WHAT DOES THE DIGITAL REVOLUTION MEAN FOR POVERTY ALLEVIATION AND INCLUSIVE GROWTH IN AFRICA? A CASE STUDY OF GHANA AND SOUTH AFRICA

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DECLARATION

I hereby declare that the thesis titled ‘’What does the digital revolution mean for poverty alleviation and inclusive growth in Africa? A case study of Ghana and south Africa’’ is my own original work, and that it has not in any way been submitted to any university for the purpose of degree or examination. The use of other academic works has been duly cited and acknowledged by the author as references.

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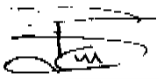
Alex Boakye

Signature 

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I would like to commence this section by quoting Proverbs 21:31 which says ''the horse is prepared for the battle, but victory is of the Lord. Indeed, this accomplishment has been of the lord, and I am not ashamed to declare that. Life they say, it's a gift, not something one works for or earn because of one's uniqueness. The life, the strength, and the wisdom I have enjoyed throughout this academic period has been a gift from God and I duly appreciate that.

As I acknowledge the goodness of the Almighty, I cannot forget the people he sent to my life to make this academic journey a success. Every story certainly has a beginning and my own began with securing scholarship from the Germany Academic Exchange Program to pursue a master's program in South Africa. Even though this PhD was not financed by DAAD, the master's opportunity they offered me formed the foundation to reach this feat. For that reason, I would like to thank the management and coordinators of the scholarship program at the South African German Centre for Development Research.

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DEDICATION

With all humility and joy, I dedicate this work to my grandmother, Maame Akua Mansa. My utmost inspiration come from your hard work, energy and love.

ABBREVIATIONS

AI	Artificial Intelligence
FIR	Fourth Industrial Revolution
GDP	Gross Domestic Product
ICT	Information and Communication Technology
ILO	International Labour Organization
IMF	International Monetary Fund
OECD	Organisation for Economic Co-operation and Development
SSA	Sub-Saharan Africa
UNDP	United Nations Development Programme
UNPD	United Nations Population Division
WB	World Bank
WEF	World Economic Forum

ABSTRACT

Background: The world is undergoing a disruptive change driven by fast pace of technological advancements that are combining our physical, digital, and biological spheres. Emerging technologies such in artificial intelligence (AI), big data, drones, Internet of Things (IoT), 3D printing, and robotics are set to transform the very nature of future jobs, skills set and business process. Around the world, many governments, business owners and entrepreneurs are taking proactive measures to harness the potentials of this new revolution while putting pragmatic strategies in place to ameliorate its negative impact. Meanwhile in Sub-Saharan Africa, preparations to leverage the opportunities of today's frontier technologies remains poor. In particular, there seems to be limited evidence on how African countries such as Ghana and South Africa can best maximise the potentials of an increasingly digitalised world economy and ensure that the digital transformation becomes inclusive. Against this backdrop, this study purported to use a comparative analysis approach to examine the readiness and capacity of Ghana and South Africa to embrace the digital economy and ensures inclusive digital transformation. **Goal and objectives:** Guided by the conceptual framework of the neoclassical theories, the overall goal of this study is to review key trends of technology adoption and jobs creation in Africa as well as to identify key policy issues for discussion among policymakers and social partners. The objectives are to 1) explore the dynamics of technological change in Africa; 2) describe the new emerging technologies and the windows of opportunities it presents; 3) assess sub-Saharan Africa's capacity to adopt technology and innovation to transform it major sectors. **Methods:** To achieve the objectives, this study shall adopt a mixed methods approach of scientific investigation. The quantitative part of this research will focus on analysing annual data from two data sources-- World Bank databank and the United Nations Development Programme. The qualitative aspect of this research employs content analysis. The content analysis of treaties and policy documents in this research are both manifest and latent. This means it considers both interpretations that are physically present and also inherent in the physical data. **Conclusion:** This research contributes to enhancing understanding of the impact on the fourth industrial revolution (FIR).

Keywords: Technologies, Poverty, Inclusive, Growth, Ghana, South Africa.

LIST OF PUBLICATIONS BY CANDIDATE

1. **Boakye, A**., Nwabufo, N., & Dinbabo, M. (2022). The impact of technological progress and digitization on Ghana's economy. *African Journal of Science, Technology, Innovation and Development,16*. https://www.tandfonline.com/doi/abs/10.1080/20421338.2021.1994239.

2. **Boakye, A.,** & Babatunde Olumide, O. (2021). The role of internet of things to support health services in rural communities. A case study of Ghana and Sierra Leone. *Transnational CorporationsReview, 13(1),4350.* https://www.tandfonline.com/doi/abs/10.1080/19186444.2020.1849937

3. **Boakye, A**., & Dinbabo, M. (2021). Alleviating poverty and achieving inclusive growth through digital innovations. Evidence from South Africa. *Journal for Creativity, Innovation and Social Entrepreneurship Tshwane University of Technology (TUT-JCISE) Vol. 5, No. 2, 2021 - ISSN 2521-0270.* https://sarchi.org/wp-content/uploads/2022/04/135097-JCISE-Vol-5-Issue-2-2021.pdf

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5. **Boakye, A. (2023).** Estimating agriculture technologies' impact on maize yield in rural South Africa. *SN Bus Econ* **3**, 149. https://doi.org/10.1007/s43546-023-00530-4

6. **Boakye, A. (2023).** Promoting inclusive health through digitisation, evidence from South Africa, *Transnational Corporations Review.* Article is undergoing peer review. Publication expected in early April 2024.

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CHAPTER ONE: INTRODUCTION

1.1 Background of the study

The world is undergoing a disruptive process driven by fast pace of technological advancements that are combining our physical, digital, and biological spheres. Emerging technologies such in artificial intelligence (AI), 3D printing, and robotics are set to transform the very nature of future jobs, skills set and business process. The two key features of this new wave of technological changes are connectivity and digitisation. According to some scholars (Manyika et al., 2016; Schwab, 2016; Liao, 2017; Stearns, 2018), these innovations hold significant possibilities for economic development, environmental protection, and education but at the same time threatens to cause wide wave of job displacement and heighten inequality. Many countries across the globe are therefore taking proactive measures to harness the potentials of this new revolution while putting strategies in place to ameliorate its negative impact (Liao, 2017).

Meanwhile, one continent that has lagged behind in embracing this new wave of innovations to spur development is the African (Firestone and Kelly, 2016). This holds true particularly with those under the Saharan belt. Despite making significant progress in adopting digital technologies within the business sector and public administration over the past decades, most Africa states has been slow in preparing to leverage the potentials that the new wave of technologies present. Like the introduction of previous major technologies such as electricity, steam engines, railways that substantially induced global economy growth, the extent to which Africa governments and local firms realized these opportunities and took action to capitalize on them to enhance their economic competitiveness and improve the quality of life of its citizens was low (Alzouma, 2005). Similar position is currently being noticed with regards to today's emerging technologies. For instance, while countries such as Germany, China and the United Kingdom are adopting proactive measures by developing national strategies that will ensure full integration of the new technologies in all sectors of the economy (Liao, 2017), most African countries are yet engage in similar efforts. There are only few Africa countries that are becoming more intensive in their use of digital technologies- Rwanda, South Africa, Ghana and Kenya (World Bank, 2016)

While sub-Saharan African countries are ill-prepared for the impending disruption to jobs and skills brought about by the technological progress, there is seemingly demographic change which is fast taking place on the continent. According to the United Nations Population Division (2016) sub-Saharan Africa is currently home to 13% of the world's working-age population; a number that is set to increase to more than 17% by 2030, the world's second largest after Asia. With more than 60% of its population under the age of 25, sub-Saharan Africa is already the world's youngest region today – and, by 2030, will be home to more than one-quarter of the world's total under-25 population (World Economic Forum, 2017). These demographic dynamics offer wide possibilities for sub-Saharan Africa to expand its economic and social opportunities driven by consumer spending and investment.

The challenge for African governments is therefore to transform their economies in a way that will generate more quality jobs and inclusive growth. In this regard, embracing today's technology revolution (popular termed fourth industrial revolution) seems to offer a possible solution. This research project therefore purports to unravel the significance of the fourth industrial revolution to Africa's development and make a case for Africa to embrace the new wave of technology progress. Concurrently, this research explores key trends of technology progress and jobs disruption in Africa and as such offer recommendation for policy actions.

1.2 Significance of the study

The world is undergoing a disruptive change characterised by advances in digital technologies that is set to impact on everything, including business dynamism, societal cohesion, and the future of work. A significant transformation of global and regional labour market is forecast over the next decades (world economic forum, 2018). On the one hand, governments around the world are taking proactive measures by developing policies that aims to capture the technological potential for sustainable growth while mitigating against job displacement. On the other hand, organisations across all industries are adopting new technologies in their business operations to increase their competitiveness in the global economy (Liao, 2017; Saturno, 2017).

Yet many institutions and states in sub-Saharan Africa are far behind from making optimal use of the recent emerging technologies and are ill-prepared for the impending disruption to

jobs and skills brought about by the technological advances. In particular, there seems to be lack of understanding on how today's emerging technologies will transform societies, businesses and governance. A primary reason for this lack of in-depth understanding is the limited data available for reference (UNCTAD, 2018). Consequently, the extent to which Africa is prepared to participate in future global economy is low. Building on this context, this study explores the various ways in which sub-Saharan Africa can capitalise on the growth of new technologies to address some of its fundamental problems such as poverty, migration, and food insecurity.

The goal of achieving food security through increasing agriculture productivity in Africa is of particular interest to the researcher since many African economies are largely dependent on Agriculture activities. Interestingly, agriculture is moving into a new phase of technology characterized by big data applications and the Internet of things which promises to trigger huge productivity gains (Lohr, 2015). The new phase includes cheap sensors and drones monitoring plants, livestock, water supplies, and weather, to provide detailed, real-time information. These precision farming technologies are highly relevant for Africa's agriculture sector (Dlodlo & Kalezhi 2015). In addition, advance Internet of things applications that based on sophisticated data analytics are being employed to address some of the challenges that farmers face (Lohr, 2015; World Bank, 2018). Yet the framework for adopting the Internet of things application to Africa's agriculture sector has not been widely explored. The steps to adoption of the Internet of things in African agriculture merit deeper analysis, given its potential impact. Finally, much of the literature on the application of digital technologies were drafted in the early 2000s when the level of ICTs was much lower and there were few visible success stories. This suggest that the most information available are outdated (World Bank, 2018). There is therefore a need for more timely research on the usefulness of digital technologies in the region.

1.3 Case study--Sub-Saharan Africa

Latest data from the World Bank data source (2022) indicates that Sub-Saharan Africa (SSA) region is currently home to more than 1.2 billion people, approximately 15% of the global population. This share is projected to increase to almost 25% or 2.5 billion by 2050 according to the United Nation (World Population Review, 2022). Meanwhile, the region is regarded as

one of the poorest in the world. Indeed, a recent publication by the World Bank showed that about 43% of the African population are still trapped in extreme poverty (World Bank, 2016). Agriculture remains the largest sector of the economy, generating almost one-third of its GDP. Other sectors such as the mining, manufacturing, tourism, and communication equally contribute to the region's economic activities, however the agricultural sector constitutes the major economic hub, providing livelihood for more than half of its population. Altogether, these sectors support the economic activities of SSA countries, however low productivity is often reported. Researchers have identified numerous drivers behind the low productivity in Africa, yet the often cited are weak infrastructure, and the low level of technological adaptation and absorption.

For example, the 2017 Global Innovation Index Report shows that the level of innovations and technological adaptation in Africa is relatively low as compared to other regions. Literature suggests two fundamental reasons underlying the low technological adaptation in Africa. First, the conditions necessary to spawn innovations are not favourable. For instance, the regulatory frameworks in most African countries are rigid and does not encourage investors to either expand their businesses or break new grounds. Second, little attention is given to research and development as well as investment in science, technology, engineering, and mathematics (STEM) education, a prerequisite of absorptive capacity and technological progress. Hence the skills needed to use sophisticated innovations remain largely insufficient.

Despite, these challenges, SSA is well-positioned and have relatively high potentials to adapt to the new wave of technology progress. Recent examples from the region affirms this position. For instance, from the use of diesel-powered base stations and genetically modified seeds to the adoption of greenfield wireless networks, as well as prepaid electricity models, most African countries are on the verge of transforming its economic circumstances. Today, digital technologies, such as mobile phone applications, 3D printing, sensors, big data, and drones, have emerged with huge potential impact on productivity and livelihoods. Unlike the traditional tools used in production, digital technologies have the capacity to raise productivity, increase income levels and transform the African economy. By focusing on two countries each from the four geo-political regions in Sub-Saharan Africa, this study assesses sub-Saharan Africa's capacity to adopt technology and innovation in its major sectors of the

economy namely agriculture, education, energy, finance, governance, and information and communications technology (ICT).

1.4 Ghana context

Ghana is home to an estimated population of 29.6 million and is placed 47th in the world (Ghana Statistical Service, 2018). Data from the Ghana Statistical Service (GSS) indicates that more than 98% of Ghanaians are Black Africans, although the country is multi-ethnic, with over seventy ethnic groups. The country is endowed with rich mineral resources, including oil, gold, diamonds, and bauxite. Although relatively industrialised, the economy of Ghana is largely dependent on the agriculture sector which employs close to 65% of the total workforce and serves as livelihood for more than 80% of rural dwellers (Ghana Statistical Service, 2018). Adult literacy rate stands at 79%. In 2018, unemployment rate for Ghana was 6.7% (Knoema, 2019). The percentage of the population living on less than $1.90 a day is 13.3%.

In the area of technology, Ghana is placed among countries with a burgeoning innovation centre, characterised with significant number of research institutions, hubs, and initiatives to support sector-based development. There are at least 16 research and development (R&D) institutes, seven public universities, 40 private universities, 10 public polytechnics, as well as several technical institutes, technology support and regulatory agencies, standardized intellectual property (IP) legislation (Ghana Statistical Service, 2018). Ghana also has a relatively strong education system with a generally stable macroeconomic political atmosphere, and a growing private sector. There are two skill areas common across Ghana and Sub-Saharan Africa but not observed among non-African participants: Mobile communication and accessing online government services is prevalent. Indeed, Ghana was one of Africa's largest mobile markets in 2017, with nearly 35 million subscribers and a 119 percent penetration rate (implying more than one phone per person) (Hatt et al., 2017). 142 Industries are expected to increasingly leverage mobile phones as a core platform for communication in business (Hatt et al., 2017).

Meanwhile, a number of structural challenges limit the country's ability to leverage technological tools to meet the demands of society. Global competitive index reveals Ghana's

limited capacity for harnessing technology and innovation to raise productivity and create industries with competitive advantage in international markets (World Economic Forum, 2018). Out of 141 countries, Ghana ranks 111th on technological readiness, innovation, and business sophistication (WEF, 2018). Ghana is currently at the bottom tier of countries, classified as "factor-driven" economies, mainly in sub-Saharan Africa. These "factor-driven" economies have minimal capacity to innovate, do not add much value to the goods and services they produce, have unsophisticated local enterprises with limited managerial and organizational capacity and minimal commercial and technological links to the global economy, and use low-wage, poorly educated, unskilled labour to produce and export unprocessed raw materials (UNTACD, 2015). Ghana has a compelling case for accelerating development, however, to achieve this requires changing from a factor driven economy into an "efficiency-driven" or "innovation-driven" is critical.

1.5 South Africa context

In 2019, Statistics South Africa (Stats SA) estimated the population of South Africa to be 58.78 million. This estimate covered all the residents of South Africa across race, gender, geographic, origin, language, and religion. South Africa has a highly developed economy and advanced economic infrastructure. The economy of South Africa is the second in Africa after Nigeria (World Economic Outlook, 2016) and it is the world's largest producer and exporter of gold, platinum, and other natural resources. The country also has well-developed financial, legal, communications, energy, and transport sectors as well as the continent's largest stock exchange. In terms of technological infrastructure, South Africa has one of the best quality mobile broadband infrastructures.

Nevertheless, the country is confronted with severe socioeconomic challenges that constraints its development progress. Over the last decade, South Africa's annual GDP growth averaged 2%, falling from 3.4% in the previous decade (World Bank, 2019). A major factor to this economic underperformance is attributed to stagnation in productivity. Based on the international poverty line of $1.90 per day, 18.8% of South Africans were poor in 2015, following a decline from 33.8% in 1996(World Bank, 2019). Unemployment remains a key challenge, standing at 27.6% in the first quarter of 2019. The unemployment rate is even higher among youths, at around 55.2%. South Africa remains a dual economy with one of the

highest inequality rates in the world, with a consumption expenditure Gini coefficient of 0.63 in 2015 (World Bank, 2019). High inequality is perpetuated by a legacy of exclusion and the nature of economic growth, which is not pro-poor and does not generate sufficient jobs. Inequality in wealth is even higher. According to the World Bank (2019) the richest 10% of the population held around 71% of net wealth in 2015, while the bottom 60% held 7% of the net wealth. South Africa also has a notably high rate of murders, assaults, rapes, and other violent crimes, compared to most countries.

Despite its robust technological infrastructure, South Africa is lagging behind on the path towards digitisation. Complex regulatory frameworks, gaps in digital infrastructure and a lack of digital skills are notable factors. In its recent publication, Accenture Strategy (2019) projects that digital transformation of South Africa's economy is likely to create the highest value for society through its impact on economic activity, productivity and service delivery. Their analysis reveals that South Africa can unlock over R5 trillion in value over the next decade—with value of R1.4 trillion created in 2026 alone if it implements 96 digital initiatives across nine industries and five government services.

1.6 Evolution or revolution? Understanding the concept of industrial revolution

Explaining the term industrial revolution has been a long-standing problem among scholars in the social science field (Hoppit, 1987; Ahlström, 1995; Stearns, 2018). Historical reference to the concept can be traced back to the 18th and 19th centuries, when European countries began to transform their means of production and manufacturing from the use of basic tools to complex machines that improved production efficiencies and quantity. Literally transforming from muscle power means of production to mechanisation (Maynard, 2015; World Bank, 2018).

