadership, governance and allegations of corruption and maladministration (Manda & Backhouse, 2018).The South African government rely on SITA for ICT infrastructure and information systems making it a centre for digital transformation. The significant role played by the private sector in rolling out Fiber-to-the-Home (FTTH) solutions for high-speed internet for homes and businesses is the main contributor to increased connectivity for the country, in addition to the 5G rollout by mobile service providers (DCDT, 2024)

Given the high poverty levels and lack of infrastructure development in the country, digital transformation often gets deprioritised regardless of its impact on driving the economy and the government does need assistance from the private sector in the form of expertise and investment. Recently, the South African economy has not been immune to geopolitical conflicts and the COVID-19 pandemic however, it remains resilient to most of the economic shocks. The quick response by the government to provide a temporary spectrum to address the high bandwidth demand due to the COVID-19 lockdown is a testament that demonstrated resilience even though it disrupted the permanent spectrum auction process (Hadzic, 2024).

The African Development Bank estimates that Africa's GDP will increase to 3.7 percent in 2024 exceeding the projected global average and making the continent the second-fastest growing economy and South Africa is estimated to increase by 2.2 percent (AfricanDevelopmentBank, 2024). The ambitions to grow the South

African economy are directly linked to government initiatives to eliminate ongoing challenges such as the electricity crisis, unemployment, poverty and inequalities.

1.3. Research Problem

Scholars have made a considerable amount of effort to understand the influence of digital transformation on economic growth in different regions of Africa and they all share similar findings that indicate positive relationships between these aspects (Awad & Albaity, 2022; Evans, 2023; Hussain et al., 2023; Nchake & Shuaibu, 2022). However, the literature has not explored enough the extent to which South Africa's economic growth has been influenced by digital transformation. The common literature seems to focus on regions but not on the nuances of specific countries. Common studies have focused on the impact of institutional quality in specific parts of the continent on economic growth (Boukhatem & Ben Moussa, 2023; Kouadio & Gakpa, 2022; Olaniyi & Odhiambo, 2023). Other studies seem to focus on foreign direct investment against digital transformation (Yeboua, 2021).

The African continent is faced with a mix of economic disparities within its regions, with sub-Saharan GDP growth of 5 percent over the recent decade however, this positive trajectory has not materialised to eliminate inequality instead, it continues to exacerbate it in some parts of the continent (Kouadio & Gakpa, 2022). This implies that some parts of Africa are experiencing good economic growth despite worsening socioeconomic conditions in other regions. As highlighted by some studies digital transformation through ICT contributes positively to economic growth (Awad & Albaity, 2022; Behera et al., 2024; Boukhatem & Ben Moussa, 2023; Ejemeyovwi et al., 2021).

However, the actual mechanisms of how digital transformation improves or deters economic growth remain unknown (Awad & Albaity, 2022). Due to these assertions, more research is needed to ascertain the underlying mechanisms of digital transformation which led to this study's direct focus in South Africa. The general perception is that the government enable the environment which stimulates ICT investment through stable regulation and forward-looking policies that attract private sector participation; failure to such can hinder ICT development ultimately impacting broader economic growth and innovation. To address these dependencies, this study

will use South African public data to surface the potential impact it has on stimulating ICT and economic growth without ignoring the previous assertion that technology alone will not eradicate all challenges.. Previous studies also found that the state of poor countries continues to deteriorate due to institutional failures (Kouadio & Gakpa, 2022).

These results indicate systematic issues that must be addressed not in isolation from each other. Also, it has been stated that the MENA regions have experienced good economic growth with high GDP due to great institutional quality (Boukhatem & Ben Moussa, 2023). Addressing issues of economic growth in South Africa and the continent at large requires a systematic approach to investigate all related aspects and to use insights from previous research findings. Therefore, since the role of digital transformation has not been explored enough concerning economic growth in South Africa, this paper will attempt to investigate that gap. It also attempts to add to the knowledge base of the relationship between digital transformation and economic growth concerning these areas in the South African context. To the best of knowledge, there is no other study which focuses on these aspects and uses the same data analysis techniques.

The governments and other interested parties often require information to be guided to allocate resources accordingly in an attempt to reduce poverty, and inequality and improve the standard for all through economic development and business investments. This study will empower future researchers, the private sector and government institutions to acquire insight and nuances which relate to these research aspects from the South African perspective. These insights will be produced through the use of credible publicly available databases and the later chapters of this paper will give details about the methodology.

1.4. Research objectives

The main objective of this study is to investigate the extent of digital transformation towards driving economic growth in South Africa using data between 1990 and 2022. The direct objectives are as follows:

1. To investigate the role of digital transformation in economic growth

2. To ascertain if a short-run or long-run relationship exists between digital transformation and economic growth

1.5. Justification of the study

Similar studies have been conducted previously investigating different matrices contributing to economic development in various regions as an example from these scholars (Boukhatem & Ben Moussa, 2023; Kouadio & Gakpa, 2022). These studies were conducted to contribute to the knowledge base for all interested parties including the government as well as international investors and other purposes. However, the role of technology in economic growth remains unexplored enough for different countries like South Africa. This paper also seeks to contribute to a similar knowledge base specifically focusing on digital transformation and economic growth.

In pursuit of the South African government's goal to eliminate poverty, unemployment and inequality and in alignment with the broader objectives of Agenda 2063 and the UN's Sustainable Development Goals, it's imperative to focus or prioritise the limited resources towards the initiative with high impact (AfricanUnion, 2020). Many scholars like Nchake and Shuaibu (2022), found that ICT investment has a positive effect on economic growth, improving productivity and reducing transaction costs and is a potential driver to improve the standard of living of the society. It is therefore important for policymakers and prospective investors to make informed decisions that will enable ICT investment. Knowing the potential hindrance that can deter such a progressive undertaking is equally important; hence, the study investigates the digital transformation to ascertain its role from the South African context.

1.6. Delimitations of the study

This quantitative study will be conducted for South Africa only; references could be used for other regions and countries as part of the literature that was investigated. The focus on South Africa for this paper is driven by the potential benefits derived from the research results to enrich scholars, government institutions and policymakers to make data-driven informed decisions for digital infrastructure. Also, the African continent presents a great opportunity for addressing socioeconomic

challenges through its youthful tech-savvy population (AfricanUnion, 2020). The exponential increase in internet access also warrants a deeper understanding of how digital infrastructure can be leveraged to reduce poverty and improve the standard of living and economic growth. Individual countries could be mentioned to expand or highlight a specific point of the study since they could provide relevant information to prove or disprove the debate of the findings from this study and other previous similar work. The data will be mainly sourced from the World Bank database from 1990 to 2022.

1.7. Definition of terms

This study will use the following definitions of the research aspects and other terms will be as per common definitions.

Term	Definition
Digital Transformation	The use of information and communication technology, not when trivial automation is performed, but in the case where fundamentally new capabilities are created in business, public government, and in the lives of people and society (Kraus et al., 2021)
Economic Development	A process of improving economic and social well-being of people in a specific area (Ručinská et al., 2016)

1.8. Assumptions

The study will utilise secondary data for all analyses. The assumption is that the data sources (World Bank) and the other sources are credible and suitable for this study as they are also commonly used in previous research.

CHAPTER 2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Introduction

The literature review on digital transformation has been extensively conducted in business and government settings. However, debates persist on the extent it has on poor countries and middle-income countries. Many studies indicated a positive correlation between ICT and economic growth. The literature highlighted the need for a comprehensive systematic view of ICT, it alone cannot solve all socio-economic challenges, but good institutions are key in the process. One of the main anchors is good institutional quality to drive economic growth and improve digital transformation. This literature review will draw insights from different scholars, countries and regions that have conducted similar studies mainly using secondary data and statistical data analyses. The literature review produced a conceptual framework after all the findings from different authors were covered. This section follows a structure a background followed by two objectives defined in chapter one section 1.4, each objective as a heading followed by the underlying hypothesis based on the findings.

2.2. Definition of topic or background discussion

Economic growth is generally measured using gross domestic product (GDP) which includes the goods and services of the country but does not account for all economic activities (Hussain et al., 2023). Economic growth serves as part of the aspect of economic development an important aspect for developing countries to improve their standard of living. The literature often uses these terminologies interchangeably and this study will focus on economic growth but also reference economic development from similar previous research. This paper also adopts ICT as a general proxy for digital transformation as different studies have been done due to the complexity and data availability concerning technology from a country's perspective.

2.3. Theoretical Framework

The pursuit of understanding the connection between digital transformation and economic growth for different economies continues to influence research and investors' perceptions. Various parameters influence digital transformation as a standalone concept, similar to economic growth; however, these artefacts are interconnected and interdependent. This indicates that each element cannot be studied in isolation, which introduces the systems thinking concept. In the quest to ascertain the relationship between digital transformation and economic growth, this paper will adopt an integrated approach to understand these two concepts and attempt to achieve the objective of this study. Given that economic growth is a complex concept that involves a vast number of stakeholders, entities and external factors, it will not be feasible to investigate all of them simultaneously hence, this paper focuses on a digital transformation and the results could be absorbed by other studies.

Solow (1956), defined a neoclassical economic theory (Solow-Swan growth model) which seeks to explain how economic growth is achieved over time, its focus is on the relationship between capital, labour and technological advancement in driving sustained economic growth. The model further outlines that simple technological changes have the potential to improve production scale significantly (Solow, 1956). Therefore, it's imperative to test this theoretical assumption in the scope of South Africa's economy. However, the model suggested that all the variables are constant which is not always the case considering population growth, hence, scholars have modified it to reflect reality (Guerrini, 2006).

North (1991), explores the role of institutions and the nation's economic development, the author defines institutions as human device constraints (both formal and informal) that structure political, economic and social interactions to create order and reduce uncertainty. He developed an Institutional theory which suggests that institutions define frameworks for economies to operate under affecting the economic development of the nation. (North, 1991). Since the theory firmly argues that institutional structures are made by human intervention, they are

susceptible to error, subjective and subject to change which can either improve or deteriorate the economic trajectory of the nation (de Almeida et al., 2024).