The term *Industrial Revolution* however was firstly coined by an English economist, Arnold Toynbee who in the 1880s used it to describe Britain's economic development (Sugarman & Rubin, 1984; Humphries & Schneider, 2019). Since then, the concept became popular within the academic circles, however not all economic historians agreed with the term revolution. Some argued that a mere transition from traditional methods of production to mechanical methods cannot in itself be describe as revolution(Hoppit, 1987). For instance Donald

Cameron argued that to describe some sort of economic progression a revolution is 'grossly misleading', implying that transformations of the kind that were happening around industrialisation are inherently non-revolutionary(Hoppit, 1987).

Other economic historians such as Peter N. Stearns also had a slightly different interpretation to the economic transformation that occurred in the 18th century. Stearns adopted a broader definition of industrialization by laying emphasis on two key features—technology transformation and the organization of production which taken together brought a single result, a sharp increase in labour and capital productivity(Göran, 1995; Stearns, 1995). It is however worth noting that the difference in perspectives observed among economic historians regarding the interpretation of the 18th century industrialisation period move beyond definitions to causes and implications assigned to the technological advancement that was happening during such time. Till date it is still problematic for historians to ascribe a single definition to the economic changes which took place in European countries during the 18th century.

Nevertheless, most agreed that the rate of change was revolutionary in only a few areas of the economy and that, more generally, change was gradual by the standards of political revolutions (Sugarman & Rubin, 1984; Brian, 2015). This agreement notwithstanding, the question of whether the economic progression which began in the mid-18th could be describe as revolution or evolution does not change the fundamental understanding that traditional methods of production were paving way for new and improved methods driving by technological advancement. The subsequent sections give an overview of the various stages of development changes that have occurred over the centuries.

1.7 Historical precedent of industrial revolution

The first technological revolution occurred between the periods of 1760 to 1840 (Mathias, 2013; Mokyr, 1999). Emerging from Great Britain and later spreading to other European countries as well as the United States, it was a period characterized by transition from agrarian and handcrafts economy to industrial economy. What made Great Britain the starting point of this revolution was their conducive legal and political systems that gave entrepreneurs the confidence to invest in new methods for mass production (Mokyr, 1999;

Mathias, 2013). In particular, the developments which lead to the pioneering of the industrial revolution was the promulgation of new laws that respected the sanctity of contracts, enforcement of property rights, removal of trade barriers and the discovery of coal (Mokyr, 1999; Goran 2005).

In essence, the discovery of coal and steam became the trademark of the first Industrial Revolution as they represented new sources of energy needed to power advance machines used for production (Mathias, 2013). For instance, in the textile industry, mechanized cotton spinning machines were powered by steam thereby enhancing labour productivity. The substitution of coke for charcoal lowered the fuel cost of iron and wrought iron production. Steam power also contributed greatly to the efficiency of steam engines and consequently led to the construction of railroads and train manufacturing.

The progress of steam power caused mass production and trade expansion, yet this was not enough to support that fast pace of the industrialisation at the mid of the 19th century, hence new discoveries such as electricity, petrol and steel were made to catch up with the industrial growth pace (Mathias, 2013). Essentially, electricity and petrol became the new sources of energy thereby ushering in the second industrial revolution which commenced from 1870 and lasted until 1914 (Mokyr, 1999; Mathias, 2013).

It is worthwhile noting that most of the changes that occurred during this period had to do with the substitution of old products with new ones. For instance, steam powered machines were replaced by electricity run machinery. Iron was transformed into steel through a process of heating and combination of other metals. The wear and tear on wrought iron machine parts and rails made them expensive in use, and form any uses, especially in machines and construction, wrought iron was insufficiently tenacious and elastic(Jevons, 2006). Railroads, personal appliances, and other industrial machines were constructed from steel. Before electricity became a critical source of light and power, candles, kerosene, and gas lamps relied on to power homes and factories. As such most work were done during daytime. The use of electricity changed the way people worked and lived. With electric lighting and energy, factories and plants could work for more than 12 hours a day. The second industrial revolution

equally produced ground-breaking inventions such as the telephone, automobile, aeroplane, electric light bulb as well as the radio (Mathias 2013).

It is important to note that although the period of the second industrial revolution were characterized by the discovery of petroleum products and electricity, it was equally dominated by scientific breakthroughs. For instance, advance research in the chemical industry led to the recommendation and application of chemical products such as fertilizers to agricultural production. In effect, it became one of the prominent examples of how formal scientific knowledge came to affect production techniques. Many other chemical products such as dyes formed part of the prominent chemical products discovered during the period (Mokyr, 1999; Goran 2005). Thus, the second Industrial Revolution differed from the previous one in many critical aspects. Firstly, it had a significant impact on real wages and standards of living. Secondly, it shifted the geographical focus of technological leadership away from Britain to other industrialized Western world such as Germany and the US. Finally, by changing the relation between knowledge of nature and how it affected technological practices, it irreversibly changed the way technological change itself occurs. In so doing, what was learned in these years prepared the way for the next Industrial Revolutions(Jevons, 2006).

From the invention of electricity, discovery of petroleum products and mass production emerged the computer, internet, and renewable energy. These new developments ushered in the third industrial revolution which began in 1960. Unlike the previous two industrial revolution, the driving forces of the third industrial revolution were (1) transition into renewable energies involving the use of solar, wind, hydro, geothermal, ocean waves, and biomass as the alternative sources of energy; (2) transforming building structures into power plants; (3) using hydrogen and other storage technologies to store intermittent energies; (4) introducing power grid and (5) transitioning the transport fleet to electric plug-in and fuel cell vehicles (Rifkin, 2011). The Third Industrial Revolution was similar to previous revolutions in the sense that it was driven mainly by technological advances in manufacturing, distribution and energy factors. However, it was unique in terms of the scale of impact and distribution to another continent. For instance, innovators such as Steve Jobs, Bill Gates and the other innovators transformed the expensive centralized main-frame computers, controlled by few

global corporations to less expensive computers and cell phones, allowing broader connectivity in the social spaces of the internet (Rifkin, 2011).

The emergence of the Industrial Revolution significantly shaped peoples' life and wellbeing as it opened avenues for new businesses which offered employment opportunities for many people. Beyond contributing to change in peoples' lives, the industrial revolution's impact was equally evident in organizational operations dynamism. From the infiltration of assembly line machines to the computer and the Internet, these revolutions impacted on organizations processes (Hartwell, 2017). The first, second and third Industrial revolutions began slowly, but over time they gather momentum and ultimately have a profound impact on shaping production, consumption, communication, and transportation systems (Hartwell, 2017). However technological progress has not halted. Today, Internet technologies, renewable energies and other smart innovations are merging to launch in a new industrial revolution that will transform the development paradigm of the global economy from policy making to consumption in the 21st century. While some scholars describe it as the fourth industrial revolution (Schwab, 2017), others argue that it's a build-up of the third industrial revolution (Lim & Mathey, 2016; Hartwell, 2017; Haftu, 2018). The subsequent section delves into exploring the concept of the fourth industrial revolution.

1.8 Overview of the fourth industrial revolution

In the past few years, there has been an increasing convergence of high-tech innovations developed using computer-based algorithms that are tightly integrated with the Internet and effectively merging the digital, biological, and physical world (World Bank, 2018; World Economic Forum, 2016, Schwab, 2017). This current revolution is driving by a combination and coordination of physical and computational elements (Harley, 2018*)* The fourth industrial revolution is marked by emerging technology advancement in the areas of advanced robotics, artificial intelligence, three-dimensional (3D) objects printing, nanotechnology, quantum computing, the Internet of Things (IoT), autonomous vehicles, biological technologies, energy storage and material science (Schwab, 2017; Harley, 2018). Led by the progression of the Internet and fast communication, these technologies are expected to disrupt almost every sector and industry in every country.

In the view of Schwab (2017), the breadth and depth of these technologies will herald the transformation of entire systems of management, governance, and production, particularly in the shift on the reliance on labour as the largest component of production management, and governance. Like the previous revolutions, the new technological revolution is expected to cause a surge in localised production driven by 3D printing and advance robotics, uncapped Internet potential for trade and significant advances in renewable energy such as wind, solar and biomass. In the transport sector, the emerging technologies are expected to facilitate daily activities such as booking flight and ordering cab. Taking together these changes will not only boost production, but also reduce trade cost, open new markets, and drive economic growth (Schwab, 2017). These expectations seem to underscore a connection between technological progress and development. The assumption is pervasive in the development literature. Hence in the subsequent section, the researcher expounds on available evidence regarding the technological improvement and development.

1.9 Technological advancement and development---a complex relationship

Many scholars (Jorgenson et al., 2000; Daveri, 2002; Gruber & Koutroumpis, 2010; Katz & Koutroumpis 2014; Donou-Adonsou, Lim & Mathey, 2016; Haftu, 2019) hold the view that technological development drives long-term economic growth, productivity, and improvement in standard of living. They particularly emphasized that it is progress in technology that differentiate a fast-growing developing economy from slow-growing ones. Joseph Schumpeter (1928) was the first economist to have argued in favour of technological progress as a catalyst for economic growth (World Bank, 2018).

Schumpeter provides that diffusion of new ideas and production techniques throughout the economy creates a process of "creative destruction'' where weakening sectors are destroyed whiles new industries emerge. Thus, Schumpeter view, extends the threshold of technological evolutionary concept beyond simply application of innovative techniques to encompass creation of new markets, new distribution systems and finding new sources for raw materials. Building on Schumpeter's conceptual framework of technological transformation, Paul Romer (1986) in his study titled 'Increasing returns and long-run growth', indicated that technical progress is the main driver for economic growth.

This growth, according to Romer (1986) can be seen in an increase Gross Domestic Product (GDP), enhancement in labour productivity and acceleration in capital accumulation. Thus, by reinforcing Schumpeter's position, Paul Romer provided that technical progress improves transformation of resources and diffusion of new ideas into products. In their book titled 'the positive sum strategy: Harnessing technology for economic growth', Landau and Rosenberg (1986) argued that leveraging technology for growth, however challenging it may be is essential for the success and prosperity of a company and nation particularly during periods of low growth.

Interestingly, during the latter part of the 20th century till the earlier part of the 21st century every new study on growth that emerged seemed to have implicated technological advancement in economic. For example, in a cross-sectional study examining the effects of technological change on economic growth and development, Malecki (1997), found that technological progress contributes to local, regional, and national development. Similar observations were made by Jorgenson and Stiroh (2000) who applied Jorgenson's *production possibility frontier* to describe the increase productivity growth the US experienced after 1995. Their findings revealed that the integration of computer systems in firms' operation contributed significantly to the growth of the US economy. This was more evident in the average labour productivity which grew faster between 1995 and 1999 as a result of capital deepening which was induce by the fall in ICT prices. By examining the post-1995 productivity performance of the individual US industries that either produce IT, use IT, or are relatively isolated from the IT revolution Stiroh (2007), discovered that U.S. productivity revival was a reflection of gains in a majority of industries that either produced or integrated Information Technology in their operations.

Some recent studies also confirm the positive link between technical progress and development. For instance, in a study which applied an econometric approach to estimate the contribution of different types of ICT investments in 26 industries in 18 OECD countries over 1995-2007, using database from the European Union Database, Spiezia (2013) found that the estimated contribution of ICT investments to value added growth in the business sector varies from 1.0% a year in Australia to 0.4% a year in Japan. The study further revealed that ICT producing industries account for no less than two-thirds of total factor productivity

(TFP) growth in Germany, Slovenia, and the United Kingdom, about 60% in the United States and just below 50% in France and the Netherlands. In Denmark, the Czech Republic and Italy, TFP increased in the ICT producing industries whereas it decreased for the total business sector. Using annual time-series data over the period 1980 to 2010 to estimate the impact of ICT investment on economic growth and energy consumption in Japan, Ishida, (2015) discovered that ICT investment contributed to a moderate reduction in energy consumption, and a long-run stability in GDP.

Using instrumental variables-Generalized Method of Moments approach in examining the impact of technological developments on economic growth in 47 countries in Sub-Saharan Africa, Donou-Adonsou et al. (2016), discovered that both the Internet and mobile phones usage contributed significantly to GDP of most Sub-Saharan African countries. In a study of the effect of Education, R&D and ICT on economic growth in high income countries, Saidi and Mongi (2018), found a bidirectional relationship between education, internet users and mobile cellular telephone, while there is a unidirectional relationship from internet users to economic growth and research and development and from mobile cellular telephone to economic growth and research and development in the long-run.

In light of the aforementioned evidence, it is likely to assume that the nexus between technology progress and economic growth points to a single direction. Yet this is not the case. Indeed, findings from studies in some developing countries suggest otherwise. One popular study that dispelled any doubts that technology improvements contribute less to economic growth was Jalava and Pohjola's (2002) study. Jalava and Pohjola's (2002) study employed an augmented variant of the neoclassical growth model to examine the impact of ICTs on growth in 39 countries. The results revealed no positive association between the ICT advances and economic growth. Similar observation was made by Bollou and Ngwenyama (2008) who investigated the total factor productivity (TFP) of the ICT sectors in six West African countries from 1995 to 2002 and found a rather declining level of TFP growth in ICT sectors of these economies.

Despite these contrary findings on the significance of technology play on economic growth, it is worth noting that the existing evidence concerning the negative relationship between technological developments and growth is relatively limited. In most cases the arguments put

forward by these scholars do not seem to undermine the potentials of technological progress but rather focus on the scale of its contribution to realising development goals such as poverty reduction and reducing inequalities. The next section examines Africa's growth trend since embracing technology. In considering the role that technological advancement has played on Africa's development, the section also takes a look at the key challenges thwarting Africa's efforts to fully leverage the potentials of technological growth.

1.10 Technological progress and its impact on Africa's development

From off-grid solar power to mobile money solutions for the unbanked, technology has helped to address some of the fundamental development challenges in sub-Saharan Africa. Across the continent, evidence has been recorded on the net effects of shifting from the use of conventional modes of production and service delivery to the adaptation of new and improved techniques (ILO, 2015; World Bank, 2018; Chavula, 2013; Donou-Adonsou et al., 2016). Most importantly, the growth of ICT in Africa has been effective in reducing transactional cost in doing business, spurring the development of new products and services, boosting agricultural production, and creating new employment. At the micro level, ICT migration contributed to firms' productivity gains by allowing firms to adopt flexible structures and locations (Donou-Adonsou et al., 2016). A typical example is by leveraging voice application to reduce unproductive traveling time, improve logistics and removal of physical constraints on organizational communication thereby leading to faster and more efficient decision making (Lewin & Sweet, 2005; World Bank, 2018).

In addition, in many African countries, the economic benefits of ICT were evident in creating employment for manufacturers, administrators, network builders, system managers, and employment through new retailing networks (Tcheng et al., 2010; Donou-Adonsou et al., 2016). Equally noteworthy is the significant transformation technology brought in the social sector. A key example is the removal of barriers to connectivity between families across borders. At the macro level, a significant body of literature has reported the net positive effect of technology migration and Africa's economic growth (Donou-Adonsou, & Sylwester, 2017; Chavula, 2013).

Previous cross-country studies focused on the effect of telecommunication technologies such as fixed-line telephones on economic growth in African countries. For example, the study by Lee et al. (2012) is among the rare studies that have focused on the effects of mobile phones on economic growth in sub-Saharan Africa. Their findings revealed marginal impact of mobile telecommunication services on sub-Saharan Africa's economic growth. Similarly, Sassi and Goaied (2013) found a positive and statistically significant impact of ICT diffusion measured by three indicators, namely, mobile phone, fixed-line telephone, and Internet, on economic growth between 1960 and 2009. More recently, Albiman and Sulong (2016) examined the long-run impact of ICT on economic growth in the SSA region for a 27-year period (1990–2014). They found that ICT proxies, such as fixed telephone lines, mobile phones, and Internet, have a positive and statistically significant direct linear impact on economic growth. By investigating the effects of ICT on economic growth in Tunisia, Saidi and Mongi (2018) discovered a positive link between the GDP and ICT.

Despite the aforementioned evidence pointing to the positive impact technology has had on Africa's growth trajectory, there has been questions raised about its scale of impact on Africa's development especially when compared to developed countries. Indeed, in some cases, inverse relationship has been noted between technological change and economic growth. For example, by analysing the effect of ICT on economic growth in developing, emerging and developed countries by using a sample of 59 countries for the period 1995 to 2010, Niebel (2014) could not find any statistical indication that developing and emerging countries gained more from investments in ICT than developed economies. Hussain (2016) also reported zero significant effect of investment in ICT and economic growth, when he investigated the possible relationship between the two variables in Bangladesh. Indeed, study after study in developing countries have revealed mixed and inconclusive results (Bollou and Ngwenyama, 2008; Bollou, 2006; Ngwenyama et al., 2006).

On the contrary, studies from developed countries have consistently reported positive impact of technological change and GDP growth (OECD, 2018; Saidi & Mongi, 2018). This has left many scholars to wonder why developing continents like Africa have failed to reap the benefits of technological revolution to spur massive growth and developments. Literature certainly offers myriad of explanations to understand this phenomenon; however they all

implicate these factors: weak infrastructure, inadequate investments in research and developments and low human capital development. Adequate infrastructure offers the basis for driving industrialization, raising incomes, accumulating human capital. Yet, evidence shows that there are severe infrastructure gaps in Africa (World Bank, 2018).

Beyond the identification of infrastructural inadequacy as key barrier to Africa's propensity to leverage the potentials of technological progress, socio political problems also tend to augment the reasons why Africans have lacked behind catching up with the prospects of technological change. It is crucial to note that technological change can only serve as a powerful tool for sustainable development when applied and managed in a way that is inclusive, transparent and complement labour productivity. In large part, it is the cultural, economic, social, and political landscape in which technology evolves which largely determines whether technology can translate into increased opportunities and well-being or deprivation and vulnerability.

1.11 New wave of technological revolution

Technology is recognised to be a powerful tool for development. Almost all contemporary growth and development theories consider technology and innovation as engine for economic growth (Aghion and Howitt 2009; World Bank 2018). Indeed, the significance of technology and innovation on development outcomes is well established in literature (Romer 1990; Aghion and Howitt 1992). Many scholars (Mathias, 2013; Mokyr, 1999; Sugarman & Rubin, 1984; Humphries & Schneider, 2019) related the unprecedented growth that many European countries experienced in the 18th and 19th century to the changes brought about by the invention of steam engine, electricity, machine tools, and the like. These inventions among others transformed various sectors including engineering, textiles, chemicals, agriculture, transport and communications and military. Without doubt, the technological revolution which started in the 18th Century dramatically changed the course of human history.

Despite the sustained economic benefits that technology advances brought to the entire world economy, the Africa region did not fully share its benefits. Indeed, ever since the dawn of the industrial revolution, Africa development rates has lagged behind the rest of the

continents. The exact reasons why Africa has trail behind reaping the benefits of technological change are not straightforward to explain, however implicit in this dilemma are underdeveloped infrastructure, poor management and governance system and underinvestment in technological tools.

Given that technology and innovations are considered a flagship feature for development, the World Bank admonishes to developing countries to fully embrace the new wave of emerging technologies which are expected to transform every sector of the economy. This research hence argues that it is time for Africa to go back to the foundation of development, make bold decisions, and enable the environment for more innovation and technology adoption for Africa to have the opportunity to experience major positive transformations that the new wave of technologies shall bring. This is not a new idea; to the contrary, it is what economic theory and history teach.

1.12 Growth theories

Many growth theories have been developed over the past decades to explain economic growth. Beginning from the classical theories to the neoclassicals, theories have helped to enhance understanding on growth mechanism. In most economic studies, theories provide the framework within which economist provides explanation to the conundrum of productivity increases. Although many theories and models exist to give meaning to economic growth, the most widely used in growth related studies are the neoclassical growth model (also known as the Solow model), the AK model and the Schumpeterian Growth model. These models first evolved to address the shortcomings in earlier theories and later transitioned into independent theories. Since then, the neoclassical growth model, the AK model and the Schumpeterian Growth model have received wide acceptance in the academic circles. Likewise, this study borrows from the underlying assumptions of these theories to answer the aforementioned research questions.

1.12.1 Neoclassical model

The neoclassical theory is associated with Robert Solow and Koopmans (1999). The theory posits that economic growth is dependent on labour force, technology and the total capital stock of a country. Thus, neoclassical growth theory relies on Cobb Douglas production

function to measure the growth and equilibrium of an economy. Cobb Douglas production function is represented as Y = AF (K, L). Where Y represents a country's total gross domestic product (GDP), K denotes share of capital, L describes labour and A indicates technology. Technology in particular is considered to be a vital component in the production function by the neoclassical theorists. For instance, they argue that economic growth cannot be attained without leveraging on technological advancement (Solow, 1999; Acemoglu, 2009). In this regard, technology is considered as an exogenous variable which serves as a differentiating factor between developed and underdeveloped countries. Interestingly, this position has invited a lot of criticism from many scholars (Romer, 1986; Aghion &Howitt 1999; Acemoglu, 2009). These scholars argue that accumulation of knowledge (technology) does not occur outside the decision of states, firms, or individuals and as such needed to regard as endogenous variable other that exogenous. Such argument forms the basis of the emergence of a new growth model known as the AK model (endogenous growth model).

1.12.2 AK model or endogenous model

In response to the shortcomings of the neoclassical model, two economists namely Romer Lucas, King and Rabelo (1994) came up with a new model called the AK model to explain economic growth. This model considers growth without diminishing returns and proposes a one-size-fits-all perspective of growth dynamics. The AK model hold its uniqueness from two perspectives. First the theory holds that growth dynamics are internal result of forces largely influenced by economic and development policies of a country (Aghion et al., 1998). In a broader sense, the theory implies that development policies that embrace openness and encourages competition will drive innovations and technology development.

As firms become more innovative inclined and adopt new technologies as result of competition, labour productivity will increase and thus impact on growth outcomes. Second, unlike the neoclassical model, the endogenous model assumes a constant-savings rate. According to the endogenous paradigm, the best approach for country to maintain high growth rates is to save a large fraction of the national income, some of which will eventually go into financing a technological advance and thus result in faster growth (Cvetanović et al., 2010). Despite its popularity among development economists, the endogenous growth model is equally criticized on a number of grounds. First, critics say that its long-run equilibrium is

not sustainable. Secondly, they argue that the emphasis on savings or capital accumulation means that in the long run growth will be dependent on capital instead of technological progress. As a result, a new model called Schumpeterian growth model is favoured.

1.12.3 Schumpeterian growth model

The next paradigm of growth model is the Schumpeterian growth model developed by Aghion and Howitt (1992). This growth model which belongs to the two parallel branches of technology- based growth models (neoclassicals and endogenous models) is distinctive base on its three underlying principles. First, growth is generated by innovations; Second innovations are driven by entrepreneurial investments and third new innovations render old technologies obsolete: a phenomenon which Schumpeter termed as creative destruction (Aghion & Howitt 1992). Growth in this model results from innovations that improve the quality of the intermediate input used in the production of the final product (Aghion et al., 2015). The fundamental effect of the Schumpeterian model is that faster growth generally means a higher rate of firm turnover, a phenomenon which arises from the process of creative destruction. The theory is flexible enough in acknowledging the contribution of past innovations for which according to Schumpeter, represents publicly available stock of knowledge which support the creation of new technologies. In essence, Schumpeterian growth model make case for innovations that leapfrogs the best old technologies (Aghion et al., 2015). It also encompasses the case of innovation that catches up to a global technology frontier, which represents the stock of global technological knowledge available to innovators in all sectors.

1.13 Relevance of the growth models to this research

A common notion among almost all the contemporary growth theories is that innovation and technology are fundamental drivers of economic growth (Aghion & Howitt 2009; Aghion et al., 2015). Evidence from the past allude to this single notion. For instance, major developments and growths which occurred in countries like the United Kingdom, the United States during the 18th and 19th century were interpreted along the conceptual framework of technology-based growth theories that linked high productivity to the adoption of better technologies. In addition, there are a number of growth-related analyses that have been

conducted based on the assumptions laid down by the contemporary growth theorists (Blundell et al. 1995; Nickell 1996). These studies point to a positive correlation between a country's growth and adoption of new technologies.

For example, in a cross-country study conducted in 1985 among 98 countries, Klenow and Rodriguez-Clare (1997) found that innovation which was measured by the natural logarithm of total factor productivity was strongly correlated with labour productivity. Similar results were reported by Easterly and Levine (2001) as well as Comin and Hobijn (2004). The researchers concluded that technology and innovation represent the bulk of cross-country differences in productivity, compared with factor accumulation (physical and human capital). Other studies providing empirical support for technology-based growth theories include Jorgenson and Motohashi (2005), Holt and Jamison (2009); Donou-Adonsou, and Mathey, (2016); Donou-Adonsou and Sylwester, (2017); Saidi and Mongi (2018). Given that the theoretical foundations, experiences around the world and empirical evidence concur to the significance of technology-based theories to explain development, this research adopted the theoretical underpinnings of the neoclassical theories.

1.14 Study hypothesis

H1. There is sufficient empirical evidence suggesting an association between technological improvement and economic growth.

H2. There is sufficient empirical evidence supporting a strong positive association between adopting new technologies and economic growth.

1.15 Operationalization and measurement of key variables

Mouton (2001) provides that the process of operationalization must seek to give practical meaning to the major theoretical concepts employed in the research questions or hypothesis. In this study, these concepts include the dependent variables (Human development Index, Gross National Product, Gross National Income, and Gross Domestic Product) and the independent variable (technological progress). These indicators were used as alternating metrics. Technological progress is about improvements in the ways by which goods and services are manufactured, marketed, and sold to the public. Economic growth on the other hand is about an increase in the production of goods and services over a specific period of

time. In this study, economic growth will be measured using a set of proxy variables--Gross Domestic Product and Job creation, while technological progress will be measured by total factor productivity (TFP). TFP is the degree of efficiency with which an economy produces goods and services given a certain amount of labor and capital.

1.16 Problem statement

Many developed countries are adopting ambitious technologically innovative strategies to transform their industries, business, education, and security spheres (Lazzarini, 2015; Liao, 2017). Their actions are based on the expectation that the fast pace of technological changes that is happening in our modern era will engineer growth by unleashing enormous jobs, raising income levels, and improving the quality of life of people. Yet, there is a lack of understanding on how the 21st century's technological advancement can cause growth in developing continent like Africa. More importantly, there seems to be knowledge gap on how to leverage the new and emerging technologies to address some of the fundamental problems bedevilling Africa.

Over the past decades many African governments have struggled to find the balance between technological progression and development (Alzouma, 2005). This is typified in the nature of response that African states gave to the first industrial revolution which began during the 18th century (Stads et al., 2015; McKibben, 2017; Juma 2017). Africa government preparedness to participate in the first industrial revolution which was driven mainly by technological progress was less desirable. Consequently, the impact that the technological-driven industrial revolution had on Africa's development was far less significant than it did on other continents (Juma 2017). Having trailed behind the earlier industrial revolutions (first and second industrial revolutions) where Africa demonstrated a low capacity to localise new technologies, the continent's adoption of the mobile technology was phenomenal.

The emergence of mobile technologies and the internet created remarkable technological enthusiasm on the continent. Depicting the potential that was identified in technological catch-up, mobile phones and internet usage served as an inspiring example of what Africa could achieve in other sectors like education, health energy, education, health,

transportation, and agriculture. Overall, the mobile revolution gave hope to Africans that they too can be dynamic and innovative players in the global economy.

But while cases such as mobile phones and internet usage offered inspiration for technological catch-up, the hope to leverage them to address the enormous economic challenges that the continent faced was largely unfulfilled. The mobile phone penetration did not contribute significantly to Africa's growth (Alzouma, 2005; Gruber & Koutroumpis, 2010). The mobile and internet revolution hardly served as a stimulus for wider industrial development and appears to have had little impact on African innovation progress. According to Juma (2017) many African economies today are in the middle of their worst downturn over the past 20 years, a case which exposes the persistent dominance of legacy economies.

Many issues explain why the previous technologies failed to serve as stimulus for rapid development in Africa, however notable among them are underdeveloped infrastructure, insufficient local content on technology development and low ICT skills capacity. Interestingly, these challenges continue to persist till today. In 2017 for instance, the World Bank ranked sub-Saharan Africa as the least of all developing regions with weak infrastructure system (World Bank 2017a). Such situation limits private sector development and investment in ICT. Today, many African economies still face low levels of advance innovations as well as limited dynamism in upgrading technologies. Production techniques in the agriculture sector which remain the largest economic sectors on the continent highlights low sophistication which is reflected in the incidence of low productivity on the continent. Looking at assimilating technologies and innovations to drive growth, Africa is very far behind. Compared to other developed continent, the level of innovation in Africa is low, as depicted in the recent report publish by the Global Innovation Index (Dutta et al., 2017). The researcher shares the opinion of other researchers (Aghion & Howitt, 2008) who posit that technology is an important factor of economic growth. Hence, it is crucial for Africa governments to return to the fundamentals of economic growth, make ambitious plans and create the atmosphere to allow for more innovation and technological penetration into the region (World Bank, 2018). Recent technological advancement in particular offers the potential to transform the continent's fortunes, but this sector is yet to be fully exploited for the benefit of Africa economies It is well known that policy incoherence and low technical capacity are the leading limiting factors

behind the slow adoption of technology in the continent, yet paucity of knowledge as a result of limited studies highlighting the positive net effects of technology is equally a major stumbling block. Against this backdrop, this study therefore purports to lay a solid ground for considering technology and innovation as the primary drivers of economic growth.

The study expands literature from three dimensions. First, it sheds light on the importance of technology in developing countries and emphasize on how technology-led programmes and policies can contribute to paving the way for economic progress. In other words, having the right regulatory environment is crucial for enabling scale up of innovations to drive growth. The study further highlights the interaction between research and development and technology adaptation. Research is an important factor of technology adoption as it allows technology to be adapted to local settings for rapid adoption. If so, Africa countries can derive growth benefits by improving their research and development capacity. This study hence identified promising areas that merit research.

1.17 Aim of the study

The goal of this study is to review key trends of technology adoption and jobs creation in Africa as well as to develop an inclusive digital readiness framework for promoting inclusive economic growth, employment and development in Ghana and South Africa.

1.18 Objectives of the study

1. To explore the dynamics of technological change in Africa
2. To describe the new emerging technologies and the windows of opportunities it presents
3. To explore the different strategies that Africa can use the emerging technologies to address its fundamental problems of poverty and food insecurity
4. To identify the common factors behind successful adaptation of digital technologies across all sectors.
5. To uncover the barriers that need to be overcome to facilitate inclusive digital transformation in the country.

1.19 Research questions

1. What are the some of the emerging technologies and their potentials
2. What is the trend of technological change in Africa

3. What are the determinants behind successful adaptation of digital technologies?

4. What are the barriers that hinder inclusive digital transformation?

5. What is the relationship between digitisation and economic growth, employment and development?

1.20 Research design

A research design is a plan, structure, and strategy of investigation in order to obtain answers to research questions (Babbie & Mouton, 2001; Craig, 2009). According to Kumar (2011), a research design must ensure that the procedures undertaken obtain valid, objective, and accurate information about the research topic. Although there are several ways of classifying research designs, Kumar (2011) notes that they fall into three general categories, namely experimental, quasi-experimental and nonexperimental. In this study, a nonexperimental research design which involved the use of secondary data is adopted. There are essentially two reasons why this approach is favoured. The first reason is for the purpose of cost and time efficiency. Second, for feasibility, as it will not be possible to either randomly select respondents or manipulate the variables (technological progress/economic growth) employed in this study.

1.21 Research methodology and data source

This study shall adopt a mixed methods approach of scientific investigation. A triangulation design aspect of mixed methods approach was used. According to Creswell, Plano Clark et al. (2003), this approach is best suited for studies that explore different complementary data on the same topic to better understand the research problem. The objective is to gather together the different strengths and nonoverlapping shortcomings of both quantitative and qualitative methods. This method was chosen for this study because of its appropriateness to compare data from different study sources and synthesis the important elements that reveals the positive net effects that adopting digital technologies have on productivity and growth.

The qualitative part focused on content analysis of literature. For a literature to qualify for inclusion in the study, it has to be relevant to the research topic, contain the key concepts of the study and must been published within the last decade. In addition, high consideration was

given to studies published in Africa and Asian exploring the relation between ICT adoption and economic growth.

The quantitative part of this research focuses on analysing annual data from two data sources-- World Bank databank and the United Nations Development Programme. The databank of the World Bank in particular constitutes a data source for both the dependent and independent variables (GDP and technical progress) of this study. It consists of time-series data on variety of topics in five-year intervals from 1960 to 1975 as well as annually since 1976 (available online). The databank which is an online visualisation and interactive tool contains more than 200 growth statistics on 192 countries. Also included are statistics on internet access which comprise fixed and mobile broadband data, ICT investments and so forth. Additionally, it provides demographic and macroeconomic data for more than 180 countries. Concurrently, this interactive online database affords researchers the opportunity to create dynamic customized reports based on their selection of countries, indicators, and years.

The UNDP annual report equally constitute relevant data source to aid this investigation. Specifically, it publishes report on nation's Human Development Index (HDI) which represent one of the primary dependent variables of this study. The Human Development Index is particularly considered to be a comprehensive measure of development than the traditional measures such as Gross National Product (GNP) and Gross Domestic Product (GDP). In contrast to these conventional measures of development, the HDI place emphasis on people, and seeks to incorporate their capabilities in gauging the development construct. The HDI summarizes mean outcomes in key development dimensions which include but not limited to health, knowledge, and living standards. For the purpose of this study, the researcher analysed data collected from 2008-2021 for Ghana and South Africa.

1.22 Quantitative analysis process

The quantitative analysis begins with a mapping of changes that has occurred within Africa's growth programmes. In doing so, particular emphasis is placed on comparative programmes that integrate new technologies in both African countries and developed countries.

Afterwards, spatial regression models were used to estimate the effect of technology diffusion on growth.

1.23 Model Specification

Methodologically, the scope of this study falls under the cluster of studies dedicated to exploring factors that drive economic growth in developing countries. Studies of this genre typically borrow from the neoclassical framework of Solow (1956) and Schumpeter (1992). Central to this conceptual framework is an aggregate production function which is derived from the Cobb and Douglas (1928) production function. Following in the footsteps of previous researchers (Njoh, 2018), the researcher employed the following model in the present study:

$Y_{it=}f(A_t K_t^a L_t^{1-a})$…… 1 where A = total factor productivity, L= labor, K= capital

This growth production function is extended by assuming that the total factor productivity is influenced by technological progress which in turn is driven by investments (I), local infrastructure (LI), technology availability (TA). Hence *A* is transformed into:

$$A_t = I_{it} + LI_{it} + TA_{it} \ldots\ldots\ldots\ldots 2$$

The specification of this model is based on two main motivations. First, within empirical literature, this model is among the commonly used measures of technology diffusion in relation to GDP. Secondly, the model takes into consideration human capital and labour productivity which are key elements for economic growth.

1.24 Test for stationarity

A unit root test on each variable in the models outlined in the previous sections was performed using the Augmented Dickey- Fuller (ADF) test. ADF test is applied on each time series. Despite the preferences for other tests, such as the Dickey Fuller (DF) test and Philips-Perron (PP) test for testing the presence or otherwise of a unit root among other researchers, in this study the ADF was applied because of its superiority when it comes to time series with autoregressive structure, as well as its reliability for ensuring white noise residuals (Ali et al., 2011).

The process commenced with first, fitting the data to linear multivariate time series model and then examining the eigenvalues from that specification. The motivation was to test

whether if a long-run relationship among variables that are non-stationary can be established. Therefore, once the unit roots were confirmed for the time series data, the next step was to establish the existence of a long-run equilibrium relationship among variables. In so doing, it established that the null hypothesis of the series test contained unit root (non-stationarity) while the alternative hypothesis had no unit root (stationarity). When the results obtained provide strong evidence that all the time series in levels are non-stationary, then the implication will be that they are integrated at an order of 0, i.e. *I* (0) at 5% significance level. This means the null hypothesis cannot be rejected for any of the variables under scrutiny. On the one hand, when the variables are found to be non-stationary in levels, their first difference will be considered. On the other hand, if the test rejects the null hypothesis at the first difference of the variables, it implies that they are integrated at an order of 1, i.e. *I* (1) at 5% significance level, which will imply that they are stationary.

1.25 Test for cointegration

After testing for unit roots, the next step is to test for co integration. The cointegration analysis was conducted to examine the existence of any possible long-run relationship among the dependent and independent variables. In doing so the study capitalised on Johansen and Juselius's (1990) approach of co integration. There are few reasons why Johansen's co integration procedure is considered. First the procedure is useful where the series are non-stationary. Second, it is an invariant test, which permits the existence of cointegration between the system variables without imposing bias on the estimates. Third, it can identify whether more than one cointegrating vector really exists.