A similar concept is from the National Innovation Systems (NIS) theory by Lundvall (2016), which argues that the diffusion of technology is dependent on the institutions and rules of the countries. The effectiveness of the NIS theory is measured by educational institutions, research and development (R&D) facilities, government policies, industrial firms, and financial systems on how they all work together to drive innovation and technology policies (Lundvall, 2016). These policies are assumed to be the driving catalysts for the economic growth of any country. It is therefore the main reason that this study attempts to explore the connection between digital transformation and economic growth. These theories will serve as a base for the arguments for this paper due to their relevance and consistency with the empirical literature review for this study.

2.4. Empirical review on digital transformation and economic growth

ICT adoption continues to be topical in research, but it is not fully understood how it's connected to financial development in the South African context. A study done by Ejemeyovwi et al. (2021), Investigating the adoption of ICT, Innovation and financial development using 54 countries in Africa using 18 years' worth of data spanning from 2000 to 2017 and using Bayesian Vector Auto-Regressive (BVAR) modelling. This study found that ICT complemented by innovation can improve financial development (Ejemeyovwi et al., 2021). It also suggested that ICT has been found to improve productivity which stimulates economic development through the reduction of transaction costs and the same has been suggested by other studies (Ejemeyovwi et al., 2021; Nchake & Shuaibu, 2022; Ofori et al., 2022). The same study also emphasises the importance of not solely relying on ICT as a solution for economic development (Ejemeyovwi et al., 2021). A similar statement was also expressed regarding financial development being a solution for economic growth in the absence of institutional quality (Boukhatem & Ben Moussa, 2023).

The prevailing effect of ICT on the provision of social services in the 31 low-income countries from different continents and the role of institutional quality using cross-sectionally augmented autoregressive distributed lag (CS-ARDL) analysis and other

methods indicate that good institutional quality enables governments to reduce the wastage of public resources (Evans, 2023). The study further argues that low-income countries can leverage ICT to improve not only social services but also expand to health and education, the ultimate findings conclude that ICT and institutional quality both have a positive effect on the provision of social services in a short and long-term basis (Evans, 2023). The findings demonstrate that an increase in ICT for the provision of social services will improve institutional quality and the opposite is true. It indicates how the two variables can influence each other for the greater good of low-income countries and provide guiding principles for policymakers to direct resources where they are most needed.

An empirical study to ascertain the relationship between sustainable economic development towards ICT, financial inclusion and economic growth in India, the study investigated 20 Indian states from 1991 to 2018 (Pradhan et al., 2021). The World Bank indicates that Sub-Saharan Africa has the most contributing number of people living in extreme poverty at 35 percent followed by South Asia at 9 percent (Baah et al., 2023). However, India is also described as a tech-savvy country with a significant increase in the adoption of mobile and internet adoption but it remains a question as to what extent ICT contributed to financial inclusion since 80 percent of the population have a bank account due to government initiatives but a low percentage benefit from financial services (Pradhan et al., 2021). This finding is in line with a similar study conducted in low-income countries which indicated that a high number of mobile phones does not necessarily translate to financial inclusion and economic growth (Evans, 2023). Similarly Dhobha and Madondo (2024), found that mobile subscriptions in South Africa showed a positive but insignificant relationship to inequality, whereas internet access was positive and significant. The study concludes that there's a strong relationship between financial inclusion, ICT and economic development in Indian states a strong ICT investment can be driven by economic growth and financial inclusion in the long term (Pradhan et al., 2021).

Nguyen et al. (2022), studied the impact of institutional quality, and ICT penetration in economic development using 35 emerging countries between 2000 to 2019 using the System Generalized Method of Moment (GMM) found that increasing ICT infrastructure investment can improve connectivity, and financial development and further cultivate economic growth. It further highlighted that low Institutional quality

produces a negative impact towards economic growth (Nguyen et al., 2022). It's consistent with previous studies which found that countries in the sub-Saharan African region with failure of institutions, poor governance, and political instability also have deteriorating poverty conditions (Kouadio & Gakpa, 2022). The phenomenon of weakness in institutional quality impacts financial inclusion which destabilises economic growth and both cannot be achieved merely by financial development this was highlighted in a study using 16 MENA countries (Boukhatem & Ben Moussa, 2023). Different regions might have unique characteristics and nuances, but the common themes from the other studies confirm a consistent knowledge regarding institutional quality.

Ayana et al. (2024), Investigated the relationship between government revenue and economic growth and the impact of institutional quality in the 43 Sub-Saharan African countries using a two-step GMM method of 2012-2022 data. The study found that government revenue does not have a positive effect on economic growth on its own but with a combination of institutional quality the impact is very positive (Ayana et al., 2024). This is consistent with other previous studies which found results aligned that indicated the importance of institutional quality as a catalyst and an anchor for economic growth (Ayana et al., 2024; Boukhatem & Ben Moussa, 2023; Fengju & Wubishet, 2024). This was also expanded by Fengju and Wubishet , that institutional quality is a prerequisite for financial development, leading to economic development for countries in East Africa (Fengju & Wubishet, 2024). This strongly shows the correlation between institutional quality as a variable from a government perspective.

An effective government's ambition and mandate require its institutions to function optimally at all levels. Fengju and Wubishet (2024), study on financial development on economic growth and the institutional quality in 18 East African countries, suggests that countries must heavily invest their resources into ensuring that institutional quality is improved for their communities to benefit from it through the improvement of the financial sector. The policymakers in African countries must prioritise institutional quality to guarantee productivity and limit corruption that can hinder economic complexity (Olaniyi & Odhiambo, 2023).

The literature generally indicates a positive correlation between ICT and economic development in different economies without specific mechanisms. However, another

study attempted to explore the impact of ICT on the environment and concluded a positive correlation between ICT, financial inclusion and sustainable economic growth (Hussain et al., 2023). However, due to the global interest in innovation and the fourth industrial revolution, the environmental impact is often overlooked. The study examined financial inclusion and ICT's role in sustainable economic development in 110 developing countries from 2004 to 2020 (Hussain et al., 2023). The key argument from the study is the notion that ICT does provide innovative solutions and devices which consume less energy which ultimately reduces carbon emissions but it is also one of the main contributors to electronic waste with high CO_2 emissions (Hussain et al., 2023). The study does not seek to disagree with the previous findings related to ICT but rather it highlights some of the ignored fundamental aspects of ICT from an environmental perspective. These findings are also equivalent to the issue of Bitcoin transactions built on blockchain technology which is estimated to consume 800 kilo-watt hours making it the worst environmentally friendly technology in recent times, it's been said that if Bitcoin was a country it would be ranked 34th globally based on energy consumption (Sapra et al., 2024). It is a reinstated finding that ICT positively impacts most aspects of business and government services but in some cases, it negatively affects the environment.

The nexus of ICT with institutional quality specifically curbing corruption for 39,796 firms from 76 countries from 2007 to 2016 indicated that technology has the potential to reduce corruption to a certain extent through automation, making information available and enabling the anonymity of whistleblowing (Fan et al., 2021). This study tried to investigate if ICT adoption changes the firm's perceived corruption (Fan et al., 2021). It is not a definite solution since human intervention can undermine the process design for personal gains. However, in authoritarian regimes, technology can be used by the government to control and invade the public's privacy (Fan et al., 2021). Given all the great benefits that ICT has to mitigate corruption, the study indicates that ICT is merely an enabling mechanism and it alone cannot mitigate corruption if not accompanied by good institutional practices (Fan et al., 2021).

This study will focus on the following hypothesis given the above empirical evidence.

2.4.1. (H_1) Digital transformation can improve economic growth

2.4.2. (H_2) Digital transformation has a positive short-run relationship with economic growth

2.4.3. (H_3) Digital transformation has a positive long-run relationship with economic growth

2.5. Conceptual Framework

Various studies have attempted to decipher the relationship between digital transformation and economic growth. The common themes from the literature review highlight that each aspect is generally linked as illustrated in **Figure 2**. This deduction is based on the empirical findings from different literature reviews conducted. This depiction **Figure 2**Error! Reference source not found. is supported by the empirical evidence that digital transformation has a positive effect on financial performance for greater economic growth. Furthermore, digital transformation in the form of ICT enables government institutions to be transparent, effective and efficient while improving the economic growth of the nation (Behera et al., 2024). The combined insights from different studies and the theories mentioned in the previous sections deduced the conceptual framework and the linkages into previously defined hypotheses.

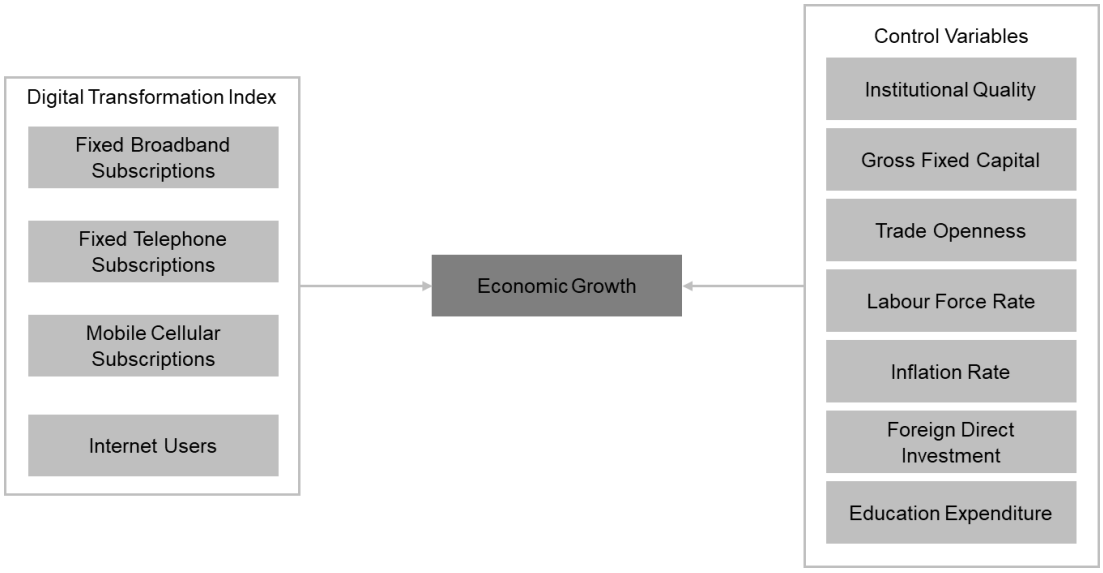

Figure 2: Conceptual Framework
Source: Author's Construction

The relationships illustrated above **Figure 2** show the key variables making up the digital transformation index and control variables that will be studied in this paper

and a conceptual framework. All assumptions and activities during this paper will be driven by the concept as illustrated by the conceptual framework. The framework was formed by following insights from different literature reviews conducted for this research and the scope of the study.