1.26 Qualitative analysis process

The qualitative aspect of this research employed content analysis. According to Bryman (2011), content analysis is a research technique for studying textual documents in a replicable and systematic manner with the aim of examining patterns in data. This technique is valuable in social science research because it offers opportunity to researchers to recover and examine the nuances of behaviours, perceptions, and trends. At the same time, it represents an important tool for bridging the gap between exclusive quantitative and qualitative research methods (Bryman, 2011). Content analysis equally allows researchers to analyse socio-

cognitive and perceptual constructs that seems challenging when one adopts traditional quantitative methods (Bryman, 2011).

In this study, the researcher examined policy documents, published articles and government reports from both developing and developed countries. Using content analysis in this research is considered appropriate because it allows for the examination of relevant policy documents and other supplementary documents that are related to the research objectives. In addition, the large bodies of text related to this study required content analysis as specific themes was created to standardise the analysis. This approach allowed the researcher to study the words in the text and to understand better the perspectives of the authors. The content analysis of treaties and policy documents in this research were both manifest and latent. This means it considered both the elements that are physically present and also interpreted the underlying structures in the physical data.

1.27 Justification of the Study

Poverty and inclusive growth are key development challenges in Africa. For many decades, public policies and programs have focused on alleviating poverty, improving the livelihoods of people and creating a shared prosperity. The end of colonisation in Africa marked a period where the pursuit of transformative change for economic growth became a central goal for many African governments. With support from development partners in the form of aid, Africa countries began to witness remarkable improvement in their production, trade and investments albeit in a fragile political environment, limited technical capacity and food insecurity, dilapidated health systems and low infrastructure among others. The structural adjustment programs and millennium development goals have all contributed to the progress seen in the continent's development journey, yet Africa is still nowhere near alleviating poverty and achieving inclusive growth. When compared to some Asian countries like Malaysia, South Korea and Singapore who were at the same development stage during the 50s, Africa has not been able to achieve the level of growth seen in these countries. Indeed, current data suggests that more than 450 million people are still living below the benchmark US$1.90 a day, meaning that about 40% of the population falls into the category of extreme poor (World Bank 2023).

Just as poverty has been a long-standing development setback for the continent, inequality has remained an accompanied problem. A significant number of people in the continent lack access to basic water and sanitation facilities, health and education. Latest report from the World Inequality database indicates that income inequality in sub-Saharan Africa remains. Only 10% of the population controls more than half of the total income. Inequality exists not just among countries in the region but also within countries. South Africa for instance has one of the highest GDP in the region but also considered the most unequal country in Africa. Inequality in Africa is a byproduct of policy weakness and low investments in basic social infrastructure. The stark disparities observed between urban and rural areas is occasioned by the high concentration of physical capital, human capital and investment in big cities. This combine with unfair distribution of natural resources drives poverty levels in rural communities.

Addressing these twin development challenges is no easy task and there is no 'silver bullet'. It requires a combination of pragmatic and progressive policy actions with key focus on investment in physical infrastructure, ICT facilities and human capital. Recent technological advancement in particular offers the potential to transform the continent's fortunes, but this sector is yet to be fully exploited for the benefit of Africa economies It is well known that policy incoherence and low technical capacity are the leading limiting factors behind the slow adoption of technology in the continent, yet paucity of knowledge as a result of limited studies highlighting the positive net effects of technology is equally a major stumbling block. The economic success of the so called 'Asian Tigers' can be attributed to the pursuit of industrialization but underneath it is the fully capitalisation of technology. This is why this research strongly focus on fully revealing the intricacies on how ICT could leverage to drive poverty reduction and inclusive growth in Africa. The results of this study will be highly beneficial to researchers to understand better the drivers of development and policy makers to better develop result-based policy actions.

1.28 Chapter Outline

Chapter one presents a general introduction to the study. It outlines the background and the context within which this study is launched. Following a review of current epidemiological and demographic trends, it highlights the problem of ill-preparedness of Africa countries to embrace the new digital age which is set to transform industries, governance, and social structure. The final section focuses on the objectives, significance of the study and the research questions. Chapter two explores the impact of technological progress and digitization on Ghana's economy analysed a time series data covering the period 2009–2019. In this research, technological progress and economic growth inter-dependency was analysed in two steps. First, the relationship was tested by Augmented Dickey–Fuller method. A significant relation was found between technological progress and investments in ICT infrastructure. Technological progress and GDP relation was then tested in the next step. Chapter three assesses the process of alleviating poverty and achieving inclusive growth through digital innovations, by using evidence from South Africa. By exploring extensive literature, this chapter showed evidence on how digitisation contributes to economic transformation, growth, and poverty reduction. Chapter four focuses on examining the role of internet of things (IoT) to support health services in rural communities. Chapter five analysis a panel data for the period 2011- 2021, to estimate the relationship between the application of agriculture technologies and maize yield in rural South Africa using a stochastic production frontier framework and Cobb-Douglas production function. Chapter six discusses the impact of digital technologies on government operations, business operations and general welfare, using evidence from South Africa. Chapter seven presents evidence on how to promote inclusive growth in health through digitisation, using evidence from South Africa. The study specifically highlighted opportunities and barriers to the adoption of digital technologies in the country. Chapter eight presents summary findings and policy recommendations.

CHAPTER TWO: THE IMPACT OF TECHNOLOGICAL PROGRESS AND DIGITIZATION ON GHANA'S ECONOMY

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2.1 Abstract

This study analysed the impact of technological progress and digitization on Ghana's economy using panel data for the period 2009–2019. Technological progress and economic growth inter-dependency was analysed in two steps. First,the relation was tested using Augmented Dickey–Fuller method. Second, we estimated the long-run relation betweenthe variables by using Engel Granger and Error Correction models. The results indicate that adopting technology or digitizing the economy has the potential to drive sustainable growth and development. In particular, it was noted that ICT investments drive high productivity rates and faster economic growth. In sum, technological progress and digitization have the potential to foster significant growth and therefore must be given high credence in the planningand designing of development programmes. This paper contributes to development theories on the role that ICT playsin economic growth and development.

Keywords: digital technology, Ghana, development, economic growth, inclusive growth, poverty

2.2 Introduction

Modern information and communication technology (ICT) tools are not just transforming societies today but also shaping jobs and changing social interactions (Boakye and Babatunde, 2020). Disruptive digital platforms such as mobile apps, data analytics, internet of things and artificial intelligence are already altering traditional business models and pathways to development, supporting better access to health services while driving significant social and economic gains. In industrialised countries, the extent to which ICTs affect growth is well established (World Bank, 2016; Wieland, 2017; Khetrapal et al., 2019; Appiah-Otoo and Song, 2021). For instance, they have helped improved living standards, increased productivity, reduced production costs and build a more inclusive society.

In Africa, ICTs have also been recognised as key instruments for addressing the continent's long-lasting development problems for decades. In the early 2000s, when ICT penetration was gradually gaining momentum, many African governments were quick to introduced new regulations to capitalise on the opportunities it presented (Spiezia, 2013; Asongu and Acha-Anyi, 2020). They were seen as means of overcoming Africa's market failures, reducing production inefficiencies and enhancing trade and financial transactions. Yet, unlike developed countries, the impact of ICTs on Africa's macroeconomic growth has been less significant. There are many contributing reasons, however key among them include lack of ICT infrastructure, low ICT skill personnel and limited investments in ICT. On the other hand, few studies have explored the long-term impact of ICT on Africa's economic growth. This suggests that limited evidence exist to provide basis for African governments to fully embrace the new digital revolution.

Using Ghana as a case, this research examines the long-term impact of ICT on macroeconomic growth. By focusing on the drivers of economic growth, the study is designed to complement other works on the interrelationship between technology and economic growth. The objective is to provide a strong basis for the full adoption of the new digital technologies both in government and private operations. In this paper, we first offer a brief situation of technology integration in Ghana's economy since the early 2000s. We then proceed to highlight existing evidence on the relationship between technology adoption and GDP growth. In doing so we draw on evidence from both developed and developing countries.

From there, we establish the contextual motivation behind the need to estimate the impact of technologies on Ghana's economy. This is then followed by a brief discussion of the theoretical framework underpinning this study. We then conduct an analysis and present findings from the study with brief discussions. Conclusion and recommendations are provided thereafter.

2.3 The scope of ICT integration in Ghana

Like many countries around the world, Ghana also shares the notion that ICT integration plays a significant role in boosting economic growth as well as reducing poverty and inequality. This has been evident in the number of ICT policies and programmes that the country has adopted since the early 1990s. For instance, in 1994 when a five-year development plan known as "Growth and Poverty Reduction Strategy II (GPRS II)" was launched, key emphasis was placed on the absorption and application of technology to enable faster growth. Even prior to the 2005 World Summit on Information Society which called on developing countries to establish ICT policies so as to benefits from the digital revolution, Ghana had already engaged in the development of an ambitious ICT policy. In 2004, the Government of Ghana initiated an ICT for Accelerated Development (ICT4AD) policy aimed at improving the quality of life of the people of Ghana through the rapid modernization of the economy using information and communication technologies as the main engine for sustainable development (World Bank, 2019).

In recent times, the country has seen the introduction of several keystone digitisation platforms that are expected to change government transactions (BoG, 2018). Some of these initiatives include e-procurement, e-immigration, e-parliament, e-justice, e-cabinet and other initiatives such as the national digital property addressing system, the introduction of paperless port operations among others. The government is equally playing a critical role in building a workforce with strong digital skills. The current National ICT in Education Policy for Ghana, for instance, has a mission to articulate the relevance, and effectiveness of utilizing technologies in the education sector, with a view of addressing current sector challenges and equipping Ghanaian learners, students and teachers with skills needed to not just be technology consumers but also producers (World Bank, 2019).

2.4 ICT contribution to Ghana's socioeconomic growth

Ghana's ICT sector has experienced impressive growth for the past decades, as a result of the liberalization and market deregulation programmes that have been pursued by successive governments (Bartels and Koria, 2014) These measures, for instance, contributed to a rapid mobile phone and internet penetration which begun in 2003. Today, Ghana's mobile internet penetration stand at about 68% (Hatt et al., 2017). Recent report from the World Bank also shows that ICT contribution to Ghana's GDP has grown steadily over the years, making it one of the best performing sectors in the country (World Bank, 2019). For example, in 2017, it was estimated that about $2 billion, representing 3.6% was the share of ICT sector's contribution to the overall GDP of country. Strong competition, increase in private sector investment, and reduction in telecommunications prices have been the driving forces for the growing innovation in the ICT sector.

Moreover, the growing desire to position Ghana as an information-rich, knowledge-based and technology driven high-income economy has led to the government's continued investment in public sector digital platforms. In 2018, a survey conducted by the UN E-Government Index positioned Ghana as the only African nation that was able to transition from the middle to high E-Government Development Index (EGDI) level (UNCTAD, 2019). The present government equally recognizes the potential that a digitised economy has for improving productivity, stimulating jobs, and accelerating inclusive growth. The government has therefore pledged to leverage ICT as a means of improving citizen experience and engagement with government.

2.5 Existing evidence on the impact of ICT on economic growth

Technology and innovations are recognised as foundations upon which strong economies are build. This position is backed by contemporary growth theories. For instance, the neoclassicals posit that economic growth is dependent on labour force, technology, and the total capital stock of a country (Solow, 1999). In particular, they argue that economic growth cannot be attained without leveraging technological advancement (Solow, 1999; Acemoglu, 2009). In this regard, technology is considered as an exogenous variable which serves as a differentiating factor between developed and underdeveloped countries. The endogenous model or the AK model also expands on the neoclassical theory to suggest that growth

dynamics are internal result of forces largely influenced by economic and development policies of a country (Aghion et al., 1998).

In a broader sense, the theory implies that development policies that embrace openness and encourages competition will drive innovations and technology development. As firms become more innovative inclined and adopt new technologies, labour productivity will increase thus impacting on growth outcomes. The other paradigm of growth model which give emphasis to ICT as a growth enabler is the Schumpeterian growth model (Aghion & Howitt 1992). The model posits that growth is driven by innovations by means of creative destruction (Aghion & Howitt 1992). In essence, growth in this model results from innovations that improve the quality of the intermediate input used in the production of the final product (Aghion et al., 2015; Agrawal et al., 2015).

Beyond growth theories, evidence from past studies also point to a positive correlation between a country's growth and adoption of new technologies (Klenow and Rodriguez-Clare, 1997; Comin and Hobijn, 2004). These researchers concluded that technology and innovation represent the bulk of cross-country differences in productivity, compared to factor accumulation (physical and human capital). Recent studies equally provide empirical support for technology-based growth theories include Donou-Adonsou, and Mathey, (2016); Donou-Adonsou and Sylwester, (2017); Saidi and Mongi (2018).

Across the African continent, several achievements have also been recorded on the net effects of shifting from conventional means of production and service delivery to the adaptation of new technologies (World Bank, 2018; Chavula, 2013; Donou-Adonsou et al., 2016). The benefits of this shift are noted in the form of reduced transactional cost in doing business, improved efficiency and increased in agriculture productivity. Kenya has emerged as a key beneficiary of this drive. Kenya's continuous push for a complete digitised economy is tracked to improvements in telecommunications, electricity, and a 2% annual growth (UNCTAD, 2018). Given the extensive evidence on the crucial role that recent digital technologies and innovations play on development, many African countries are beginning to revise their ICT policies and goals. The Egyptian government for instance has a goal of increasing IT-related contributions to over 8% of GDP annually from 2020. Kenya has targeted the ICT sector to contribute more than 8% to the country's GDP. A number of countries,

including Cote D'Ivoire, and Nigeria, have transitioned to a unified licensing regime to reflect convergence of the telecommunications sector (World Bank, 2019).

Despite the substantive evidence, few studies have measured the long-term effects of digitisation on development in African countries (Haftu, 2019). This study therefore provides new empirical evidence on the relationship between digital technologies and economic growth using Ghana as a case study.

2.6 Empirical analysis and results

This study analysed the growth impact of digitisation in Ghana by using annual time series data for the period 2009–2019. The scope of this study falls under a cluster of studies that focus on exploring factors that drive economic growth in developing countries. The underlying context of this study adopts the conceptual framework derived from Cobb and Douglas (1928) production function where growth is expressed as a function of physical and human capital, labour, and the level of technological progress. Following the footsteps of previous researchers (Njoh, 2018; Haftu, 2019), we employ the following model in the present study:

$Y_{it=}f(A_tK_t^aL_t^{1-a})$…… 1 where A = total factor productivity, L= labor, K= capital

This growth production function is extended by assuming that the total factor productivity is influenced by technological progress which in turn is driven by investments in digital tools (I), local infrastructure (LI) and technology availability (TA). Hence *A* is transformed into:

$$A_t = I_{it} + LI_{it} + TA_{it} \ldots\ldots\ldots\ldots 2$$

The specification of this model is based on two main motivations. First, within empirical literature, this model is among the commonly used measures of technology diffusion in relation to GDP growth. Second, the model takes into consideration human capital and labour productivity which are key elements for economic growth. To measure the elasticity between the variables, we apply log form into equation (1):

$LogY_{it=}$ $\alpha 0+LogI_{it} + LogLI_{it} + logTA_{it}+ \beta LogK_t^a+LogL_t^{1-a}+\varepsilon t$…… 3

The values in Equation (3) can be interpreted as follows: α represents the elasticity of output/growth with respect to physical capital and human capital, while β represents the

output with respect to labour. Therefore, the regression coefficients in this double-log model can be simply interpreted as the respective elasticity. It is further assumed that the dependent variable (*GDP*) and the technological progress (A) are exogenous variables and as such grows at time variant rate g(it) while (ε) represent a random error. By using autoregressive distributed lag (ARDL) modelling approach, the estimation of the stationarity test can be expressed as

$\ln Y_{t=} \alpha 0 + \alpha t\, T + \beta_1 \ln I_{it-1} + \beta 2 \ln LI_{it-1} + \beta 3 \ln TA_{it-1} + \beta_4 \ln K_t^a + \beta 5 \ln L_t^{1-a} + \sum_{i=1}(n-1) \gamma_{1\Delta} \ln I_{it-1} + \sum_{i=1}(n-1)\ \gamma_{2\Delta} \ln LI_{it-1} + \sum_{i=1}(n-1)\ \gamma_{3\Delta} \ln TA_{it-1} + \sum_{i=1}(n-1)\ \gamma_{4\Delta} \ln K_t^a + \sum_{i=1}(n-1)\ \gamma_{5\Delta} \ln L_t^{1-a} + \varepsilon t$ 4

In this model (equation 4), the dependent variable (*Yt*) is examined through the long-term and short-term relationship with technology progress. *βi* represents long-term parameters, γi, short-term parameters, *T,* time trend, and *ε*, is random error.

2.7 Test for stationarity

A unit root test on each variable in the models was performed using the Augmented Dickey-Fuller (ADF) test. ADF was applied because of its superiority when it comes to time series with autoregressive structure, as well as its reliability for ensuring white noise residuals. The process commenced by fitting the data to linear multivariate time series model and then examining the eigenvalues from that specification. The purpose of this exercise is to test whether a long-run relationship among variables that are non-stationary can be established. In doing so, it was assumed that the null hypothesis which is indicate as: economic growth and ICT progress are independent will contain unit root (non-stationarity) whiles the alternative hypothesis that growth is dependent on ICT progress will have no unit root (stationarity). When the results obtained provide strong evidence that all the time series in levels are non-stationary, then the implication will be that they are integrated at an order of 0, i.e. *I* (0) at 5% significance level. This means the null hypothesis can be rejected for any of the variables under scrutiny.

2.8 Empirical analysis and results

In this study economic data were drawn from the World Bank country growth index and reports while telecommunications data were drawn from the annual publications from the International Telecommunication Union. Table 1 presents details of data sourced.