2.6. Conclusion of Literature Review

The literature indicates a positive relationship between digital transformation and economic growth in different countries but no specifics on the South African perspective. It further suggests that technological advancement improves institutional quality through the reduction of corruption using automation enabling transparency by making information publicly available. The literature indicated that not enough research has been conducted to cover the individual countries in Africa. It further reveals that more investigation of digital transformation on economic growth has been widely studied for different regions as indicated in the literature review.

However, the evidence suggests that there is no unified method to measure digital transformation due to the unavailability of comprehensive data in some of the underdeveloped regions. Nonetheless, all studies on economic growth and digital transformation share the consistent results which indicate a positive relationship between the two aspects regardless of the detailed methods of measurement. It has been consistently suggested that a digitally transformed economy has a high propensity to improve economic growth in the form of gross domestic product. The other most echoed sentiment also included the impact of good institutions on the countries and not to solely rely on ICT to solve all socio-economic challenges. The literature further expresses that poor countries have not always benefited from digital transformation due to a lack of good institutional quality.

CHAPTER 3. RESEARCH METHODOLOGY

This chapter provides a detailed breakdown of how this study conducted its analysis using secondary data of time series data from the World Bank and the United Nations Conference on Trade and Development (UNCTAD) for a control variable. The data for digital transformation and economic growth from 1990 to 2022 for South Africa. The data period was driven by the availability of the data, prior to 1990 only one ICT variable data was collected by the World Bank for South Africa and the 33 years' worth of data was sufficient for this research analysis and it's also consistent with previous similar studies' sampling strategies. The approach follows a quantitative method using the recommended STATA tool for principal component analysis for the index and regression.

3.1. Research Paradigm

Interpretivism is founded on the notion that one perceives the world's realities based on human experience and social constructs, which makes it appropriate to study human behaviours and is commonly used in qualitative studies (Goldkuhl, 2012; Pervin & Mokhtar, 2022). The interpretation of human behaviours can be observed from the language and actions. Pragmatism is concerned with the study investigating action and change and the dynamic relationship between knowledge and action, generally employed where active involvement (i.e. public administration) occurs not merely observations (Goldkuhl, 2012). While positivism strongly suggests that any truth must be tested and confirmed through empirical evidence (Junjie & Yingxin, 2022).

This study will attempt to address its objectives using empirical data from public databases and conclude on its observations thus following positivism. The findings will rely on quantitative evidence using statistical techniques as similar studies have demonstrated the approach previously like the following (Fengju & Wubishet, 2024; Kouadio & Gakpa, 2022; Olaniyi & Odhiambo, 2023). The sole focus on empirical evidence without any form of Interpretivism and the elimination of subjectivism

through data analysis during this study suggests the use of positivism (Junjie & Yingxin, 2022). This approach will allow the research to deduce its conclusion objectively without any biases for its validity.

3.2. Research Approach

The quantitative method is a research strategy which uses numerical data to test theories and hypotheses, it emphasises the gathering of data and analysis using statistical and mathematical techniques (Foster et al., 2021). This approach incorporates natural science methods embedded in positivism (Foster et al., 2021). This study will therefore use a quantitative method for its data analysis since it meets the research approach to use quantifiable data to test its hypothesis. This is a quantifiable approach to analyse numeric data representing proxies for digital transformation and economic growth. The statistical technique will be deployed to assist this research in understanding the correlation between variables and to test the hypothesis for conclusions. All findings for this study are dependent on the quantitative methods to reject or fail to reject the hypothesis. This approach is also a common tool researchers use to investigate data related to economic activities and the only feasible means to assess this study's scope considering the scale.

3.3. Data and Sample

This study employs secondary data of a longitudinal design by investigating annual time series data from 1990 to 2022 for South Africa. The population selection is based on data availability and provides sufficient 33 years' worth of data to confidently conclude its findings. The analysis attempted to derive statistical observations using this design commonly used by similar studies (Gustafsson, 2010). The characteristics of this study and the intended types of data to be used to address the objective have directed the choice to use this research design. Also, this research is characterised by most of the characteristics of longitudinal design involving observing the same unit at more than one time and it does not permit any form of manipulation (Gustafsson, 2010). The analysis was conducted using

regression to test the dependent variable (economic growth) with the independent variable (digital transformation) and controlling variables. The end goal was to test the hypothesis as defined in chapter one however, due to missing data from the World Development Indicators (WDI) datasets, the study implemented the “ipolate” command from the STATA tool and moving averages to address missing data. The study acknowledges the common challenges of using these methods, one being that they assume data linearity; therefore, interpolation may be misleading in some cases and can also cause multicollinearity. Due to this, further tests were conducted as discussed next chapter to diagnose the data suitability.

3.4. Definition of variables and source

3.4.1. Dependent Variable

3.4.1.1. Economic Growth (GDP)

The dependent variable for this study is economic growth in the form of real GDP per capita (current US$) as a proxy from the World Development Indicators (WDI) of the WorldBank (WorldBank, 2024c). This is in line with previous studies which implemented real GDP per capita ensuring that the population's standard of living, economic well-being and inflation are all considered (Awad & Albaity, 2022; Behera et al., 2024; Kouadio & Gakpa, 2022; Mwananziche et al., 2023). Therefore, economic growth is the dependent variable to be measured for this study to ascertain how it is influenced by the independent variable.

3.4.2. Independent Variables

3.4.2.1. Digital Transformation Index (DTI)

Digital transformation refers to the adoption of digital technologies enabled through ICT infrastructure to fundamentally change business or government operations and create value for customers (Kraus et al., 2021). Digital transformation is a complex phenomenon that continues to disrupt every industry. However, there is insufficient data to quantify every aspect of it; therefore, an approach based on previous literature was adopted. This study will implement a Digital Transformation Index (DTI) using a data reduction technique: Principal Component Analysis (PCA) to reduce the large data sets into a small and manageable dataset while preserving the features of the original data (Horvey et al., 2024; Salih Hasan & Abdulazeez, 2021). This study

will calculate the DTI using PCA in line with other previous similar studies as described in the literature by using mobile cellular subscriptions (per 100 people), fixed broadband subscriptions (per 100 people), fixed telephone subscriptions (per 100 people), individuals using the Internet (% of the population), similar to previous studies (Adeleye et al., 2022; Horvey & Odei-Mensah, 2024; Raifu et al., 2023). Due to the lack of digital transformation data availability in South Africa, this study adopted the above-mentioned variables as a proxy to calculate the index. The speed of digital transformation is not uniform and can be measured in different forms; it is therefore important to use multiple variables to ensure that all technological advancements for countries are considered. The following gives details on the individual data/variable of the DTI and its importance in this study.

3.4.2.2. Fixed Broadband Subscriptions (FBD)

Access to high-speed to public internet ((a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s) is important for consideration therefore, fixed broadband subscriptions part on the index (WorldBank, 2024c). The fixed broadband provides ultra-fast internet connection using cable, fibre optics, and wireless enabling optimal operations for businesses and individuals. This variable provides a picture of how advanced the country is at from fast internet connectivity. The general information indicates that most African countries are behind on high-speed infrastructure connectivity which is important for this study to consider it (AfricanUnion, 2020)

3.4.2.3. Fixed Telephone Subscriptions (FTS)

The fixed telephone is one of the early forms of communication to disseminate information, it is commonly used in office spaces and it can be converted into an internet service if connected to broadband (Adeleye et al., 2022). The fixed telephone subscriptions will contribute to this study by accounting for the total number of active analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones (WorldBank, 2024c). Since this variable holds the old method of communication, it will provide data which indicates how the country has transitioned over time.

3.4.2.4. Mobile Cellular Subscriptions (MCS)

Likewise, mobile cellular subscriptions will ensure the study accounts for the availability of ICT infrastructure and the use of cellular technology also contributes by indicating postpaid subscriptions active accounts, as previously indicated that most people in Africa access the internet using mobile (AfricanUnion, 2020). The mobile phone is a commonly used communication device for both individuals and corporations due to its small size making it portable and easy to use to disseminate information. Mobiles also serve as the channel for most of the financial services including mobile money such makes it more important to individuals for economic activities.

3.4.2.5. Internet Users (IU)

Lastly, the study will also use the number of individuals using the Internet regardless of the actual device used i.e. computer, mobile phone, personal digital assistant, games machine, digital TV etc. This data point will contribute to the creation of the index by accounting for the percentage of the population using the internet as one of the indicators for a digitally transformed country.

3.4.3. Control Variables

3.4.3.1. Institutional Quality (InIQ)

The study uses institutional quality as one of the controlling variables from the Heritage Foundation database (Index of Economic Freedom), also known as the Heritage Index of Freedom as previously used by other studies (Ayana et al., 2024; Behera et al., 2024). The Index of Freedom eliminated issues like multicollinearity, which can arise due to the vast number of variables that institutional quality entails (Evans, 2023; HeritageFoundation, 2023). The index is based on 12 quantitative and qualitative factors which are aggregated into four groups Rule of Law (property rights, government integrity, judicial effectiveness), Government Size (government spending, tax burden, fiscal health), Regulatory Efficiency (business freedom, labour freedom, monetary freedom) and Open Markets (trade freedom, investment freedom, financial freedom), each variable is scored between 0 and 100 and an overall score that is an average of all twelve factors (HeritageFoundation, 2023). This study only uses the overall score to analyse the role of institutional quality. It has been argued that poor institutional quality in emerging countries weakens the

ambitions of economic development (Boukhatem & Ben Moussa, 2023). For an economy to grow it requires a strong and stable government with high institutional quality, zero tolerance for the wastage of public resources (Evans, 2023). It is therefore important to consider the government's involvement in this study as a controlling variable.