Table 1: Data sources

Representation	Variable definition	Sources
Y**t**	Growth of gross domestic product	World bank
I	Investments	World bank
LI	local infrastructure	World bank and ITU
TA	Technology availability	ITU
L	Labour contribution	World bank
K	*Capital contribution*	*World bank*

2.8.1 Technological progress model estimation

The technological progress model was estimated using the Augmented Dickey–Fuller (ADFL) method. In this model, there are three independent variable and one dependent variable. The model is given below:

Technological progress (A) = investments (I), local infrastructure (LI), technology availability (TA).

$$InA_t = \beta 1 \ \mathrm{In} I_{it} + \beta 2 \mathrm{In} LI_{it} + \beta 3 \mathrm{In} TA_{it}$$

In the above model, each variable series natural base logarithm is applied in the analysis. Unit root tests were employed in each series. As shown in Table 2, the test indicates a significant serial correlation or no serial correlation in the residuals. The series were also found stationary at level. The ADFL model was then run by these stationary variables. Results is highlighted in Table 3.

Table 2: Unit root test results of In(A); In(I); In(LI); In(TA)

Variable	Model	T-statistics	Probability	Integration results
In(A)	Trend and intercept	-3.183673	0.0484	1(0)
In(I)	Trend and intercept	-4.842390	0.0045	1(0)
In(LI)	Trend and intercept	-2.264956	0.0675	1(0)
In(TA)	Trend and intercept	-3.364349	0.0566	1(0)

Table 3: Estimation results on the drivers of technological progress

Dependent variable: A **Sample: 165** **Included observation: 30**				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
Constant	-6.237448	0.943874	-6.585672	0.0000
In(I)	0.384642	0.352844	2.845643	0.0011
In(LI)	0.887454	0.426437	3.484464	0.0003
In(TA)	0.249574	0.674649	6.008474	0.0020
R-squared	0.038947	Mean dependent var		3.7263
Adjusted R-squared	0.736464	S.D. dependent var		0.2928
S.E. of regression	2.848567	Akaike info criterion		0.0043
Sum squared resid	0.828445	Schwarz criterion		1.8477
Prob(F-statistic)	0.001010			

A significant relation was found between the independent and dependent variables. Results also show that all variables have their expected signs. The test further shows a high coefficient of t-statistics. From the results of the probabilities, the null hypothesis is rejected at the 95% confidence level in addition to the no serial correlation found at the 95% confidence level. The S.E regression tests has a p-value of 0.004. This implies that we can reject the null hypothesis that technological progress is not driven by digital infrastructure investments (I)

and technological availability (TA). Based on the diagnostic tests we conclude that our model is working well, and results are reliable. Furthermore, the coefficient on the constant value of the Technological progress is -6.237448 with its corresponding p-value of 0.0000. This means that outcome of investments in past technological infrastructure affects decision to invest in future technologies.

2.8.2 Growth model estimation and results

The growth model was estimated using Augmented Dickey–Fuller (ADFL) method. In this model, there were three independent variable and one dependent variable. Growth was expressed as a function of physical and human capital, labour and the level of technological progress; $InGDP_t = \beta 1 InA_t\ (I_{it} + LI_{it} + TA_{it}) + \beta 2 \mathrm{In} K_t^a + \beta 3 \mathrm{In} L_t^a$.

Each variable series' natural base logarithm is applied in the analysis. Unit root tests were employed in each series. The series were found stationary at level as depicted in Table 4.

Table 4: Unit root test results of ln(GDP); ln(A); ln(K); ln(L)

Variable	Model	T-statistics	Probability	Integration results
ln(GDP)	Trend and intercept	-1.340483	0.0343	1(0)
ln(A)	Trend and intercept	-3.032944	0.2344	1(0)
ln(K)	Trend and intercept	-2.562120	0.7434	1(0)
ln(L)	Trend and intercept	-1.834535	0.6342	1(0)

From Table 4, the test indicates a significant serial correlation or no serial correlation in the residuals. The Durbin-Watson statistic was hence replaced by the Breusch– Godfrey Serial Correlation test which is appropriate as a test for serial correlation in this case. This is because a lagged dependent variable is observed on the right-hand side of the equation. The t-statistics indicate that the residuals are not serially correlated, meaning that the equation has a good specificity. To test the long run relationship between economic growth and

technological progress, we employed the Engel Granger Error Correction Model. Results is given in Table 5.

Table 5: Impact of technological progress on GDP growth

Dependent variable: GDP **Sample: 165** **Included observation: 30**				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
Constant	-2.84730	0.523455	-2.482630	0.0024
In(A)	0.437053	0.442643	4.482945	0.0234
In(K)	0.547240	0.213448	7.145636	0.0737
In(L)	0.582374	0.938645	2.283644	0.0128
R-squared	0.032442	Mean dependent var		2.4726
Adjusted R-squared	0.062047	S.D. dependent var		0.0485
S.E. of regression	1.234052	Akaike info criterion		0.0424
Sum squared resid	0.454444	Schwarz criterion		1.3736
Prob(F-statistic)	0.402455			
CointEq(−1)	-1.053432	0.325474	-2.434245	0.0304

In Table 5, the error-correction coefficient is negative (−1.053), as expected, and this was found to be significant. This output suggests that 1.05 short-term errors are automatically corrected over time to achieve long-term equilibrium. This means that GDP needs about 1 year (10 months) to reach its long-term equilibrium value. Hence, it can be concluded that there is a relatively quick adjustment in the GDP growth rate when the technological progress (A), Capital (K), and labour (L) changes. It can also be assumed from the long-run coefficients that a 1% increase in the contribution of capital and labour services improved by technological progress leads to a 10% increase in the GDP. Furthermore, using the critical value of regression-residual based on the co-integration test the value of Engel Granger test at 10% is -2.84. This means the absolute value of t-statistic is higher than the absolute value of critical value. Hence it can be concluded that GDP and technological progress are co-integrated and have a long run relationship. The result is in line with previous studies conducted by Donou-

Adonsou et al. (2016). In particular, the contribution of technologies is positive and significant at the 10% significance level. Ten percentage investments in advance technologies raises GDP per capita income by 1.5%.

2.9 Conclusion

In this paper, we study the growth impact of digitisation on Ghana's development by using annual time series data for the period 2009–2019. We noted that technology progress contributes to economic growth and long-term development prospects. Technological progress and economic growth inter-dependency was analysed in two steps. First, the relation was tested by ADFL method. A significant relation was found between technological progress and investments in ICT infrastructure. Technological progress and GDP relation was then tested in the next step. Consequently, a long run relation was observed between the two variables by Engel Granger and Error Correction Models. The results indicate that adopting technology or digitising the economy has the impetus of driving sustainable growth and development. This finding is consistent with that reported by other researchers (Adak, 2015; Haftu, 2019; Boakye & Babatunde, 2020). Policymakers should therefore give high priority to investing in digital infrastructure if they wish to accelerate economic growth and improve public service delivery.

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CHAPTER THREE: ALLEVIATING POVERTY AND ACHIEVING INCLUSIVE GROWTH THROUGH DIGITAL INNOVATIONS. EVIDENCE FROM SOUTH AFRICA

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3.1 Abstract

The recent times have experienced a growing technological change with greater potential and more far-reaching implications. These transformations have been reflected in several new approaches and concepts relevant to harnessing the potentials of digital innovations to achieve global and national goals. Meanwhile, there is limited evidence demonstrating how digital innovations can be leveraged to transform African economies, reduce poverty, and improve overall wellbeing. Using South Africa as a case study, this research explores literature to show how technologies and smart applications contribute not just to innovation in products and service delivery, but also help address policy challenges in a wide range of sectors, including agriculture, education, public governance, health, and the environment, among others.

Keywords: Poverty alleviations, inclusive growth, digitisation, South Africa

3.2 Introduction

Eradicating poverty in all its forms and dimensions has been one of the greatest challenges the world has grappled with over the years. Despite the remarkable progress made in combating poverty, a significant proportion of people worldwide still live in extreme poverty. According to a recent publication from the World Bank, about 689 million people, equivalent to 9.2% of the world's population live in extreme poverty with sub-Saharan Africa accounting for more than half of the global extreme poverty cases (World Bank, 2020).

Nonetheless, several African countries have made impressive gains in reducing poverty and improving general economic wellbeing. Today, many people in Africa have access to better education, water, electricity, sanitation, health, and jobs. Yet new threats such as covid-19 and climate change are beginning to reverse fortunes made in the fight against poverty and income inequalities in Africa. To address this problem requires a new way of thinking and approach. The ICT revolution presents a viable option for facilitating economic transformation and reducing the economic effect of COVID-19, thereby contributing towards poverty reduction. Innovations such as artificial intelligence, the Internet of things, data analytics and blockchain are shaping the way businesses are done in the agriculture, health, education, manufacturing, and service sectors. They are contributing to improved efficiency and increased productivity.

Sub-Saharan Africa has not been completely left out in the digitisation drive. The widespread adoption and integration of ICTs in countries like Kenya and Ghana has reduced information and transaction costs, created new jobs, generated new revenue streams, conserved resources, and helped improved service delivery. Digital transformation in sub-Saharan Africa, for example, has been found to boost annual growth by almost 2% and reduce annual poverty by 1% (Ndulu et al., 2021). Meanwhile, not all countries within the region have benefited from the net positive effects of digitisation on poverty reduction. In most countries, the adoption and integration of ICTs have been slow. This is largely because of the limited evidence demonstrating how digital innovations are transforming economies, reducing poverty, and improving overall wellbeing.

In this article, we show how digitisation can contribute to economic transformation, growth, and poverty reduction, with a focus on South Africa. In particular, it purports to demonstrate how adopting technological innovations enhance productivity and help contribute to better wellbeing. A content analysis method of research was adopted. Using content analysis in this research was considered appropriate because it allows for the examination of relevant policy documents and other supplementary documents that are related to the research objectives. In addition, the large bodies of text related to this study required content analysis as specific themes was created to standardise the analysis. This approach allowed the researcher to study the words in the text and to understand better the perspectives of the authors. The content analysis of treaties and policy documents in this research were both manifest and latent. This means it considers both interpretations that are physically present and also inherent in the physical data. For a literature to qualify for inclusion in the study, it has to be relevant to the research topic, contain the key concepts of the study and must been published within the last decade.

The structure of this paper is as follows. The next section describes the status of poverty and economic growth in South Africa. The paper proceeds to show how digital innovations can help address the challenges of poverty and inequality in South Africa. The following section highlights available evidence on digitisation and poverty reduction. The final sections focus on polices mix needed to leverage digital technologies to achieve economic and inclusive growth in South Africa and conclusion.

3.3 Status of poverty and economic growth in South Africa

Poverty, inequality, and unemployment have persistently been the core challenges to South Africa's development agenda. For over two decades, the country has sought to respond to these challenges with a wide range of social and economic policies as well as initiatives that aim at ensuring fair distribution of resources. These measures can be traced back to the post-apartheid era when the then government made it a central objective to reduce poverty and inequality with the launch of the Reconstruction and Development Program. This program had the core goal of bridging inequality using investing in education, health, and other social amenities in poor communities. As an assessment of the program, 10years after its implementation revealed positive outcomes. For instance, poverty levels declined from 33.8%

in 1996 to 25.5% in 2006 (IDC, 2013). A further decline of 8% was witnessed between 2006 and 2014.

Despite this progress, the trend of poverty reduction was reversed between 2011 and 2015. In 2015, nearly half (49.2%) of the South Africans adult population fell below the upper-bound poverty line according to data from the Department of Statistics in South Africa (Biyase & Zwane 2018). Today, it is estimated that nearly 55.5% of the population are living in poverty (World Bank, 2020). Rural communities remain the regions with the highest poverty concentration. Female black South Africans are generally more vulnerable to poverty. An analysis of the poor shows that a typical poor household in rural areas is often headed by a single and economically inactive female black South African. The steadily increase in poverty rates in South Africa since 2011 has been driven by a combination of international and domestic factors such as low and weak economic growth, continuing high unemployment levels, lower commodity prices, higher consumer prices and covid-19 pandemic (World Bank, 2020.

Despite its poverty situation, South Africa economy is regarded as one of the robust economies in the world. With a gross national income (GNI) per capita of $6,040, the country is among the developed countries classified as an upper-middle-income. The South African economy is generally characterised by stable growth with relatively low taxes and tariffs, flexible exchange rates as well a controlled fiscal deficit. The political transition from the apartheid regime to democratic governance triggered robust growth and development owing to major adjustments made in the economy. For instance, the expansion of the labour market, increased household expenditure, capital reallocation and growth in commodity markets which characterised the period between 1994 and 2008 saw the economy grew at an average rate of 3.3%. Between 2015 and 2019 real GDP growth averaged at 0.80%, however with the advent of covid-19, the economy fell by 8%, the worst ever since the end of the apartheid (World Bank, 2020). This situation, if not responded to swiftly with innovative measures is set to roll back the economic gains made over the years.

3.4 How digital innovations help address the issue of poverty and inequality in South Africa?

Technological innovations are all about improving means of production and services delivery to achieve better outcomes. Technologies and smart applications contribute not just to innovation in products and service delivery, but also help address policy challenges in a wide range of sectors, including agriculture, education, public governance, health, and the environment, among others. They play an important role in spurring income growth and reducing poverty.

To a significant degree, the adoption of technologies is what differentiates between advanced countries and poor countries. Although South Africa is regarded as an upper middle-income country, its poverty level is among the highest in the world. According to the 2020 World Bank's estimates, about 30.3 million South Africans live in poverty at the national upper poverty line (R992) with a total of 13.8 million people experiencing food poverty (World Bank, 2020). Poor households depend on a combination of subsistence agriculture, government social grants and remittances from working-class family members.

Despite having a diverse economy such as mining, manufacturing, tourism and communication, the agricultural sector contributes significantly to the country's economic activities, providing a livelihood for more than half of its population. Yet, the sector suffers from low levels of technological adaptation and absorption. Solutions for raising agricultural productivity in South Africa requires sustainable farming and technology adoption within the domains of crop farming, weather forecasting, wildlife management, forestry, and livestock farming.

As a catalyst for growth, digital technologies may be disruptive, but they have far-reaching impacts on agriculture and rural livelihoods. Unlike traditional practices such as irrigation, fertilizers application and pesticides, digital technologies such as sensors, mobile applications, satellites, and drones among others can have a significant effect on crop and weather monitoring, animal control and access to markets thereby raising agricultural productivity. Given the strong relationship between agriculture growth and poverty reduction, adopting these technologies in the agriculture sector means helping to raise the livelihoods and incomes of poor households who depend on agriculture activities.

Digital technologies are relevant for addressing a wide range of issues, not just poverty in South Africa but also inequality. South Africa is known to be one of the most unequal countries in the world. Inequalities can easily be identified along racial lines, ethnicity, gender, and geographical location (Ataguba, & Alaba, 2012). Similar to education and employment, health inequality in South Africa is a general reflection of the persistent socio-economic, racial and political disparities the country has experienced over the years. Inequalities in health care arise along various dimensions: distribution and provision of care; availability of services and health infrastructure; and accessibility of quality services.

Technological innovations present a large and unexploited potential for transforming the health sector of South Africa to achieve inclusive health (Mckinsey, 2019). Digital health tools, such as mobile applications, biometric skin sensors, short messaging services, interactive voice response, mobile diagnostic devices, and big data analytics. The opportunities of these tools as core enablers for inclusive health in South Africa can be found in the areas of promoting health education and awareness programmes, allowing real-time monitoring of an individual's health, enabling data collection for surveillance and public health in rural areas and supporting diagnostic and treatment support, communication for health-care workers in remote settings.

South Africa education sector is equally one that stands to benefit considerably if digitisation is given the necessary attention. It is well established that improvements in education are linked with sustainable advances in economic performance. Education contributes to economic progress in areas such as improving labour force skills and enhancing the ability to develop and share new ideas and technologies. All these helps to achieve greater productivity and thus contributing to economic growth. In South Africa, low quality and unequal access to education perpetuate poverty and inequality in the country.

A recent report published by Amnesty International characterised the South African education system, as one with crumbling infrastructure and overcrowded classrooms (Amnesty International, 2020). Such situations perpetuate inequality and high unemployment particular for those from a poor background. To address this challenge means exploring other alternatives. Fortunately, adopting digital technologies into the education sector offers a potential solution. For instance, using digital platforms such as video conferencing can

connect teaching halls in different parts of the country and allow students in different locations to participate in the same lessons. This also presents an effective way for learners to collaborate across large distances and thereby overcoming the challenge of inadequate physical infrastructure.

3.5 What does the evidence say about digitisation and poverty reduction?

Many scholars (Gruber & Koutroumpis, 2010; Katz & Koutroumpis 2014; Donou-Adonsou, Lim & Mathey, 2016; Haftu, 2019) hold the view that technological development drives long-term economic growth, productivity, and improvement in the standard of living. They particularly emphasized that it is progress in technology that differentiate fast-growing developing economies from slow-growing ones. Joseph Schumpeter (1928) was the first economist to have argued in favour of technological progress as a catalyst for economic growth (World Bank, 2018). Schumpeter provides that diffusion of new ideas and production techniques throughout the economy creates a process of "creative destruction'' where weakening sectors are destroyed whiles new industries emerge. Thus, Schumpeter view extends the threshold of the technological evolutionary concept beyond simple application of innovative techniques to encompass the creation of new markets, new distribution systems and finding new sources for raw materials.

Building on Schumpeter's conceptual framework of technological transformation, Paul Romer (1986) in his study titled 'Increasing returns and long-run growth', indicated that technical progress is the main driver for economic growth. This growth, according to Romer (1986) can be seen in an increase in Gross Domestic Product (GDP), enhancement in labour productivity and acceleration in capital accumulation (Zhao, 2019). Thus, by reinforcing Schumpeter's position, Paul Romer provided that technical progress improves transformation of resources and diffusion of new ideas into products. In their book titled 'the positive-sum strategy: Harnessing technology for economic growth', Landau and Rosenberg (1986) argued that leveraging technology for growth, however challenging it may be is essential for the success and prosperity of a company and nation particularly during periods of low growth.

Interestingly, from the latter part of the 20th century till the earlier part of the 21st century, every new study on growth that emerged seemed to have implicated technological

advancement in the growth of an economy. For example, in a cross-sectional study examining the effects of technological change on economic growth and development, Malecki (1991), found that technological progress contributes to local, regional, and national development. Similar observations were made by Jorgenson et al., (2000) who applied Jorgenson's production possibility frontier to describe the increased productivity growth the US experienced after 1995. Their findings revealed that the integration of computer systems in firms' operations contributed significantly to the growth of the US economy. This was more evident in the average labour productivity which grew faster between 1995 and 1999 because of capital deepening which was induced by the fall in ICT prices.