3.4.3.2. Gross Fixed Capital Formation (% of GDP) (formerly gross domestic fixed investment) (lnGFC)

To ensure that the findings of this study are independent of other influencing factors, it used multiple control variables, with one being Gross fixed capital formation (% of GDP) (formerly gross domestic fixed investment) which incorporates improvements in plant, machinery, and equipment purchases and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings (WorldBank, 2024c). This will allow the study to account for investment in fixed assets by businesses, governments, and households within an economy. It also provides a view of how the economy is investing in the future of productive capability.

3.4.3.3. Labour Force Rate (lnLR)

The labour force rate from WDI, this variable will mitigate any effects from the workforce participation that can influence the study (WorldBank, 2024c). This indicator contributes to the study by measuring the extent to which the working-age population is engaged in the economy through active work or actively seeking employment.

3.4.3.4. Trade Openness (lnTR)

Behera et al. (2024), suggested that countries that openly communicate trade information are more likely to receive investment interest from the global market which can stimulate economic growth, so trade openness from WDI will be the third controlling variable.

3.4.3.5. Foreign Direct Investment (lnFDI)

Meanwhile, an economy with a strong ICT infrastructure investment becomes a catalyst for foreign direct investment (FDI) by simplifying communication with the global market (Awad & Albaity, 2022). This study therefore, implemented FDI as the fifth controlling variable from the United Nations Conference on Trade and Development (UNCTAD) database which is consistent with previous literature (Kouadio & Gakpa, 2022; UNCTAD, 2024). The significant investment, expertise and global standards for digital infrastructure is generally driven by the private sector therefore, this study must account for FDI.

3.4.3.6. Education Expenditure (% of Gross National Income – GNI) (InE)

An educated society is more likely to benefit more from ICT through the Internet and mobile services due to the level of digital literacy acquired, which ultimately contributes to economic growth and R&D initiatives (Aljneibi et al., 2024). The education expenditure (% of Gross National Income – GNI) will be the sixth implemented controlling variable for this study.

3.4.3.7. Inflation Rate (InIF)

The study also used the inflation rate from the WDI, which is a measure of the consumer price index calculated by the annual percentage change of the cost of an average basket of goods and services originally sourced from the International Monetary Fund and International Financial Statistics (WorldBank, 2024c). The high inflation increases the cost of importing technology equipment and subsequently discourages local businesses, foreign investors and the government from investing in ICT infrastructure. Therefore, a low/stable inflation is a favourable one for economic growth and it can stimulate spending on digital services, hence it is also accounted for during this study.

3.5. Regression and Estimation Technique

This study employed multiple linear regression to analyse the impact of digital transformation on economic growth from the South African perspective.

The model for estimating the dependent variable (DGDP) is given as follows:

$$DGDP_t = \beta_0 + \beta_1 GDP_t + \beta_2 DTI_t + \beta_3 X_t + \varepsilon_t \ldots\ldots\ldots\

3.6.2. Cointegration Test

Once the data stationarity has been tested for this study's time series data, it is then imperative to subject it to an appropriate cointegration test. Given that there are multiple cointegration approaches, the result of the stationarity test will determine the appropriate method. The stationarity results indicate a series integrated at order 1 indicating stationarity at first difference a Johansen test will be conducted (Johansen, 1991). However, a series integrated in both orders I(0) and I(1), the study employs the Bound test (Pesaran et al., 2001). The ARDL bounds testing approach to cointegration for this study is as follows in equation (3). This ARDL bounds test model is essential for this study to ensure that the long-run or short-run relationship between the dependent and explanatory variables is determined.

$$DGDP_t = C+\alpha GDP_{t-1}+\beta DTI_{t-1}+\gamma InGFC_{t-1} + \psi InLR_{t-1} + \delta InTR_{t-1} + \eta InE_{t-1} + \text{ɤ}InIQ_{t-1} + \iota InIF_{t-1}$$

$$+ \sum_{i=1}^{k} \lambda_i DGDP_{t-1} + \sum_{i=0}^{k} \mu_i DDTI_{t-1} + \sum_{i=0}^{k} \pi_i DInGFC_{t-1} + \sum_{i=0}^{k} \varpi_i DInLR_{t-1} +$$

$$\sum_{i}^{k} \rho_i DInE_{t-1} + \sum_{i=1}^{k} \tau_i DInIQ_{t-1} + \sum_{i=1}^{k} \text{ɟ}_i DInIF + \varepsilon_t \quad \text{.....(3)}$$

The long-run multipliers are α, β, γ, ψ, δ, η, ɤ and ι, where the first difference is denoted by the letter *D,* and the coefficients measuring the short-term dynamics are represented by λ, μ, π, ϖ, ρ, τ, ɟ and error term ε.

The study assumes a null hypothesis of no cointegration (no long-run effect).

Thus,

$H0$: $\alpha = \beta 0 = \gamma 1 = \psi 2 = \delta 3 = \eta 4 = \text{ɤ}5 = \iota 6 = 0$ (no cointegration)

HA: $\alpha \neq \beta 0 \neq \gamma 1 \neq \psi 2 \neq \delta 3 \neq \eta 4 \neq \text{ɤ}5 \neq \iota 6 \neq 0$ (cointegration exists)

A further calculation of the ECM model specified is represented in equation (4) which provides details of short-run relationship given cointegration or if long-run relationship exists between the dependent and explanatory variables.

$$DGDP_t = C + \sum_{i=1}^{k} \lambda_i DGDP_{t-1} + \sum_{i=0}^{k} \mu_i DDTI_{t-1} + \sum_{i=0}^{k} \pi_i DInGFC_{t-1} + \sum_{i=0}^{k} \varpi_i DInTR_{t-1} +$$

$$\sum_{i}^{k} \rho_i DInE_{t-1} + \sum_{i=1}^{k} \tau_i DInIQ_{t-1} + \sum_{i=1}^{k} \upsilon_i InIF_{t-1} + \varphi ECM_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

φ denotes the adjustment speed towards equilibrium in the long-run. ECM_{t-1} denotes short-run disequilibrium adjustments of long-run error term estimates.

3.7. Ethical considerations

This study will use secondary data from reputable online databases (World Bank, and UNCTAD) and both have been used extensively by previous studies which validate academic reliability. These sources have made the data publicly available for policymakers, advocacy groups, businesses and academia to make informed decisions about global issues as indicated by them (HeritageFoundation, 2023; UNCTAD, 2024; WorldBank, 2024c). It is therefore ethical to use this data and all data analysis during this study will ensure that the data integrity is always maintained and no unethical data processing will be conducted.

CHAPTER 4. PRESENTATION OF RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter presents all the results of the data variable trends, ADF unit root test, and regression model as defined in chapter three and discussions of the results.

4.2. Trends in GDP

The **Figure *3*** below depicts the real GDP per capita of South Africa from 1990 to 2022, which is the gross domestic product divided by midyear population and data in current U.S. dollars from WDI (WorldBank, 2024c). The GDP data was further transformed into logarithm values (Log GDP) using the STATA tool. This study adopted the use of log values for GDP throughout the analysis to ensure simplified data while preserving the original integrity. The data shows a volatile GDP over time with the lowest being 14% in 2002 against 1990 however, a significant increase was observed between 2001 to 2010 of over 181%. South Africa as an active player in the global economy and heavily reliant on commodity prices, is therefore not immune to any external shocks that ultimately impact its GDP. However, the most contributing factors of GDP volatility are mainly driven by the electricity crises (load shedding) which started in 2007 and later became stronger in 2022, in addition to corruption issues and political instability (WorldBank, 2024b). These challenges have exacerbated socio-economic conditions through high unemployment and high inequality (WorldBank, 2024b).

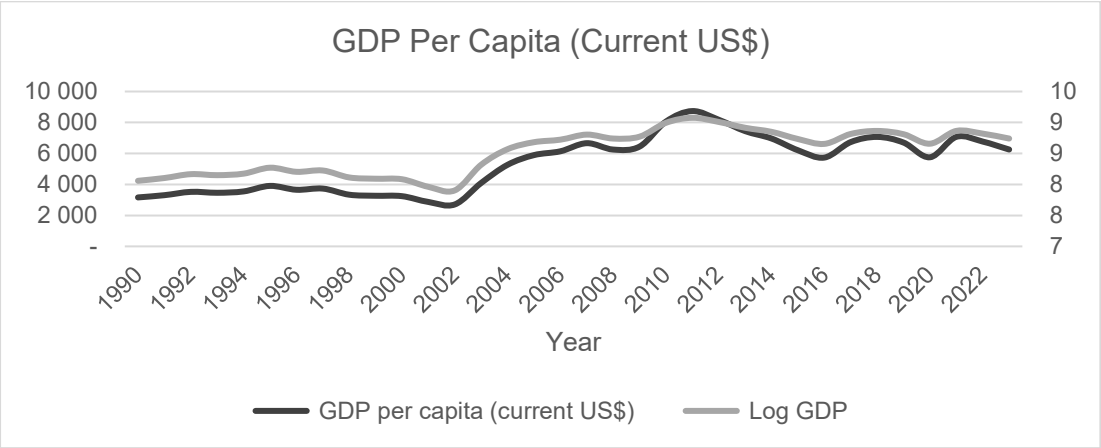

Figure 3: Trends in GDP
Source: Author's Construction with WDI

4.3. Trends in Mobile Cellular and Internet Users

The **Figure *4*** below indicates the number of individuals using the internet or mobile cellular (per 100 people) between 1990 and 2022 from WDI (WorldBank, 2024c). The data shows that in South Africa, very few people had access to either the internet or mobile cellular prior to 1998, a steady increase started thereafter and continues to increase. This data shows a positive undertaking by the country to invest more in mobile and internet connections. These technological adoptions further highlight that people are using more than one mobile since the latest number is above 100 per 100 people and this aligns with the same finding from the African Union (AfricanUnion, 2020). Similarly, with internet users, they are close to 100 per 100 people which shows that more people have access to the internet than before and such will have a potential positive impact on economic growth and socio-economic conditions of the society. The more communities have access to technology it makes it easy for them to participate in economic activities and access valuable information that can improve living conditions.

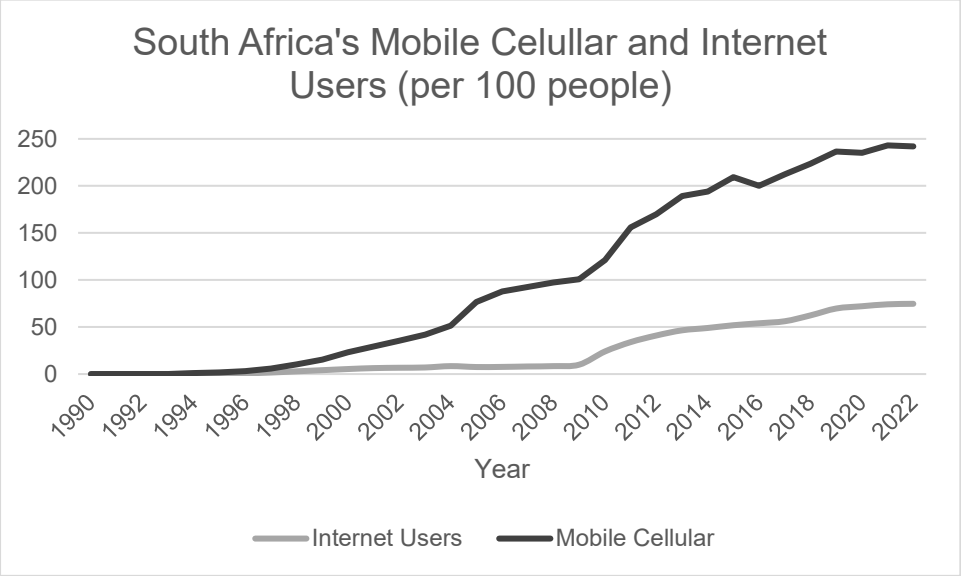

Figure 4: Mobile Cellular and Internet Users
Source: Author's construction with WDI

4.4. Trends in Fixed Telephone and Fixed Broadband

Figure *5* below depicts fixed telephone (per 100 people) and fixed broadband (per 100 people) trends over the 33 years (1990 – 2022) from WDI (WorldBank, 2024c).

The data for fixed telephone shows an upward trajectory from 1990 until 1999 and thereafter a downward trend with a noticeable 65% decrease between 2007 and 2019. Whereas fixed broadband started at a very low level but continued to increase over time. These two trends indicate a possible future intersection with one on an upward trajectory and the other deteriorating trend. This indicates that in South Africa more investment is being made in fixed broadband and fixed telephone is no longer prioritised due to other substitute technologies. The deterioration of fixed broadband from 2014 is partly driven by a decline in fixed-line broadband, the traditional ADSL that was experienced by the major supplier Telkom and that was attributed to fibre-to-the-home deployed by companies like Vumatel; also, other internet mobile services providers were introducing fixed-LTE products (MyBroadband, 2018). These developments demonstrated a positive trajectory of digital transformation for the country since high-speed infrastructure was being deployed while mobile services were also increasing.

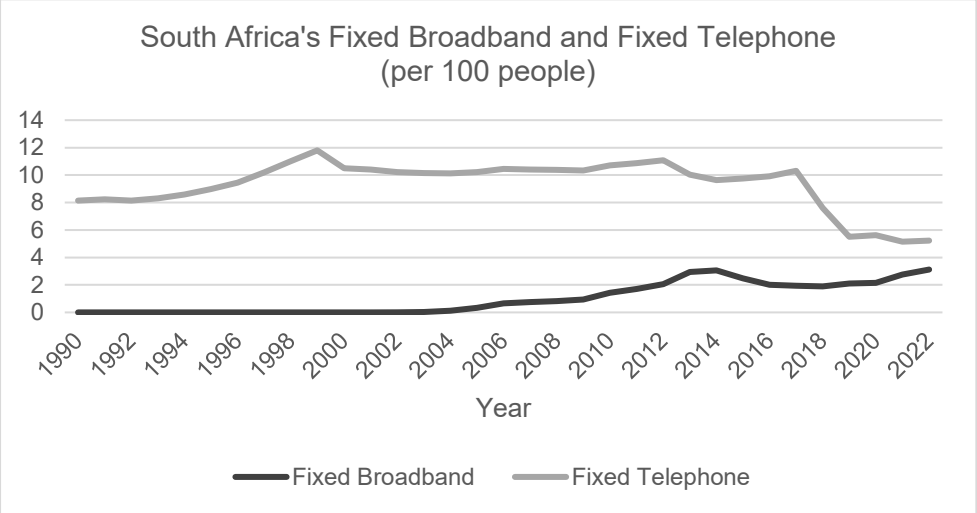

Figure 5: Fixed Broadband and Fixed Telephone
Source: Author's Construction with WDI

4.5. Principal Component Analysis (PCA) for Digital Transformation Index (DTI)

Different approaches have been employed to measure digital transformation due to a lack of a unified definition and data availability. Due to the complexity and several variables often highly correlated contributing to digital transformation for any given country, this study implemented a PCA to reduce variables in one index. The eigenvalue of the first component is 3.54 and explains 88% of the variation as

illustrated on **Table 1,** making it the only component used for the PCA calculation ("a value greater than 1 means that the component captures more variance than its nominal share of the total variance of the variables") as previously mentioned (Adeleye et al., 2022). To further justify the index, a Kaiser-Meyer-Olkin (KMO) index is employed which is a measure of sampling adequacy and it compares the partial correlations and correlations between variables (Adeleye et al., 2022). A KMO value of above 0.5 justifies the use of PCA (Adeleye et al., 2022; Horvey et al., 2024). Therefore, the KMO of 0.7506 from this study allows the use of PCA to calculate the digital transformation index. Furthermore, **Figure *6*** illustrates the eigenvalue in the scree plot as shown indicating the use that only the first component is above the value of 1.

Table 1: DT Index, eigenvalues, correlation matrix and KMO

Component		Eigenvalue	Difference	Proportion	Cumulative
Component 1		3.54	3.18	0.88	0.88
Component 2		0.36	0.30	0.09	0.98
Component 3		0.06	0.03	0.02	0.99
Component 4		0.04	-	0.01	1.00
Variables	DTI	FBD	FTS	MCS	IU
DTI	1.000				
FBD	0.963	1.000			
FTS	-0.859	-0.738	1.000		
MCS	0.952	0.945	-0.687	1.000	
IU	0.983	0.927	-0.831	0.933	1.000
Kaiser-Meyer-Olkin (KMO) Index = 0.7506					

Note: DTI = Digital transformation index; FBD = Fixed broadband subscriptions; FTS = Fixed telephone subscriptions; MCS = Mobile cellular subscriptions; IU = Individuals using the Internet
Source: Authors' Construction

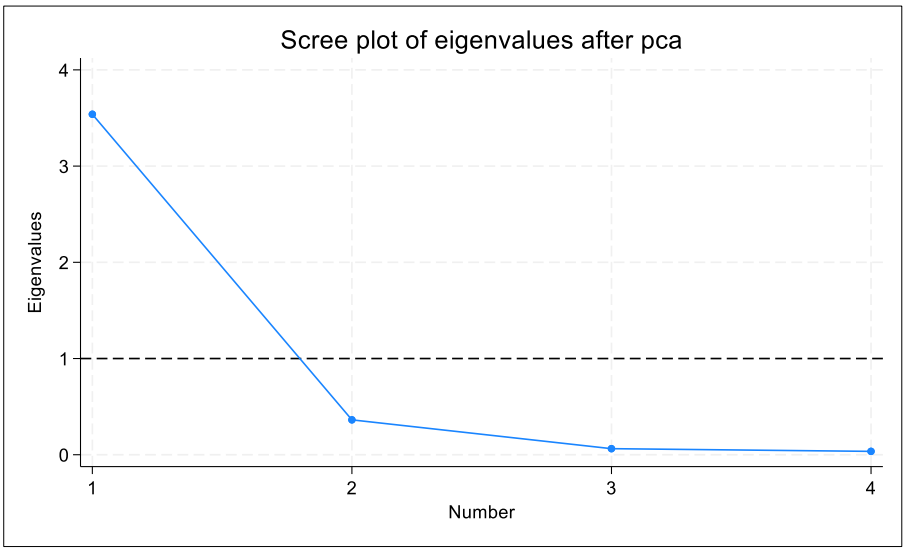

Figure 6: Scree plot of principal component of DT Index
Source: Authors' Construction

4.6. Descriptive Analysis of Variables and Interpretation

The study uses annual time series data of 33 years from 1990 to 2022. **Table 2** shows the statistical characteristics, including mean, standard deviation and variance inflation factor (VIF) for this study. The GDP in a log value shows a mean value of 8.5 for the study periods with institutional quality having the maximum mean of 62 over the study period. The VIF values show that the data is not highly correlated, which proves this series' nonexistence of multicollinearity (Horvey et al., 2024).

Table 2: Descriptive statistics of variables

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max	VIF
GDP	GDP per capita	33	8.519	0.361	7.900	9.080	-
DTI	Calculated via PCA	33	0.000	1.881	-2.007	3.815	3.08
lnGFC	Gross fixed capital formation (% of GDP)	33	16.461	1.971	13.180	21.610	1.66
lnLR	Trade (% of GDP)	33	52.086	5.328	37.510	59.070	4.21
lnTR	Labor force participation rate	33	49.393	8.484	34.320	65.970	4.79
lnE	Education expenditure (% of GNI)	33	5.592	0.532	4.800	6.600	2.32
lnIQ	Institutional Quality	33	62.409	5.728	42.400	83.500	1.52
lnIF	Inflation, consumer prices (annual %)	33	6.657	3.386	-0.690	15.330	1.97

Note: DTI=Digital transformation index
Source: Authors' Construction

4.7. Correlation analysis

The **Table 3** below is the result of the Pearson Pairwise matrix for correlation, which indicates that there is a positive correlation between DTI and GDP. The relationship is also significant. lnTR is the second most correlated to GDP, followed by lnGFC and lnLR and is highly significant, while DTI is the highest correlated and significant. Only lnIQ and lnIF have a negative correlation to GDP. There is also a strong correlation between DTI and lnTR. The series shows a mix of correlations some being positive and others negative.