By examining the post-1995 productivity performance of the individual US industries that either produce IT, use IT, or are relatively isolated from the IT revolution Stiroh (2002), discovered that U.S. productivity revival was a reflection of gains in a majority of industries that either produced or integrated Information Technology in their operations. Some recent studies also confirm the positive link between technical progress and development. For instance, in a study which applied an econometric approach to estimate the contribution of different types of ICT investments in 26 industries in 18 OECD countries over 1995-2007, using the database from the European Union Database, Spiezia (2013) found that the estimated contribution of ICT investments to value-added growth in the business sector varies from 1.0% a year in Australia to 0.4% a year in Japan. The study further revealed that ICT producing industries account for no less than two-thirds of total factor productivity (TFP) growth in Germany, Slovenia, and the United Kingdom, about 60% in the United States and just below 50% in France and the Netherlands.

In Denmark, the Czech Republic and Italy, TFP increased in the ICT producing industries whereas it decreased for the total business sector. Using annual time-series data over the period 1980 to 2010 to estimate the impact of ICT investment on economic growth and energy consumption in Japan, Ishida, (2015) discovered that ICT investment contributed to a moderate reduction in energy consumption, and long-run stability in GDP. Using instrumental variables-Generalized Method of Moments approach in examining the impact of technological developments on economic growth in 47 countries in Sub-Saharan Africa, Donou-Adonsou et al. (2016), discovered that both the Internet and mobile phones usage

contributed significantly to GDP of most Sub-Saharan African countries. In a study of the effect of Education, R&D and ICT on economic growth in high-income countries, Saidi and Mongi (2018), found a bidirectional relationship between education, internet users and mobile cellular telephone, while there is a unidirectional relationship from internet users to economic growth and research and development and from the mobile cellular telephone to economic growth and research and development in the long-run.

In light of the above evidence, it is likely to assume that the nexus between technological progress and economic growth points to a single direction. Yet this is not the case. Indeed, findings from studies in some developing countries suggest otherwise. One popular study that dispelled any doubts that technology improvements contribute less to economic growth was Jalava and Pohjola's (2002) study. Jalava and Pohjola's (2002) study employed an augmented variant of the neoclassical growth model to examine the impact of ICTs on growth in 39 countries. The results revealed no positive association between ICT advances and economic growth. A similar observation was made by Bollou and Ngwenyama (2008) who investigated the total factor productivity (TFP) of the ICT sectors in six West African countries from 1995 to 2002 and found a rather declining level of TFP growth in ICT sectors of these economies. Despite these contrary findings on the significance of technology play on economic growth, it is worth noting that the existing evidence concerning the negative relationship between technological developments and growth is relatively limited. In most cases, the arguments put forward by these scholars do not seem to undermine the potentials of technological progress but rather focus on the scale of its contribution to realising development goals such as poverty reduction and reducing inequalities.

3.6 Policies to reap the benefits of digitisation for the South Africa economy

The degree of poverty and the depth of inequality in South Africa provides a good justification for the country to chart a new and innovative path of development. As demonstrated in the previous sections, digitisation of the economy has shown to be a good enabler for sustaining livelihoods, increasing household income, and enhancing wellbeing. However, the ability to leverage digital technologies to achieve economic and inclusive growth depends on designing and implementing the right set of the policy mix.

For South Africa, the first policy direction is the need to establish the right regulatory framework. A friendly legal environment does not only create avenues for increased investment and private participation but also enables innovation by allowing new business models to be generated tested and distributed to all corners of the economy and society. A key action step is to develop a policy to reduce sunk costs and improve access to finance, which happens to be a critical challenge to adopting new technologies by young entrepreneurs and small enterprises. Equally essential is designing appropriate guidelines and standards to ensure digital security and privacy.

The second step is investing in digital skills acquisition through training and capacity building. The world of 2030 and beyond will be very different from the present, as a result of the widespread deployment of digital technologies. This suggests identifying the mix of skills needed to ensure active participation in a digitalised economy to boost quality employment. To avoid being left behind means improving digital literacy levels through training and capacity development. For South Africa to be prepared for the future, the curriculum in its educational institutions should be revised and reoriented to give priority to science, technology, engineering, and mathematics (STEM) subjects, with a special focus on technical and vocational education and training (TVET). Moreover, given that the skills disparities tend to be high for people in low-skilled work, it is essential to ensure that the benefits of ICTs and other technologies reach out to all of society.

The third step is the need for South African Governments to prioritize public spending on research and development. It is crucial to point that R&D is essential to the extent that it can effectively foster technological learning and build innovation capacities in a country. The government must put support programmes in place for business research and innovation to accelerate the level of technological innovation in business sectors.

The fourth step is improving ICT infrastructure and fixed-line or mobile phone connectivity. It is important that the government continually invest in digital infrastructures to meet existing and future skills demand and help bridge digital divides. Promoting availability, accessibility and affordability of ICT infrastructure, devices, and connectivity through increased investment in low-cost, high-speed broadband is a sure way to go. A critical area for policy

action involves establishing national broadband plans that address the key barriers to the deployment of high-speed networks and services, particularly in rural areas.

3.7 Conclusion

Recent times have experienced a growing technological change with greater potential and more far-reaching implications. These transformations have been reflected in several new approaches and concepts relevant to harnessing the potentials of digital innovations to achieve global and national goals. In this study, we have demonstrated how digitisation contributes to economic transformation, growth, and poverty reduction, with a focus on South Africa. In particular, the study has revealed how adopting technological innovations impacts productivity and general wellbeing. The paper argues that leveraging digital technologies to achieve economic and inclusive growth depends on designing and implementing the right set of policy mix. This policy mix includes establishing the right regulatory framework; investing in digital skills acquisition through training and capacity building; prioritising spending on research and development; and finally investing in ICT infrastructure. The study can also be utilised by developers of new digital technologies in South Africa to build country-specific technologies based on the identified need.

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CHAPTER FOUR: THE ROLE OF INTERNET OF THINGS TO SUPPORT HEALTH SERVICES IN RURAL COMMUNITIES. A CASE STUDY OF GHANA AND SIERRA LEONE

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4.1 Abstract

Incidence of preventable diseases in rural parts of Ghana and Sierra Leone is unacceptably high, which calls for innovative solutions to be directed towards addressing this issue. The intention of this research is to examine the potential contributions of internet of things technologies (IoT) towards health improvement in low-resourced settings with emphasis on transforming patients care and improving efficiency in rural Ghana and Sierra Leone. The research project investigates and identifies appropriate mechanisms by which IoTs technologies could be leveraged to mitigate health burdens in poor communities with emphasis on enhancing remote monitoring of patients' health, increasing access to health information, training of healthcare professionals and reducing out-of-pocket health expenditure.

Keywords: Health improvement; internet of things; rural communities; Ghana; Sierra Leone

4.2 Introduction

The use of information and communication technologies (ICT) to support healthcare services is advancing exponentially across the globe. This is particularly so because of the greater demands for improved and quality care, particularly for underserved communities. Moreover, achieving universal health coverage and ensuring that all persons have access to quality and essential health services has become critical health agenda around the world (Nambiar, Reddy & Dutta, 2017; GovUK, 2019). Recent data shows that close to half the world's population lack access to essential health services, while nearly 100 million people are pushed into extreme poverty annually as a result of out-of-pocket health expenses (WHO, 2019). Residents in underserved community bear the highest burden of this situation. This phenomenon has generated a lot of research interests on how to harness the potentials of today's emerging technologies to ensure health equity and improve health outcomes of people in remote areas.

In this study, we focused on examining the role of internet of things technologies (IoT) towards improving health outcomes for residents in rural Ghana and Sierra Leone. In particular, we highlight some of the health technologies that are relevant for augmenting healthcare delivery in rural communities. In doing so, we draw lessons from developed and developing countries and identify appropriate mechanisms by which IoTs technologies could be leveraged to mitigate health burdens in rural Ghana and Sierra Leone.

The Internet of Things (IoT) refers to the use of intelligently connected devices and systems to leverage data gathered by embedded sensors and actuators in machines and other physical objects (Baker, Xiang & Atkinson, 2017, Barro, Degila, Zennaro & Wamba, 2018). Within the healthcare sector, IoT uses connected medical devices with combined health applications to deliver quality healthcare and improve diagnostics. This development has the potential to resolve shortcomings of rural healthcare delivery. For example, it presents an opportunity to support a shift of treatment in primary care clinics and hospitals to home through the use of digital communication such as e-visits, e-prescriptions and remote monitoring. Meanwhile, there are barriers to the adoption of IoT in poor communities. Language differences, cost of adoption, or simply lack of telecommunications infrastructure often represent key barriers for ICT use in rural areas (Rothstein et al., 2016). On the other hand, issues of confidentiality,

privacy, ethics, and human resource capacity also slows effort to introduce new technologies in remote settings. The rest of the paper is structured as follows: Section 2 presents the problem statement. Section 3 provides an overview of the state of healthcare in both Ghana and Sierra Leone. Section 4 discusses the potentials of IoT systems for health. Section 5 is on related literature. Section 6 is on benefits of IoT to health. Section 7 is the conclusion.

4.3 Significance of the study and research questions

Communicable diseases and other public health problems impose a heavy burden on rural communities in Ghana and Sierra Leone. The systems for delivering healthcare in these areas are often inefficient and ineffective, yet these shortcomings only underscore a small scale of the numerous challenges experienced by residents in poor communities. Adopting innovative technologies offers enormous economic and social benefits. Internet of things health technologies can help to bridge the health divide between rural and urban healthcare centres. However, to achieve this requires understanding the mechanisms through which they can be deployed to mitigate health burdens. Accordingly, this study focuses on the role of IoT in improving and addressing key challenges in healthcare delivery in rural communities with a spotlight on Ghana and Sierra Leone. Special emphasis is placed on how issues of limited access to health information, shortage of health personnel, and control of counterfeits products can be address. Drawing on current inefficiencies and shortcomings, an IoT solution is being envisioned in this study as powerful means not only for improving efficiencies in health service delivery but also expanding health access. The research questions address in this study are:

1. What are the existing health challenges faced by residents in rural poor communities that, if addressed will lead better health outcomes?
2. What are the key IoT health technologies that can be adopted to address health needs in remote communities?
3. What mechanisms are needed to guarantee successful implementation of IoTs health technologies?

4.4 Methodology

In order to address the research questions, our analysis integrates the concepts of interpretive approach. This approach is based on the assumption that social reality is not singular or objective, but rather influenced by human actions, experiences and social contexts, and is therefore best studied by reconciling the subjective interpretations of its various participants. The approach was adopted because it enabled the researchers to understand that social reality is better interpreted through sense-making process rather than a hypothesis testing process (Maskin, 2019).

We started our analysis by first mapping out prominent IoT technology platforms that have emerged to support health systems. We laid out the potentials it holds in respect to improving health and social care services delivery and based on this information, we find out whether they are applicable to rural settings. A key task in this regard consisted of conducting a review to underscore the health needs of residents in rural Ghana and Sierra Leone. Documents were reviewed using an analysis framework to classify key issues discussed in the texts, gaps in literature, research findings and the methods adopted by the research. Overall, 40 documents (32 publications/ reports and 8 health policies) were included in the review. We included data on developed countries, complemented with further important information from emerging countries. The final product is recommendations on IoT technologies for the domain of health, looking especially at solutions to the identified needs.

4.5 The status of health in Ghana and Sierra Leone

Ghana operates a decentralized administrative structure that follows a four-tier system divided into national, regional, district, and sub-district levels. Healthcare is equally decentralized along these administrative structures with the community level serving as the first point of the primary healthcare system. Compared to most African countries, Ghana's health system is relatively better when measured along health indicators developed by the World Health Organization. For instance, in 2016, the WHO's health profile projected Ghana's average life expectancy to be sixty-three years old, surpassing the average life expectancy on the continent (WHO, 2018). This notwithstanding, there are existing systemic challenges and barriers that impede the delivery of healthcare. For instance, shortage of health workers remains a critical challenge. The ratio of doctors to the population stands at 1.1: 10,000

inhabitants. That of nurses and midwives stand at 9.8:10,000 (WHO, 2018). The training of healthcare professionals is extremely low relative to the country's health needs. T

here are also notable inequities in the provision of healthcare in Ghana. For instance, only 24% of births from remote areas are attended by a skilled health professional, leading to much higher infant mortality rates. Domestic health expenditure also accounts for only 1.09% of GDP, a figure which is below the regional average (World Bank, 2017). On top of these, the country faces a number of digital health challenges ranging from poor ICT infrastructure to shortage of skills. However, given the high uptake of mobile phones in Ghana, there is enormous potential to extend health information and services to the nearly 50% of residents in rural areas.

Sierra Leone on the other hand experience similar health problems like Ghana. The healthcare system in the country is heavily underfunded with high chronic disease burden and insufficient numbers of health workers. The ratio of physicians to the population stands at 0.25:10,000, compared to 9.1 in South Africa (WHO, 2018). According to WHO estimates, the country has one of the world's highest maternal and child mortality ratio (WHO, 2018). Maternal mortality ratio in the country stands at 1120 deaths per 100,000births compared to Japan with 5deaths. Child mortality on the other hand stands at 82 per 1000 births compared to Japan with 1.9 (WHO, 2018). There also exist high levels of inequities in terms of access to services as well as health outcomes among regions.

A fundamental barrier to accessing health services is the high cost of services and the inability of the larger rural population to access service. Attaining adequate quality of healthcare is a recurrent issue in the country, which is often exacerbated by drug shortages and stock-outs. The country's Domestic General Government Health Expenditure (GGHE-D) as a percentage of Gross Domestic Product (GDP) is 1.85% compared to 6.13% in Botswana (World Bank, 2018). In 2018, the government launched the Sierra Leone Social Health Insurance (SLeSHI) scheme to address access to care with it associated high cost to reduce the burden on the poor population yet capacity in terms of numbers and distribution of health workers remain primary barriers to improving the healthcare in the country. Currently ranked 106 of 194 countries in terms of network readiness, Sierra Leone is not well placed to take advantage of the benefits of AI in their operations and delivery of public services.

Remote areas in these two countries bear the highest burden of these challenges adding to the compelling problems of limited infrastructure for communication, water, sanitation, roads, and transport. To respond to these challenges demands adoption of innovative solutions such as Internet of things heath technologies. The next section presents some of the key IoT health technologies that can be adopted to address health needs in remote communities.

4.6 Potentials of Internet of Things in the delivery of healthcare

Internet of things technologies have become more influential in healthcare due to four major shifts in the health industry: growing demand of personalised care, rising healthcare costs, inadequate health infrastructure and limited health workers (Nambiar et al., 2017; Saleh et al., 2018). Internet of things health technologies are part of the whole digital health ecosystem' which is define as the use of information and communication technologies to provide care, train healthcare professionals, track and monitor diseases (Hanson, Puplampu & Shaw, 2017). These platforms include mobile health (mHealth), ethalth, telehealth, digital imaging, eperscription, early warning systems etc. It also encompasses a whole range of components such as mobile applications, biometric skin sensor, short messaging service, interactive voice response, health management information systems, mobile diagnostic devices, wearables, drones, and big data analytics. Their usefulness ranges from enabling healthcare professionals to bring care closer to patients to empowering patients to assume control of their own health.

In most rural parts of Ghana and Sierra Leone where access to essential health services is notable challenge, mHealth technology can provide remarkable opportunities. mHealth has emerged rapidly in many emerging economies due to the large penetration of mobile phones. In 2016, mobile phone penetration in Africa reached nearly 90 percent of the population (Allsop, Powell & Namisango, 2018). This phenomenon has encouraged the development of low-cost digital health technologies used to reach underserved populations and enabling people to self-manage their health and wellbeing. It is estimated that about 80% of residents in rural areas of Ghana and Sierra Leone own mobile phones (Abekah-Nkrumah, Guerriero & Purohit, 2014; Wurie, Samai & Witter, 2016).

Implementing mobile health in remote areas can be highly beneficial in the areas of delivering higher quality of care to patients, reducing health cost, increasing patient compliance, and decreasing health disparities. Some African countries are already benefiting from the mhealth services. For example, in Tanzania, Airtel Tanzania provides a free service that facilitates text messages about infant care to mothers and pregnant women. In South African, MomConnect a mobile messaging platform which is integrated with a national pregnancy registry and a help desk for questions and feedback has seen over 465,000 users adopt the service since its launch in 2016.

Telehealth is another IoT technology that enables the delivery of quality care to individuals located in areas with limited access to services. Telehealth allows health professionals to remotely offer care through the exchange of information with patient thus avoiding hospital admissions and improving self-care (Blusi, Dalin & Jong, 2014). One fundament challenge to receiving care in remote areas of Ghana and Sierra Leone is the lack of quality road infrastructure. Deplorable state of roads in rural areas increases the cost burden of patients in accessing healthcare. Even in places where roads are fairly in good state, limited ambulances contribute to missing emergency treatments.

To mitigate this burden requires a new way of delivering healthcare and telehealth can be useful in this regard. It has the benefit of contributing to reducing transportation cost and increasing convenience of patients in obtaining care. Some advance countries have already integrated telemedicine in their healthcare delivery. The Korean UHealth program is a typical example. The UHealth program supports caring for aged and sick patients by virtually monitoring their vital signs and other critical health information. This can include blood pressure, blood sugar, body weight, cholesterol levels and ECGs. Monitoring can also include physical activity, exercise, nutritional intake, and other lifestyle information that might be relevant to an individual's health. In 2015, the government of Kenya also introduced a national telemedicine strategy to extend health services to the poor and marginalised in remote areas (GBChealth, 2019). The strategy allows patients and healthcare providers in rural areas to use video conferencing to interact with experts at the national hospitals.

Electronic health records (EHR) and ePrescription also have the potential to address some of these fundamental problems like theft and corruption in rural healthcare. Electronic health

record is computerized health record used to capture, store, access, and share summary information (WHO, 2019). E-Prescription on the other hand is a computer-generated order for a medication, transferred by electronic communication to a national or regional repository or directly to a pharmacy (WHO, 2019). Beyond the challenge of limited health infrastructure in rural Ghana and Sierra Leone, absenteeism, corruption, and theft of limited medical supplies are serious problem in rural healthcare. According to a report by the United Nations Development Programme, theft has been found to increase when the potential benefit from theft is high, when the probability of detection is low, and when the expected penalty is minor (UNDP, 2011). Electronic health records (EHR) and ePrescription technologies can contribute to reducing costs and combating fraud and corruption in rural healthcare delivery.

Drone technology could also be influential in addressing the issue of delayed medical supplies in rural communities. Drones could deliver medical supplies and blood to patients in timely manner, especially for those in critical emergency situations. A typical scenario is a child who unknowingly drinks a poisonous substance in a remote village. A lack of swift medical attention will mean being in a life-threatening situation. With poor road infrastructure in such a community, delivering medication by car will be highly ineffective. The best alternative will be the use of drones which is less costly and less time-consuming.

Drone technology can also be instrumental in home-based care for older and bedridden patients who may have difficulties to travel for long distance. For example, during the process of giving care, the medical professional can take blood sample and transport immediately by drone to the laboratory for analysis. Results with medications and antibiotics could be delivered back to the home by drone. Rwanda was the first African country to adopt drone technology for the transport of blood supplies and essential commodities to rural communities. In 2017, Tanzania government announced its plans to adapt the Zipline drone delivery system to enhance the delivery and access to essential medicines (GBChealth, 2019). In 2016, Matternet and UNICEF partnered to use drones to improve HIV testing and treatment procedures in Malawi.

Drone technology has been found to be more cost effective in delivering essential commodities than vehicles in one study (Tavares, 2019). This case study analysed the cost effectiveness of drones compared to electric vehicles for the delivery of biomedical samples

in the city of Rouen (France) between three hospitals located in three different areas of the city. Results from the analysis revealed that delivery of biomedical samples with drones takes approximately 15 min, almost a third of 42 min estimated for vehicles. In addition, the delivery by drones is also expected to be 60% cheaper. The cost per delivery by drones was also found be 60% cheaper than delivery by vehicles. In effect, drone technology can serve as a viable means of leapfrogging the infrastructural challenges in rural Sierra Leone and narrow the healthcare divide between rural and urban population.

Investing in digital health technologies in these two countries is essential not only for securing the right to health but also has economic benefits. For instance, in Ghana the health sector contributes 2.1% to the overall Gross National Income (GNI) while in Sierra Leone the figure is 0.42% (Ghana STATS, 2019; Natalie, 2015). However, in countries like Switzerland and Norway where digital health technologies are widely adopted, the average share of its healthcare to their economy is about 6% (OECD, 2019). Digital health technologies therefore have the potential to transform not only the health industry of Ghana and Sierra Leone but also its overall economy.

4.7 Related literature

The prevailing evidence regarding the link between internet of things technologies and health outcomes is relatively limited, as the main focus of several studies has been more broadly on the potential benefits of emerging technologies on productivity and growth. However, the limited evidence covering a number of countries, generally depicts the capacity of internet of things technologies to transform healthcare by enabling more effective integration of care (Garrity, 2015; Baker, Xiang & Atkinson, 2017).

For example, a study conducted in rural Tanzania shows that the use of telemedicine that links specialists to local areas via digital devices is allowing paediatric care to be offered to remote areas (Krüger & Niemi, 2012). This system appeared to work because the specialists involved had had some previous experience within the Tanzanian health system and therefore understood local situations.

Another study examining the benefits of eHealth kiosks in rural India, revealed that the use of eHealth kiosks in seeking professional medical care by mothers concerning the care of their

infants ultimately contributed to low infant mortality (Venkatesh, Rai, Sykes & Aljafari, 2016). The authors presented that e-health kiosk enables the delivering of authenticated and accessible medical information. In Lebanon, one study revealed that eHealth facilitates equitable access to primary healthcare for those living in rural and refugee settings (Saleh et al., 2018). In a comparative study conducted among rural family caregivers receiving e-health caregiver support and those receiving conventional, non-e-health caregiver support, Blusi, Dalin and Jong (2014), discovered that the e-health support system improved care effectiveness particularly within the domains of preparedness, enrichment, and predictability.

Investments in IoT health technologies have also been found to have social benefits. For instance, a study in developing countries on the benefits of eHealth in 11 public and private healthcare delivery organizations of varying sizes and settings (rural/urban) revealed that investment in e-Health can contributed to 50%-80% reduction in medication error rates, increase the use of formulary and generic drugs by 30% and increase patient screening and preventive healthcare procedures by 40% (Abolade & Durosinmi, 2018).

Other scholars suggest that IoT technologies could be used to provide better access to healthcare for those living in rural areas by allowing remote monitoring of non-critical patients at home rather than in hospital, thereby reducing strain on hospital resources (Baker, Xiang & Atkinson, I., 2017). The authors further provide that mobile health technology has the power to give patients in remote areas the opportunity to assume more control over their health thereby making them less dependent on health workers for health information. Essentially, it can offer access to healthcare resources whilst reducing strain on healthcare systems.

Trends in IoT-based healthcare have also been widely explored in recent times with much of these studies focusing on the development of platforms, new services and applications, interoperability, and security, among others (Hanson, Puplampu & Shaw, 2017; Bagula et al., 2018). Moreover, policies and guidelines that enable easy and quick deployment of the IoT technology in the medical field have been analysed in many countries and organizations across the globe yet, the potentials of IoT technologies in the healthcare field remains in its infancy. At present, the pace of development in the whole digitisation ecosystem is increasing

at an exponential rate, however experts wonder whether these developments could lead to little or complete transformation of the healthcare industry.

4.8 Roadmap for building resilient digital health systems in rural communities

Integrating Internet of things health technologies in rural healthcare systems offers new ways of improving healthcare in remote parts of Ghana and Sierra Leone. Within those communities, the primary focus must be on reducing healthcare burden, optimizing efficiency of resources usage, expanding access to basic healthcare, and reducing the shortage of well-educated healthcare professionals. Innovative and proactive thinking are key to building a supportive environment for the strategic implementation of resilient digital health systems in rural communities. Obviously, this must involve increasing connectivity, forging strategic partnerships, training of healthcare professionals, and developing favourable legislation.

Increasing connectivity means expanding investment in communications technologies such as high-speed telecommunications networks, wireless systems, and computer-based systems. This is an important strategy towards leveraging the benefits of IoTs. Limited internet coverage and poor connectivity are some of the fundamental problems experienced by health workers in rural areas. Even in places where network systems exist, cost is a significant barrier. To benefit from the opportunities of IoTs means African governments must make investment in digital infrastructures and the removal of key barriers to the deployment of high-speed networks to remote areas a development agenda. A critical area for policy action involves establishing national broadband plans with well-defined goals and targets. It is important to mention that in both countries, there has been effort to build knowledge and infrastructure capacity on which digital health interventions could take place. Investment in broadband internet infrastructure has significantly increased since 2010 in rural communities. ICT training has also been included in most educational curricula. Yet, most of these initiatives are private sector driven, for-profit models. There is a need for a broader national broadband strategies and large-scale, state-sponsored ICT training and digital infrastructure investments.

The feasibility of using IoT technologies to support health systems in remote areas is also dependent on forging smart partnerships. Digital health is a nascent area for operators. It

requires a mixed set of ICT and health skills and resources, and a partnership-based model. If IoT health technology opportunities are to be fully exploited, industry players will have to proactively build strategic partnerships and establish sustainable and cooperative health models. This approach could enable the pool of different strengths and capabilities that facilitate the delivery smart healthcare in remote areas.

Training and sensitization are equally important elements for facilitating acceptance and use of new systems among health workers. Health professionals who experience difficulties in understanding and using digital health technologies, may have negative perceptions about its usefulness, and would be less likely to accept these interventions. Providing training can eventually contribute to shaping their digital literacy, reduces anxious about making errors and encourage the usability of digital systems and devices. Training should be reinforced by basic processes of inventory management, surveillance, contact tracing, prescribing medicines, and stock distribution.

It is important to note that an ideal IoT health solution for rural healthcare works with mobile phones through the means of text or voice messaging. However, to ensure that messages are read and well understood, the solution must be adaptable to the cultural and linguistic attributes of the rural population. There are widely available health and wellness apps yet, many of them currently lack multilingual functionalities. Developing health apps with features that are adaptable to rural culture offers a great opportunity to accelerate its adoption (Rozen-Bakher, 2018). More importantly these solutions must be cost-effective.

Strong legislation, policy and compliance are essential for building resilient systems for IoTs health technology penetration in rural areas. Inadequate rules governing data storage, privacy and confidentiality issues can have implications for confidence depose in the use of digital technologies. To stimulate quick acceptance of IoTs health technologies, authorities must ensure that strong legal frameworks exist to protect the rights of technology developers and users.

4.9 Conclusion

This study has shown that Internet of Things technologies have the power to improve health outcomes for people located in rural and remote locations, particularly for those with mobility

problems or who find travel difficult. It has identified various domains by which IoT can support healthcare delivery. These domains include remote monitoring, diagnosis, care extension, inventory control and self-care. The study has also outlined a number of roadmaps for building and implementing resilient digital health systems in rural communities. The study is meant to influence policy on the adoption of IoT improving health in rural communities. The study can also help policy developers to recognize that emerging digital health technologies can contribute to improving equity in health by connecting underserved populations in rural areas with urban health facilities with highly qualified personnel.

4.10 References

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CHAPTER FIVE: ESTIMATING AGRICULTURE TECHNOLOGIES' IMPACT ON MAIZE YIELD IN RURAL SOUTH AFRICA

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5.1 Abstract

New technologies and digital infrastructures are enabling smart farming with high productivity levels across countries. Yet, there is dearth of evidence on how they are enabling small holder farmers in Africa to increase their farm produce. By focusing on small holder maize crop producers in South Africa and relying on a panel data for the period 2011- 2021, this study applied a stochastic production frontier framework and Cobb-Douglas production function to estimate the relationship between variance of yield increase in relation to aggregate modern technologies adopted. The stochastic production frontier model was estimated using simple ordinary least square, maximum likelihood estimation and probit regressions. The analysis adopted a three-stage procedure which began with the specification of regression model, the calculation of least residuals squares of the explanatory variables and finally the estimation of the variances in the functional forms of output levels. The results revealed a positive relation between the application of digital agriculture technologies and increased crop performance for rural maize cultivators in South Africa. The policy inference from this study is that accelerating investment in digital agriculture infrastructure offers the promise of a quadruple return for South Africa's agriculture sector.

Key words: Digital technologies; Small-holder farmers, Crop productivity; South Africa

5.2 Introduction

New technologies and digital infrastructures such as robotics, remote sensing technologies and unmanned aerial vehicles, artificial intelligence and big data analytics among others are enabling smart farming with high productivity levels across the world (Boakye & Babatunde, 2021; Boakye et al., 2021). Thanks to advances in today's digital revolution, agriculture is now becoming more integrated in the global value chain. Yet, the interplay between technology adoption and increased crop yield is one that is not well explored in literature. Given the significance of yield productivity as a determining factor of measuring a country's overall output, examining the drivers of high crop yields is crucial to inform better policy decisions (Edgerton et al. 2012; Evans, 2018).

Crop yield is a principal unit of measuring agriculture's productivity. Crop yield also forms part of the basis to understand the efficiency of new techniques introduced in farming practice. Yet, few studies have explored how yield productivity is driven by the application of modern tools and techniques in small scale farming. The lack of extensive research in this field suggests that data on how farm produce are influenced by technology application is limited. The study of crop yield and its relation to technology application is critical to understand the capacity of agriculture to contribute to overall welfare. As emerging technologies continue to be integrated in the agriculture sector, this study explores how they influence maize yield performance in rural South Africa.

Maize is one of the most important grain crops cultivated in South Africa. An average of 9 million metric tons of maize are produced annually in the country. In 2020, South Africa's total production of maize was estimated at 15 million metric tons, indicating a slight increase from 14million metric tons in the previous year. Although large scale maize production is generally carried out by commercial farmers, emerging and small-scale farmers equally contribute significantly to the country's overall production capacity (Aguera et al., 2020). However, in recent times, maize yields by small scale farmers in rural areas have been declining. The decrease in the yields has been attributed to harsh climate conditions, yet it is difficult to rule out farmer's limited farming skills and the lack of climate smart technologies applied in crop production. There is generally a low uptake and application of modern technologies by these farmers because of capital constraints and limited government

support. Moreover, many of the rural farmers have not been exposed to the benefits of adopting modern innovations in farming and as such do not fully appreciate their usage.

Given the growing levels of maize related food consumption in the country amidst the disruption of global food supply chain orchestrated by the Russia Ukraine conflict, South Africa famers may need to adopt new and better approaches to increase their maize production. Fortunately, there are several proven technologies and interventions that can support maize production sustainability. What is needed is to encourage their adoption by farmers including small scale farmers in rural areas. To achieve this objective however requires having reliable data that demonstrate strong positive net effects of technology application on yield performance. As indicated earlier, the study of technological impact on yield performance is critical to understanding South Africa's agriculture sector capacity to provide sustainable food for long periods. This position forms the foundation of this study.

When it comes to estimating technological contribution to yields, most evidence from agriculture literature exclusively focus on highly industrialised countries (Ramirez & McDonald. 2006; Tolhurst & Ker. 2016). In contrast, there is limited evidence from South Africa even though technology integration in farming practices is widely adopted. This study therefore purports to contribute to literature by drawing evidence from South Africa using the country's yield data for the period 2011-2021. The study draws on the overwhelming evidence which suggest that adopting digital technologies in small scale farming is good for maximizing productivity and increasing production levels.

This study is novel in that it adopts a sophisticated methodology which relies on a stochastic production framework and Cobb-Douglas production function. The focus on small-holder farmers yield in rural South Africa also contributes to the study's uniqueness since the area has not attracted the needed attention from recent scholars. The overall objective is to encourage policy makers to design and implement policies that promote the fast adoption of smart technologies in rural farming. The structure of the article proceeds as follows: the next section provides an overview of crop production in South Africa. It then explores the potentials of modern technologies in crop production after which literature on technology adoption and increase in crop yield is presented. The subsequent sections focus on methodology, results, discussion, and policy recommendation.

5.3 Overview of crop production in South Africa

The agriculture sector is one of the important sectors of South Africa's economy. The sector contributes around 10% to the country's total export earnings and remain a key source of livelihoods for most rural population (Aguera et al., 2020). Among the major agriculture practices in South Africa, crop production represents one of the key practices engaged by most farmers. Different kinds of crops are cultivated in South Africa. Meanwhile the predominant ones are maize, wheat, soybeans, and oat (Christiansen, & van den Brink, 1994). Approximately 9 million metric tons of maize are produced annually on a 2.5million hectare of land. According to the Food and Agriculture Organisation, both hybrid and local maize are grown in South Africa, yet the local ones are often preferred for home consumption (Christiensen & Demery, 2018).

The local maize which is mostly cultivated by farmers in rural areas has recently been experiencing low yields. This phenomenon has been attributed to the lack of modern techniques and poor farming practices adopted in crop production by small scale maize growers. Traditionally, their farming operations are characterised by aggressive practices such as ploughing, burning and the application of toxic chemicals which decrease soil fertility. In addition, majority of crop cultivators in rural communities engage in land intensification, a practice which has negative consequence on land productivity. All these factors contribute to low crop production. Within the past decade for instance production levels have suffered fluctuations (Lowder et al., 2016; Gray et., 2018). As indicated in Figure 1, in 2016, South Africa experienced a decline in the production of maize to about 8 million metric tons from a previous 15 million metric tons in 2014. Similarly, production dropped from approximately 17 million metric tons in 2021 to 15.3 million metric tons in 2022.

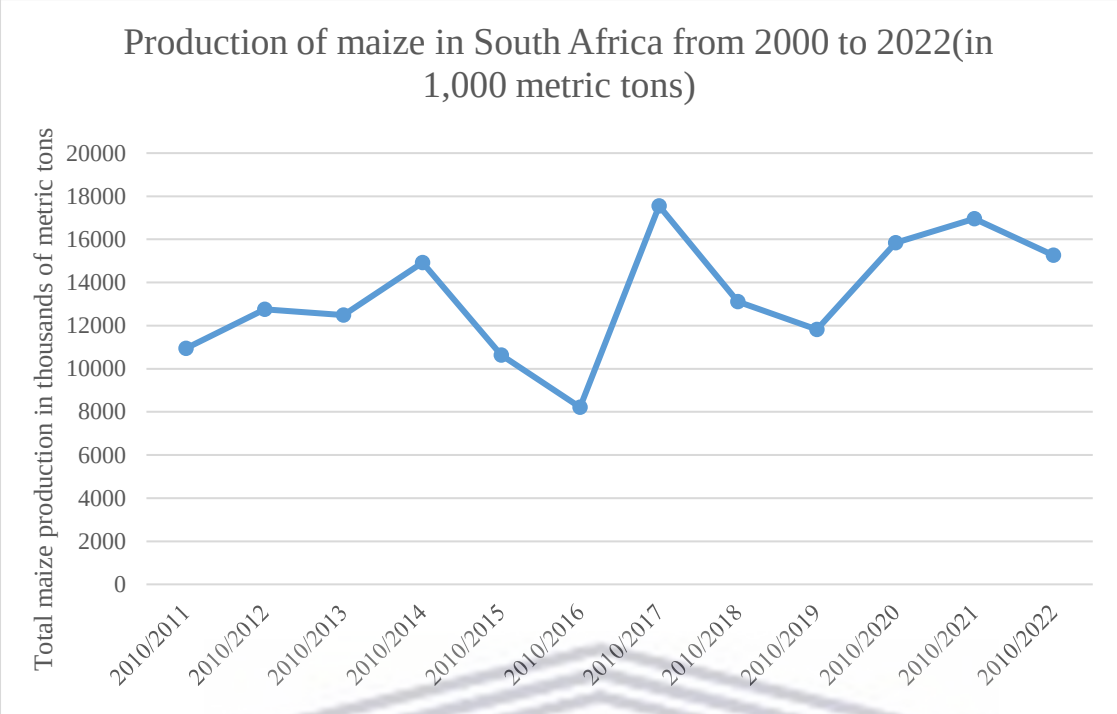

Figure 1: Production of maize in South Africa 2010-2022.

Source: Adapted from Statista 2023

The cause of this reduction is not well known however, experts attribute it to harsh climate conditions, inadequate land preparation, low access to quality seed varieties and lack of innovative farming practices (Dihel et al., 2018 Alvarez, & Berg, 2019). Some scholars do not also rule out the impact of COVID-19 pandemic on the low maize production recorded in 2021 and 2022. The restrictions on movement, meant that farmers had limited access to important agriculture inputs such as fertilisers.