Table 3: Correlation Analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GDP	1.000							
(2) DTI	0.750***	1.000						
(3) lnGFC	0.357**	-0.027	1.000					
(4) lnLR	0.376**	0.278	0.074	1.000				
(5) lnTR	0.727***	0.704***	0.258	0.628***	1.000			
(6) lnE	0.120	0.332*	-0.283	-0.470**	-0.057	1.000		
(7) lnIQ	-0.072	-0.223	-0.027	-0.250	-0.091	-0.153**	1.000	
(8) lnIF	-0.521**	-0.366	0.280	-0.531**	-0.449**	0.052	-0.053	1.000

Note: Significant values include: *** p < 0.01, ** p < 0.05, * p < 0.1; GDP= Gross domestic product per capita; DTI=Digital transformation index; lnGFC=Gross fixed capital formation; lnLR=Labor force participation rate; lnTR=Trade; lnE=Adjusted savings: education expenditure; lnIQ=Institutional Quality; lnIF=Inflation
Source: Authors' Construction

4.8. Regression Analysis

The main purpose of this study is to determine whether there is a relationship either positive or negative between digital transformation and economic growth from the South African perspective. Further, the study extended to investigate whether the relationship is short-run or long-run. Given these objectives, the regression was therefore employed as a statistical tool to ascertain the relationship between a dependent variable and an independent variable (Lewis-Beck & Lewis-Beck, 2015). The relationship between a dependent variable and an independent variable could be influenced by other factors directly or indirectly hence the use of control variables was implemented during the analysis.

Table 4, Shows the data observed by the main model (1) is represented by R^2 of 88% on the DTI variable and the R^2 of the individual variables is 80% and 88%. This reveals that the dependent's variability is observed similarly in the consolidated index of the individual variables making up the digital transformation index. The Durbin–Watson d-statistic of 0,86 from the model (1) reveals a value lower than the R^2 of the same model.

The regression of the dependent variable (GDP) against all independent variables is illustrated in **Table 4**. This summary includes the regression of DTI and the individual variables making up the index. **Table 4** shows the positive relationship between the dependent variable against DTI, FBD, MCS and UI with all controls being constant at a 1% significance level. However, FTS indicate a significant and negative relationship with all controls remaining the same. The noticeable deviation of FTS is

consistent with the trends from **Figure *5*** which indicated a downward trend of FTS contrary to MCS on **Figure *4***. The inverse of FTS and MCS indicates that both individuals and organisations continue to migrate to new and portable device for communication which is the mobile device.

Table 4: Digital Transformation Index (Fixed telephone, Fixed broadband, Mobile cellular subscriptions and Internet Users) and economic growth

Variables	(1)	(2)	(3)	(4)	(5)
lnGFC	0.101***	0.080***	0.080***	0.107***	0.121***
	(0.017)	(0.018)	(0.016)	(0.019)	(0.019)
lnLR	0.002	0.000	-0.002	0.000	0.004
	(0.01)	(0.011)	(0.009)	(0.011)	(0.01)
lnTR	-0.002	-0.002	-0.004	0.002	0.004
	(0.007)	(0.008)	(0.006)	(0.007)	(0.006)
lnE	0.084	0.043	0.089	0.094	0.140**
	(0.074)	(0.084)	(0.07)	(0.082)	(0.074)
lnIQ	0.005	0.002	0.002	0.003	0.007
	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
lnIF	-0.050***	-0.047***	-0.038**	-0.049***	-0.064***
	(0.011)	(0.012)	(0.011)	(0.012)	(0.011)
DTI	0.114***				
	(0.024)				
FBD		0.194***			
		(0.05)			
MCS			0.004***		
			(0.001)		
IU				0.007***	
				(0.002)	
FTS					-0.069***
					(0.015)
Observations	33	33	33	33	33
Prob > F	0.000	0.000	0.000	0.000	0.000
R-squared	0.877	0.849	0.883	0.842	0.883

Note: Standard errors in parentheses, Significant values include: *** p < 0.01, ** p < 0.05, * p < 0.1.
GDP= Gross domestic product per capita; DTI=Digital transformation index; FBD = Fixed broadband subscriptions; FTS = Fixed telephone subscriptions; MCS = Mobile cellular subscriptions; IU = Individuals using the Internet; lnGFC=Gross fixed capital formation; lnLR=Labor force participation rate; lnTR=Trade; lnE=Adjusted savings: education expenditure; lnIQ=Institutional Quality; lnIF=Inflation
Source: Author's Construction

4.8.1. Digital transformation index (DTI) and economic growth

The results demonstrated a highly significant relationship between the main independent variable (DTI) and economic growth based on the p-value. These results concur with the empirical evidence from previous studies that digital transformation has a positive impact on economic growth (Awad & Albaity, 2022; Evans, 2023; Hussain et al., 2023; Nchake & Shuaibu, 2022). Using this index, the

study fails to reject the null hypothesis and confirms the relationship between these variables. Further, the standard error of 0.024 affirms that the results are reliable due to the small discrepancy in the population it explains. However, it's worth noting that the standard error for DTI is slightly higher yet acceptable compared to the individual variables on the index except for FBD. Given these results, literature has highlighted and cautioned against the sole dependence on digital transformation to resolve all socio-economic problems through economic growth for any country (Ejemeyovwi et al., 2021). The future investment into digital transformation could be endorsed by such data-driven insight for all interested parties, whether private or public.

4.8.2. Fixed broadband subscriptions (FBD) and economic growth

The regression of FBD on GDP as an individual variable of the DTI with all other control variables constant is illustrated from **Table 4** as model (2). The results of model (2) show that there is a stronger and highly significant relationship between FBD and GDP which aligns with the main results of model (1), for every increase in FDB of 1% the GDP will increase by 0.194 assuming all other variables remain constant. There is a continuous increase in investment in FBD as illustrated on **Figure 5**, this is partly driven by the drop in the price of broadband and an increase in infrastructure by the private sector (Gaglio et al., 2022). The impact of having an increase in FBD ensures that other ICT technologies such as mobile also improve since it provides the base for fast internet. However, it has also been argued that not every country with an increase in technology like FBD have benefited but developed countries turns to benefited more due to lack of good institutional structures from underdeveloped economies (Behera et al., 2024; Boukhatem & Ben Moussa, 2023).

4.8.3. Mobile cellular subscriptions (MCS) and economic growth

Model (3) from **Table 4** shows the results of the regression of MCS on GDP with all other variables constant. Among all the individual variables of the DTI, the MCS results indicate the lowest coefficient and standard error of 0.001 and 0.004 respectively and highly significant with an R^2 of 88%. This means that the strength of the relationship between MCS and GDP is relatively weak with less variability in the estimate model. The number of MCS in South Africa has been on an upward trajectory surpassing the FTS at a higher rate than those from the high-income

countries considering a low start (Gaglio et al., 2022). The data evidence suggests that MCS continues to increase at a higher rate than that of GDP hence the relationship is weak, this surfaces the previous findings which suggested that tech-savvy nations like India do not exhibit enough evidence to confirm that the ICT advancement rate will always lead relative economic growth rate (Pradhan et al., 2021).

4.8.4. Internet Users (IU) and economic growth

The number of people using the internet is driven by the availability of infrastructure for connectivity, access to the appropriate devices and individual skills. The results of IU represented by model (4) from **Table 4** shows a similar result as the model (2) and model (3) with a coefficient and standard error of 0.007 and 0.002 respectively. The result also confirms that there is a positive relationship between UI and GDP at 1% significance level. These results are consistent with other studies which show technological advancements such as the internet have contributed positively to economic growth (Awad & Albaity, 2022; Behera et al., 2024; Boukhatem & Ben Moussa, 2023; Ejemeyovwi et al., 2021; Zhang et al., 2022). The results further encourage that a high number of internet users indicate there is interconnection with the global economy and information dissemination to better equip and upskill the public on economic participation.

4.8.5. Fixed telephone subscriptions (FTS) and economic growth

Among all the variables used to derive the DTI using CPA, FTS is the only one which shows a negative relationship with GDP, as illustrated in the regression model (5) from **Table 4**. These results are consistence with the trend illustrated in **Figure *5*** showing a downward trend. As such as FTS is one of the old ICTs, it has seen disinvestment due to other convenient, efficient and cheaper alternatives. The results show a coefficient of -0.069 with a standard error of 0.015 at a 1% significance level, proving that FTS has an inverse relationship to GDP. However, this type of relationship does not always imply a cause-and-effect phenomenon. The general assumption is that using new and advanced technologies to replace FTS will not necessarily reduce the GDP but instead could increase it through the alternatives.

There is no evidence from previous literature for FTS impact from a South African context, however, ICASA (2024) has reported that fixed-line revenue has reduced by 18.24% over the past 5 years which aligns with the results of this study.

4.8.6. Control variables and economic growth

Notable and consistent results of gross fixed capital formation (% of GDP) (formerly gross domestic fixed investment) (lnGFC) show a significance at level 1% and a positive relationship between this variable with GDP throughout all the models as illustrated on **Table 4**. These findings are also consistent with previous studies which have concluded that lnGFC enhances economic growth in BRICS countries inclusive of South Africa (Kesar et al., 2023). The capital investment in assets represented by lnGFC indicates that economic growth will likely improve provided that all other institutional structures are operating optimally. The regression on lnLR shows a mix of results with model (2) and model (4) coefficient at 0.000, the rest being very low and negative, indicating there is no relationship between the variable and GDP. The rate of unemployment has impacted the lnLR which the World Bank has highlighted as one of the factors negatively impacting economic growth in the country (WorldBank, 2024b).

Trade Openness (lnTR) shows a negative coefficient for the first three models, however, (Maliaga, 2019) has concluded that trade openness has a positive impact on economic growth in the long run for South Africa. A similar regression result for lnE and lnIQ showed a positive relationship with the variables with GDP. It has been highlighted by scholars that institutional quality is very important for any endeavour to improve economic growth, even technological advancement without it could be non-beneficial (Evans, 2023). Lastly, the lnIF representing inflation show a negative and 1% significance level mostly affirming the previous study which concluded that South Africa's inflation impacted economic growth negatively (Sekwati & Dagume, 2023). This proves that inflation has been deteriorating in South Africa which has a direct impact on the economy. Interventions are generally employed by the government to control inflation for economic growth to flourish.

4.9. Unit Root Test

Part of making sure the econometric series data is fit for purpose is to test for data stationarity to ensure the is not spurious rendering the analysis invalid. **Table 5**, reveals the t-statistic result of the Augmented Dickey-Fuller (ADF) Unit Root Test (Dickey & Fuller, 1979). The test indicates the series is not stationary at level I(0) except for lnIF and the rest of the variables at stationary first difference log level I(1). This indicates a series that is integrated in different orders a combination of I(0) and I(1).

Table 5: ADF Unit Root Test on Variables

	Log level (t-statistics)	1st Difference at log level (t-statistics)	Conclusion
GDP	0.699	-3.8780	I(1)
DTI	0.097	-3.5430	I(1)
lnGFC	-0.476	-3.9300	I(1)
lnLR	0.591	-4.7810	I(1)
lnTR	0.963	-4.1860	I(1)
lnE	0.365	-5.3820	I(1)
lnIQ	-1.183	-13.991	I(1)
lnIF	-1.967	-5.1210	I(0)

Note: GDP= Gross domestic product per capita; DTI=Digital transformation index; lnGFC=Gross fixed capital formation; lnLR=Labor force participation rate; lnTR=Trade; lnE=Adjusted savings: education expenditure; lnIQ=Institutional Quality; lnIF=Inflation
Source: Authors' Construction

4.10. Bounds Cointegration Test

The results of the unit root test from **Table 5** provide guidelines for the test to use after the unit root test. Pesaran et al. (2001), prescribe a Bound Cointegration test to use when a series exhibits the combination of stationarity at level I(0) and at first difference I(1). **Table 6**, below shows the F-statistic, lower bound and upper bound values at a 5% significant level.

Table 6: Cointegration (Bound Test)

F-statistics	Lower Bound I(0)	Upper Bound I(1)
1.786	2.03	4.26

Source: Author's Construction

The null hypothesis of the cointegration test suggests that there is no long-run relationship between the dependent and independent variable; therefore, if the null

hypothesis is not rejected, it indicates that there is no statistical evidence to support the existence of a long-run relationship (Kripfganz & Schneider, 2023). The test statistic provides conclusive evidence when it falls outside the critical value bounds I(0) and I(1), not rejecting the null hypothesis if it is below the lower bound, rejecting null hypothesis if it above upper bound and inconclusive if it falls between the bounds (Kripfganz & Schneider, 2023; Pesaran et al., 2001).

Given results from **Table 6** the value of the F-statistic is lower than both the lower and upper bound which indicates that the study can firmly not reject the null hypothesis and can statistically support that there is no long-run relationship between GDP and DTI for South Africa. Therefore, the study fails to reject the null hypothesis meaning there is no cointegration and concludes there is only a short-run relationship. The bound test results further confirm the objective of this study which seeks to ascertain if digital transformation and economic growth have a long-run or short-run relationship in South Africa and the results confirm the short-run and not the long-run relationship since the F statistic of 1.786 falls below lower critical value bound of 2.03 as per guidelines of the bound test (Pesaran et al., 2001).

4.11. Analysis of Long-Run and Short-Run Results

The **Table 7** present the results of Autoregressive Distributed Lag (ARDL) and Error Correction Model (ECM) model estimations as defined earlier in chapter three on equation (3) and (4).

Table 7: Results of the Estimated ARDL (1 2 2 2 0 0 0 1) ECM Coefficients

The Dependent variable is GDP		
Independent Variable	**Coefficient**	**Probability**
C	-2.749	0.300
DTI	0.175	0.569
lnGFC	0.185	0.396
lnLR	-0.266	0.701
lnTR	0.044	0.766
lnE	-0.609	0.736
lnIQ	-0.070	0.707
lnIF	-0.118	0.580

R-squared = 0.69 Adj. R-squared = 0.38 Prob(F-statistic) =0.00 DW statistics=2.167

Note: GDP= Gross domestic product per capita; DTI=Digital transformation index; lnGFC=Gross fixed capital formation; lnLR=Labor force participation rate; lnTR=Trade; lnE=Adjusted savings: education expenditure; lnIQ=Institutional Quality; lnIF=Inflation
Source: Author's Construction

The Autoregressive Distributed Lag model with order 1 2 2 2 0 0 0 1 or ARDL (1 2 2 2 0 0 0 1), the order is mapped as DTI, lnGFC, lnLR, lnTR, lnE, lnIQ, lnIF.

The F statistic seeks to explain the significance of the variance of variables while R^2 and the R^2 adjusted seek to explain how well the explanatory variables explain the dependent variable. Therefore, explains 69% of the relationship between economic growth with all explanatory variables: DTI, lnGFC, lnLR, lnTR, lnE, lnIQ and lnIF. The constant term's coefficient is estimated at -2.749 with all other variables at zero. This implies that GDP will decrease by 2.749 given all variables being constant. The variable of interest (DTI) shows a positive and significant coefficient of 0.175.

4.12. Conclusion of Results and Discussions

The chapter presented the results and discussions of dependent and independent variables. The economic growth of South Africa exhibits volatile changes over time, while the digital transformation variables show continued increases. The country's data shows investments have been made towards digital transformation except for fixed telephone which is on a downward trend due to the high adoption of mobile devices used as a primary form of communication. The results indicated that digital transformation has a positive and significant relationship with economic growth in South Africa. The data stationarity test exhibited results of the series integrated on the level and the first difference using the ADF Unit Root Test and such results prescribed the use of the Bound test. The relationship between digital transformation and economic growth is only a short-run phenomenon as per the calculation of the Bound test and ARDL model; however, the is no evidence of causality

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

The objective of this study was to investigate the impact of digital transformation on economic growth in South Africa using secondary data from 1990 to 2022 from the World Bank. The study used statistical tools namely regression, correlation, bound test, Augmented Dickey-Fuller (ADF) Unit Root Test and Autoregressive Distributed Lag model (ARDL) for analysis techniques and it also ascertained the type of relationship between the dependent and independent variables. This chapter presents the conclusion and the recommendations for this study based on the results and literature review. It also extends to suggest possible research which was not covered in this study's scope and purpose.

5.2. To investigate the role of digital transformation in economic growth

The results of this study showed that South Africa as a developing economy, has benefited positively from the digital transformation using data from 1990 to 2022. There is a positive correlation between digital transformation in an index form towards economic growth in South Africa. The study, therefore, failed to reject the null hypothesis that digital transformation can improve economic growth. The results are aligned with the previous studies which have concluded the same.

5.3. To ascertain if a short-run or long-run relationship exists between digital transformation and economic growth

The study employed the Bound test and ARDL to test the type of relationship and the results of the F-statistic value were less than the lower bound of the critical values and therefore concluded that only a short-run relationship exists between digital transformation and economic growth in South Africa. Therefore, the existence of a long-run relationship was inconclusive in this study given the time series data used. There was no evidence to suggest a causal-and-effect phenomenal between the dependent and independent variables.

5.4. Recommendations

The study highlighted policy implications that should be considered for South Africa to realise the digital transformation impact as an enabler to achieve some of the UN's sustainable goals. The continuous improvement in digital transformation remains a question for the country as the pace of ICT policy development increases, and the rate of policy implementation is an ongoing concern. Having great policies in documents without implementation plans for ICT policies will render the country a laggard in the digital era. A continuous review and improvement of the ICT framework should be adopted to ensure new technologies are addressed accordingly to ensure they are up to date with international best practices. The speed of technology globally is very high and often government entities are behind in innovations and expertise, it is therefore recommended that a public-private partnership is prioritised to ensure capacity and resource allocation for all digital transformation journeys for South Africa which can also stimulate local investment in ICT.

To test the policy and regulation for technology the use of a Regulatory Sandbox (RSB) could leverage as it has been used by the Intergovernmental Fintech Working Group (IFWG) which seeks to foster innovation in the financial sector and an internationally adopted practice (IFWG, 2022). The lack of data was one of the challenges for this study, continuous data collection on ICT for both public and private can assist in accurate measurements of ICT pace in the country and eliminate the use of proxies.

5.5. Suggestions for further research

While this study provides valuable insights into the relationship between digital transformation and economic growth in South Africa, some limitations are acknowledged. Firstly, the definition of digital transformation has not yet reached a consensus among scholars and its index was derived based on the existing ICT data points in line with previous studies. Secondly, the sample size from 1990 to 2022

was based on the availability of the data and further studies could be explored with a larger sample size.

The literature review consistently highlights the influence of institutional quality as one of the key drivers of digital transformation at a country level. Future research can investigate institutional quality as a moderating variable for digital transformation and compare different countries. The research also indicated that Africa has a younger population and is perceived to be more technologically savvy, future studies can investigate this topic with a demographic perspective to ascertain the extent of its veracity. The study of digital transformation in corporate and private sectors has the potential to assist the South African government in learning from other industries and improving policy and regulations. The comparison of South Africa and other developing economies could provide more valuable insights into areas of improvement and investment priorities for technology. Also, such a study could assist with surfacing the lessons learned from other countries and limit the chances of implementing initiatives that will not yield any positive results and instead waste resources.

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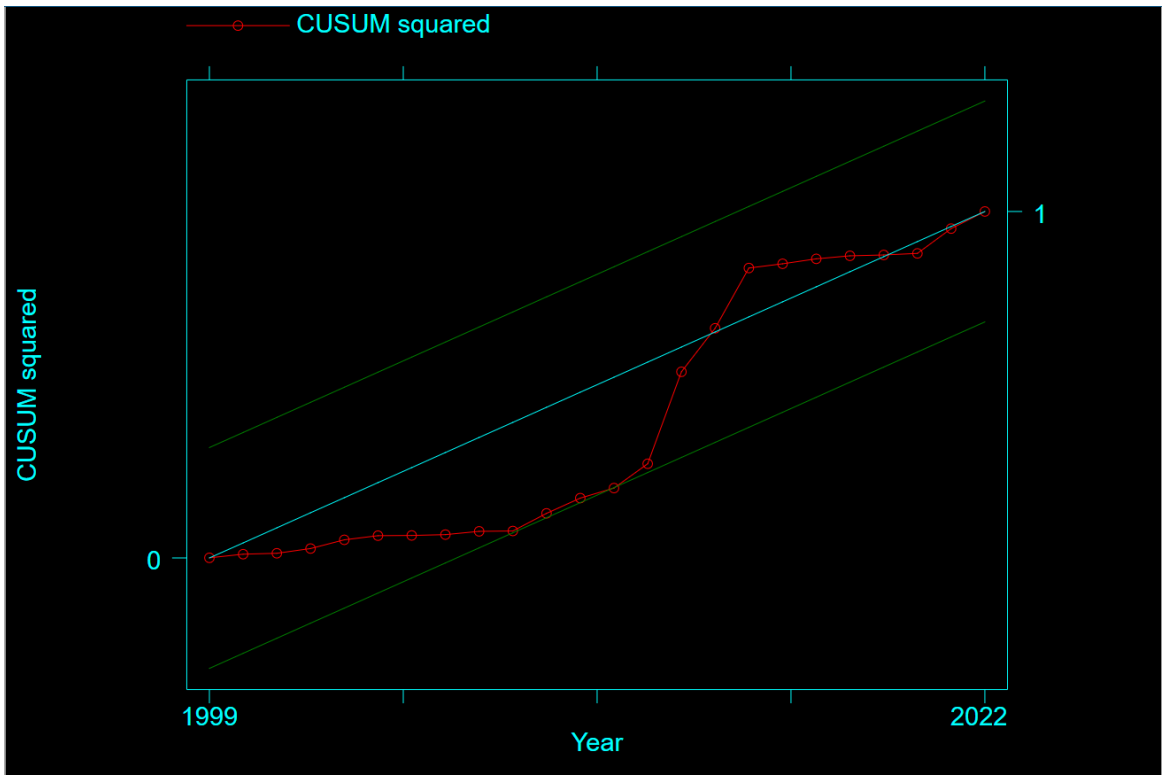
APPENDIX A

STATA Stability Tests - (cumulative sum (CUSUM) and cumulative sum squares (CUSUMSQ) tests)



APPENDIX B

STATA Results of the Estimated ARDL (1 2 2 2 0 0 0 1) ECM Coefficients

```
. ardl GDP DTI InGFC InLR InTR InE InIQ InIF ,  lags( 1      2      2      2      0      0      0      1) ec btest

ARDL(1,2,2,2,0,0,0,1) regression

Sample: 1992 thru 2022                              Number of obs =     31
                                                    R-squared     = 0.6930
                                                    Adj R-squared = 0.3860
Log likelihood = 38.635704                          Root MSE      = 0.1000
```

D.GDP	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
ADJ						
GDP						
L1.	.1080236	.2820213	0.38	0.707	-.4930904	.7091377
LR						
DTI	.1754305	.3015685	0.58	0.569	-.4673475	.8182085
InGFC	.1847188	.2112861	0.87	0.396	-.2656268	.6350644
InLR	-.2660269	.6789329	-0.39	0.701	-1.713138	1.181084
InTR	.0440498	.1452446	0.30	0.766	-.2655317	.3536314
InE	-.6094548	1.777301	-0.34	0.736	-4.397683	3.178773
InIQ	-.0700427	.1830978	-0.38	0.707	-.4603064	.320221
InIF	-.1184552	.209615	-0.57	0.580	-.5652391	.3283287
SR						
DTI						
D1.	.0543276	.0829651	0.65	0.522	-.1225082	.2311635
LD.	-.1381921	.0827496	-1.67	0.116	-.3145687	.0381844
InGFC						
D1.	.0354623	.0233114	1.52	0.149	-.0142248	.0851495
LD.	-.0358876	.0262021	-1.37	0.191	-.0917362	.0199609
InLR						
D1.	-.0183937	.0081264	-2.26	0.039	-.0357147	-.0010728
LD.	-.0147691	.0056963	-2.59	0.020	-.0269105	-.0026278
InIF						
D1.	-.0263408	.0144803	-1.82	0.089	-.0572049	.0045233
_cons	-2.748816	2.561644	-1.07	0.300	-8.208831	2.711199

```
note: estat btest has been superseded by estat ectest
      as the prime procedure to test for a levels relationship.
      (click to run)

Pesaran/Shin/Smith (2001) ARDL Bounds Test
H0: no levels relationship             F =  1.786
                                       t = 0.383

Critical Values (0.1-0.01), F-statistic, Case 3
```

	[I_0] L_1	[I_1] L_1	[I_0] L_05	[I_1] L_05	[I_0] L_025	[I_1] L_025	[I_0] L_01	[I_1] L_01
k_7	2.03	3.13	2.32	3.50	2.60	3.84	2.96	4.26

```
accept if F < critical value for I(0) regressors
reject if F > critical value for I(1) regressors

Critical Values (0.1-0.01), t-statistic, Case 3
```

	[I_0] L_1	[I_1] L_1	[I_0] L_05	[I_1] L_05	[I_0] L_025	[I_1] L_025	[I_0] L_01	[I_1] L_01
k_7	-2.57	-4.23	-2.86	-4.57	-3.13	-4.85	-3.43	-5.19

```
accept if t > critical value for I(0) regressors
reject if t < critical value for I(1) regressors

k: # of non-deterministic regressors in long-run relationship
Critical values from Pesaran/Shin/Smith (2001)
```

APPENDIX C

STATA Results of the Estimated ARDL Lags (1 2 2 2 0 0 0 1) regstore (ecreg)

```
. ardl GDP DTI InGFC InLR InTR InE InIQ InIF ,  lags(1 2 2 2 0 0 0 1) regstore(ecreg)

ARDL(1,2,2,2,0,0,0,1) regression

Sample: 1992 thru 2022                              Number of obs =     31
                                                    F(15, 15)     =  24.06
                                                    Prob > F      = 0.0000
                                                    R-squared     = 0.9601
                                                    Adj R-squared = 0.9202
Log likelihood = 38.635704                          Root MSE      = 0.1000

------------------------------------------------------------------------------
         GDP | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         GDP |
         L1. |    1.108024   .2820213     3.93   0.001     .5069096    1.709138
             |
         DTI |
         --. |     .035377   .1017239     0.35   0.733    -.1814423    .2521963
         L1. |   -.1925198   .1241687    -1.55   0.142    -.4571791    .0721395
         L2. |    .1381921   .0827496     1.67   0.116    -.0381844    .3145687
             |
       InGFC |
         --. |    .0155083   .0435423     0.36   0.727    -.0772999    .1083166
         L1. |     -.07135   .0368075    -1.94   0.072    -.1498034    .0071034
         L2. |    .0358876   .0262021     1.37   0.191    -.0199609    .0917362
             |
        InLR |
         --. |    .0103435   .0077971     1.33   0.204    -.0062756    .0269625
         L1. |    .0036246   .0096819     0.37   0.713    -.0170119     .024261
         L2. |    .0147691   .0056963     2.59   0.020     .0026278    .0269105
             |
        InTR |   -.0047584   .0071954    -0.66   0.518    -.0200951    .0105783
         InE |    .0658355   .0711796     0.92   0.370    -.0858802    .2175513
        InIQ |    .0075663   .0129935     0.58   0.569    -.0201287    .0352612
             |
        InIF |
         --. |   -.0135448   .0153356    -0.88   0.391    -.0462318    .0191421
         L1. |    .0263408   .0144803     1.82   0.089    -.0045233    .0572049
             |
       _cons |   -2.748816   2.561644    -1.07   0.300    -8.208831    2.711199
------------------------------------------------------------------------------

. estimates restore ecreg
(results ecreg are active now)

. regress

      Source |       SS           df       MS      Number of obs   =        31
-------------+----------------------------------   F(15, 15)       =     24.06
       Model |  3.61154815        15  .240769877   Prob > F        =    0.0000
    Residual |  .150090637        15  .010006042   R-squared       =    0.9601
-------------+----------------------------------   Adj R-squared   =    0.9202
       Total |  3.76163879        30  .12538796    Root MSE        =    .10003

------------------------------------------------------------------------------
         GDP | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         GDP |
         L1. |    1.108024   .2820213     3.93   0.001     .5069096    1.709138
             |
         DTI |
         --. |     .035377   .1017239     0.35   0.733    -.1814423    .2521963
         L1. |   -.1925198   .1241687    -1.55   0.142    -.4571791    .0721395
         L2. |    .1381921   .0827496     1.67   0.116    -.0381844    .3145687
             |
       InGFC |
         --. |    .0155083   .0435423     0.36   0.727    -.0772999    .1083166
         L1. |     -.07135   .0368075    -1.94   0.072    -.1498034    .0071034
         L2. |    .0358876   .0262021     1.37   0.191    -.0199609    .0917362
             |
        InLR |
         --. |    .0103435   .0077971     1.33   0.204    -.0062756    .0269625
         L1. |    .0036246   .0096819     0.37   0.713    -.0170119     .024261
         L2. |    .0147691   .0056963     2.59   0.020     .0026278    .0269105
             |
        InTR |   -.0047584   .0071954    -0.66   0.518    -.0200951    .0105783
         InE |    .0658355   .0711796     0.92   0.370    -.0858802    .2175513
        InIQ |    .0075663   .0129935     0.58   0.569    -.0201287    .0352612
             |
        InIF |
         --. |   -.0135448   .0153356    -0.88   0.391    -.0462318    .0191421
         L1. |    .0263408   .0144803     1.82   0.089    -.0045233    .0572049
             |
       _cons |   -2.748816   2.561644    -1.07   0.300    -8.208831    2.711199
------------------------------------------------------------------------------

. estat dwatson

Durbin-Watson d-statistic( 16,    31) =  2.166893

. estat bgodfrey, lags(1)

Breusch-Godfrey LM test for autocorrelation
----------------------------------------------------------------------------
    lags(p) |          chi2               df                 Prob > chi2
------------+---------------------------------------------------------------
          1 |         0.987                1                        0.3205
----------------------------------------------------------------------------
                     H0: no serial correlation

. estat imtest, white

White's test
H0: Homoskedasticity
Ha: Unrestricted heteroskedasticity

   chi2(30) =  31.00
Prob > chi2 = 0.4154

Cameron & Trivedi's decomposition of IM-test

---------------------------------------------------
              Source |       chi2     df       p
---------------------+-----------------------------
  Heteroskedasticity |      31.00     30    0.4154
            Skewness |       9.67     15    0.8403
            Kurtosis |       2.90      1    0.0887
---------------------+-----------------------------
               Total |      43.56     46    0.5749
---------------------------------------------------

. drop _est_ecreg

. predict resid, residuals
(2 missing values generated)

. jb resid
Jarque-Bera normality test:  1.192 Chi(2)   .551
Jarque-Bera test for Ho: normality:
```