South Africa is one of the key producers and exporters of maize within the Africa region. The country does not only export maize to neighbouring countries but also beyond the African borders to Asia and European markets. In 2022, for instance South Africa exported about 2.47 million metric tons of yellow maize and 568,569 metric tons of white maize to Asia and European markets (Statista, 2023). Amidst the increasing climate impact on agriculture productivity, maize producers may need to adopt new and improved practices if they are to sustain their production levels. To achieve this will however not be easy as the lack of technical expertise among maize growers especially those in rural areas continues to be a hindrance to efforts to achieving food security. To boost productivity in the coming years will

mean applying innovative techniques and practices by farmers (Tolhurst & Ker, 2016; Evans, 2018).

Against this backdrop, this study estimates the benefits of digital technology application on maize crop production with a focus on rural South Africa. In particular the research sought to stimulate the idea that adopting digital technologies can have greater impact on agriculture productivity as well as serve as corner stone of both continues growth and poverty reduction. To achieve this underlining objective, the paper responds to the following research questions:

1. What are the potentials of modern technologies in crop production?
2. What are the parameters for estimating technological impact on farm productivity?
3. How does the application of digital technologies drive crop productivity?

Answers to these questions will provide a better understanding on how modern digital technologies bring value to small scale farmers in South Africa. The paper also examines the evidence regarding the impact of technology change on farming and poverty reduction and highlights areas of doubts, particularly relating to the role of digital technologies in agriculture growth.

5.4 The potentials of modern technologies in crop production

In view of the growing world population and the concerns about food security, the issue of improving crop yield has become more relevant in the discourse of many scholars and policy makers. From time immemorial, farmers have adopted diverse ways to boost their agriculture productivity. From the use of fertilisers to the planting of different seed species, increasing crop performance has been a fundamental objective of most farmers. Today, thanks to new innovations, the agriculture sector is also benefiting from the prospects of modern science and technology services (Duncombe, 2016; Knierim et al., 2018; Rotz et al., 2019). For instance, novel digital technologies are enabling farmers the opportunity to monitor their crop growth, apply fertilisers as well as predict accurate weather (Aboh, C. 2008; Rotz, 2019; Klerkx, 2019).

Today's farming operations rely on sophisticated innovative tools like sensors, robotics and aerial images and satellites to drive long term productivity and increase profitability. The evolution of stress factors and plant diseases has given importance to the use of sensors to

monitor crop growth and performance at every stage of development process (Trendov et al., 2019; McCampbell et al., 2021; Boakye et al., 2022). For instance, from the early stages of planting to harvesting, regularly monitoring of crop growth is an essential practice for timely detection of any potential threat which may affect crop yield. Digital technologies offer this possibility. For example, internet of things enabled sensors and drones do not only allow efficient monitoring of plant growth but also help gather valuable data on temperature and nutritional contents for optimal decision making. Drones in particular are considered useful in pest control and fertiliser applications in ways that do not expose plant soil to toxic chemicals.

As indicated earlier, weather has a profound influence on crop development and growth. Hence ensuring accurate weather analysis is critical for crop performance. The good news is that farmers today have the opportunity to adopt modern tools and techniques to obtain accurate weather predictions. For instance, big data analytics as well as soil thermometer enables the collection and analysis of soil temperature, humidity, precipitation to inform decisions on when to plant, irrigate and apply pest control interventions (Thompson, & Gyatso, 2020; Nguimkeu, & Okou,2021). In essence, proper weather forecast, and analysis allow farmers to avoid heat or frost damages thereby contributing to their crop yield.

Another important factor in the farming revolution is the invention of seed drills. Seed drills are devices used to plant seeds in an evenly and required depth to allow for proper germination. Seed drills contributes to labour efficiency in that it reduces the amount of time one spent on planting seeds manually. The use of seed drills improves crop yield significantly in that it correctly sows seeds in the right depth and distance to prevent pest invasion (Townsend, 2016; Subramanian, 2021). In addition, the high level of accuracy benefited from direct drilling means low cost as a result of less soil damage and wasted resources.

Finally, robotic technologies enable more reliable management and monitoring of water, air and soil quality. Robotic technologies equally give farmers greater control over crop production, processing, transportation and storage which results in high efficiencies, increase profitability and reduce environmental and ecological impact (Nakawuka et al., 2018; Ng & Ker, 2019; Shah, 2020). These technologies offer huge potentials for increased yield productivity if they are combined and used properly.

5.5 What does literature reveal about technology adoption and increase in crop yield?

A growing number of studies have explored the impact of digital technologies in crop production. Most of these studies have revealed a strong linkage between technology adoption and increased agriculture productivity (Klerkx et al., 2019; Thompson & Gyatso, 2020).). Emerging evidence from Africa also shows how digital technologies are transforming small scale farmers productivity and profitability by increasing efficiency, reducing vulnerability and improving access to farm inputs (Kansiime et al., 2014; Ogada & Nyangena, 2015; Thomas, 2020). In Kenya for example, limited access to quality fertiliser is often cited as one of the shortcomings of crop performance. To respond to this challenge, a group of innovators are using a software known as SafiOrganics to downsize and decentralise fertiliser production using locally available resources and labour. This platform is now allowing rural farmers to cut down logistical cost while producing high quality fertilisers capable of increasing their yields by 30%.

In other part of Kenya, start-up companies called UjiziKilimo and SunCulture are using big data analytics to enhance farmers' insights in irrigation, fertiliser application and pest management (Ogada & Nyangena, 2015). These platforms are enabling farmers to increase their crop produce while achieving high level of efficiency. In some rural areas in Nigeria, mobile phone applications, sensors, satellites, radio-frequency identification are being adopted by local farmers to measure and analyses soil quality to inform planting and irrigation decisions (Aboh, 2008). In Ghana, Farmerline and AgroCenta are leveraging data-driven farming practices for small-scale farmers to reduce import waste and improve crop yield (Thompson & Gyatso, 2020).

Given that sustainable farming reflects the capacity to generate sufficient food in an economically efficient, socially responsible, and environmentally sound way, solutions for raising agricultural productivity are influenced by the shifting relationship between technology adoption and sustainable farming. In a study exploring the potential impact of innovation and adoption of digital agriculture within the Middle East and North Africa (MENA) region, Bahn et al., 2021 found that digital agriculture shows promise in generating high-value agricultural production as well as improving supply chain and logistics performance while ensuring optimise use of scarce natural resources in rural MENA countries.

It is well known that plant disease and pest invasion are some of the biggest problems local farmers in rural areas face. Crop damage from pests often have huge economic consequences, hence taking actions to reverse pest infestation is essential to combating this adverse impact (Edgerton et al., 2012; Trendov, 2019). In East Africa, yields from smallholder crop production are typically only 20-30% of what could be produced if the best seeds, fertilisers, pest control, agronomic and water management practices are applied (Kansiime et al., 2014; Nakawuka et al., 2018). Interestingly, a startup company called farm Africa has identified this problem and is combining farmer driven innovations with local knowledge to boost farm productivity and crop yield.

Evidence from other parts of Africa also reveal transformative results in the adoption of digital technologies in agriculture productivity. For example, in Ethiopia, a government sponsored initiative know as Farmer Hotline is offering farmers free advisory services via interactive voice response (IVR)/short message service (SMS) on how to maintain crop health and boost crop production.

Rwanda government is also supporting smart agriculture by investing in large scale digital hardware and software systems that enable smart farming. The government has recently introduced a Crop Intensification Program (CIP) policy which is aimed at boosting agricultural productivity through an improvement of productive inputs use, irrigation coverage and soil quality.

5.6 Methodology

5.6.1 Data sources

South Africa - Maize yield (kg per hectare) actual values, historical data, forecasts and projections were sourced from World Bank from 2011 to 2021. Maize yield, measured as kilograms per hectare of harvested land. Production data on relate to crops harvested for dry grain only. Crop harvested for hay or harvested green for food, feed, or silage and those used for grazing were excluded. The traditional production variables include yield (per hectare of farm), labor, fertilizer, seed, and irrigation.

The technology variables considered in this study included farmer-preferred adaptation technologies. Environmental variables were also included to capture effects of climate

variability on the mean and variance of maize crop production. These included the climate satisfaction index of the preceding main agricultural season.

5.6.2 Estimating the contribution of technological progress in crop yield

To accurately estimate the contribution of technological progress in crop yield for small scale farming is very challenging due to the highly heterogeneous performance of crop within a given plot. In most cases, the approach to measure the impact of technology is conditioned on observing yield trend relative to adoption of particular technology over a period of time. Several scholars have suggested that the best approach to use is the one based on change in total output over a given time period per the level of technological change (Adrian, 2012; Tolhurst, & Ker, 2015; Park et al., 2019). Their argument is that if a researcher chooses a base period (t_o) by which a farmer operates at a near equilibrium output and adopt new techniques to achieve a new level of output in the second year (t_1), then the difference represent the contribution which technological change has made to outputs between (t_o) and (t_1). This approach is based on the concept of Cobb Douglas linear production function. For instance, if a production function is constructed for a base year and a technological progress is adopted in a given period, one can estimate the influence which technological change has made to the change in output between the two periods by the difference between the index of output actually produced in the given period and the index of output estimated from the base period production function (Ng & Ker, 2019).

The Cobb-Douglas production function is given by:

$$\mathrm{InQ}_{j\,t} = \beta_0 + \sum_{i} \beta_1\ \mathrm{InX}_{j\,t} - U_{j\,i} + V_{j\,i}$$

where $Q_{j,t}$ is the output of the vessel j in period t and $X_{j,i,t}$ and $X_{j,k,t}$ are the variable and fixed vessel inputs (i,k) to the production process. As noted above, the error term is separated into two components, where $v_{j,t}$ is the stochastic error term and $u_{j,t}$ is an estimate of technical inefficiency.

Other methodologies have also been suggested by different authors in estimating technological change in crop yield. One common approach usually mentioned is the deterministic approach. This approach measures output changes given capital stock inputs;

nondiscretionary stock inputs and existing technology (Ramírez & McDonald, 2006; Renard et al, 2013). In this approach, the output level is estimated by using linear programming procedures and is interpreted as the output that could be produced with full and efficient utilization of the variable input(s), given the capacity base.

This is express as: $\ln Y_{t=} \lambda_j + \sigma_2 j + \beta_1 \ln N_{it-1} + \beta 2 \ln H_{it-1}$

where the unknown parameters λ_j , σ_2 j and functions hj (t) are estimated with a maximum likelihood approach using the heuristic EM algorithm for the j components of the mixture. A limitation of the deterministic approach is that it does not quantify uncertainties as part of its production decline evaluation.

Another approach is stochastic approach which uses probability simulator to perform multiple iterations. It conducts outputs estimation through modification of the inputs incorporated in the production (or distance) function. A potential advantage of the stochastic production frontier approach over DEA is that random variations in catch can be accommodated, so that the measure is more consistent with the potential harvest under "normal" working conditions. A disadvantage of the technique is that, although it can model multiple output technologies, doing so is somewhat more complicated, requires stochastic multiple output distance functions, and raises problems for outputs that take zero values. The stochastic model is given as:

$$\ln Q_j = f(Inx) + U_{j\,i} + V_{j\,i}$$

where q_j is the output produced by firm j, x is a vector of factor inputs, v_j is the stochastic (white noise) error term and u_j is a one-sided error representing the technical inefficiency of firm j. Both v_j and u_j are assumed to be independently and identically distributed with variance σ_v^2 and σ_u^2 respectively.

It should be noted however that, whatever method used for crop yield forecasting and estimation at any level of aggregation, it is important to distinguish between accuracy claims and a publicly available and independently verifiable track record between the forecast and the final yield estimate after harvest. Within the context of small holder crop production,

standardizing methods for yield estimate is crucial to obtaining accurate date and determining the suitability of farming practices under different environment (Hanuschak 2013). This is because a standard methodology allows for identifying any trade-off in crop performance after adopting a particular technology.

It is equally important to stress that technology adoption may also contribute to the efficiency of other factors of production. It may be therefore inconsequential to attribute crop yield performance to only improved technology. For instance, how can one be certain that differences in crop yield is as a result of the sole application of a particular technology? To address this uncertainty or casual inference requires the use of experimental date. Experimental data are gathered through a process of active intervention to produce and measure change when a variable is altered. This data usually allows the researcher to determine a causal relationship and is typically projectable to a larger population. However, without experimental data, there are two problems a researcher may have to contend with. One is self-selection, which has an element of bias and the second is relativity, which does not account for unobserved characteristics. Hence for better estimation of the impact of technology on crop performance, it is advisable to combine different methods (Ramírez &McDonald, 2006).

5.6.3 Research Framework and Model Specification

This study employed the stochastic production frontier framework. This model is applied to study the technical efficiency of production inputs in relation to outputs. The model operated from the assumption that for any given bundles of inputs, the production process faces two random disturbances: either negative or positive with different characteristics. The stochastic production frontier model was selected for this analysis because of its consideration for technical inefficiencies and symmetric errors in explaining variance of output. The analysis specifies and adopts the cobb-douglas production function to estimate the relationship between variance of yield in relation to aggregate inputs. The model is given as

$$Y = f(X, \beta) + \mu = f(X, \beta) + h(X, \alpha)\, 0.5 + \varepsilon$$

Where Y denotes outputs, X represents the explanatory variable, μ = estimated coefficients, f= denotes deterministic variable μ = disturbance term with a zero mean, h = the variance

function, and ε= error term. Table 1 shows how the parameters used varies from the average (mean)

Table 1: Estimating parameters of the model

Parameters	Standard Error	Mean	Probability
μ	-0.038	0.563	0.019
ε	-0.652	0.368	0.005
h	-0.021	0.864	0.181
X	0.139	0.554	0.229
Y	0.736	0.467	0.611

The stochastic production frontier model is estimated using simple Ordinary Least Square (OLS), maximum likelihood estimation (MLE) and probit regressions. The analysis adopts a three-stage procedure. It begins with the specification of regression model for both the predicted efficiency in technology application and the level of production efficiency with respects to the explanatory variables and random disturbance. The parameters of the model at this stage employs the simple Ordinary Least Square (OLS).

The second stage involves calculating least residuals square and in the third stage, we estimate the variances in the functional forms of output levels using linear, logarithms and exponential functions. The decision to add logarithm function in our estimation is based on the fact that it helps improve normality of dependent variable and residuals, thus controlling for any possible outliers. Throughout this procedure, we apply propensity score matching (PMS) to control for bias as a result of observable heterogeneity. The explanatory variables included farmer-preferred technologies which were correlated with the observed crop yield. The technology variables considered in this study are both mean precipitation and mean temperature.

5.7 Results

Table 2 presents a summary of the set of new digital technologies used by farmers in South Africa. Majority of the maize farms and farmers were in areas where connectivity is low

making full digital integration in real time challenging. Nevertheless, the analysis revealed that most farmers rely on drones, sensors and aerial images among others in their farming practices. For instance, drones help farmers to scout and monitor their crops while sensors, seed drills and aerial images are used to assess soil temperature, plant seeds and gather data respectively. The output revealed that data are more clustered to the mean as low variation can be observed.

Table 2: Set of new digital technologies preferred by farmers in South Africa

Technologies	**Uses**	Mean	Standard Deviation
Drone	For crop scouting and monitoring	0.467	0.003
Sensors	For measuring soil temperature	0.934	0.002
Seed drills	For planting seeds	0.048	0.120
Smart Irrigation	For precision irrigation	0.185	0.113
Aerial images	For data gathering	0.305	0.001

Econometric results on regression coefficients of corn yield data are presented in Table 3 and 4 for the probability and variance functions of corn production in general. Land size (acre), kernels per ears, kernels per rows and total corn harvested showed positive and significant impacts on the mean of crop output. In terms of estimating the average crop yield with respect to the rates of digital technology application as depicted in Table 4, land cultivation size showed the largest production elasticity among the technologies applied (p value of 0.003). Technology effects on yield variability also differed with regards to the frequency of technology usage, duration and crop quantity, all indicating significant positive coefficients.

Table 3: Regression coefficients of corn yield data

Coefficient of	**Standard Error Estimate**	**Probability**
acre	0.388	0.0005
Kernels per ears	0.482	0.0332

Kernels per rows	0.474	0.0024
Crop harvested	0.940	0.0032

Table 4: Average corn yield from rates of digital technology application

Rate of application per	Estimated yield	Mean	P-values
Farm size	2.4564	0.078	0.0003
Frequency	1.4337	0.739	0.0078
Duration	1.0343	0.384	0.0056
Crop quantity	2.0474	0.356	0.0057

5.7.1 Estimating the impact of technologies on mean and variance of crop yield

Results as depicted in Table 5 depicted varying effects of the various technologies by variables. Assessing the effect of technological variables on the mean and variance of crop production indicated that plant health, soil nutrition, crop density, pest control significantly and positively affected the mean yield variability. The effects, however, varied across the value of crop yield. For instance, with respect to how technology adoption on improves plant health (p-value= 0.024) and pest control (p-value =0.012) in relation to yield volumes, there was a significant positive correlation between adoption and increased crop yield. On the other hand, the results are not statistically significant for soil nutrition (p-values 0.280 and crop density (p-values =0.41) at a 5% significance level. Crop density variation in relation to yield volumes was generally rated less effective than soil nutrition. These results suggest that technological adoption does not necessarily affects the factors that contribute to change in crop yield. Nevertheless, the analysis indicates an overall positive relation between technology application and crop yields. That is in the long run, an improvement in plant health, pest control and soil nutrition driven by technological adoption leads to an increase in crop yield.

Table 5: Impact of technologies on mean and variance of crop yield

Variables	Crop yield value Log for Mean		Crop yield value Log for Variance	
	P values	Std. Error	P values	Std. Error
Plant health	0.024	**0.033**	-0.353	
Soil nutrition	0.280	0. 409	-0.082	0.002
Crop density	0.408	0.423	0.914	0.023
Pest control	0.012	0.211	0.036	0.073
Yield quality	0.251	0.455	0.677	0.012
Control of soil temperature				
R-squared	0.0034	Mean dependent var		0.402
Adjusted R-squared	0.1563	S.D. dependent var		0.034
Prob(F-statistic)	0.6434			
CointEq(−1)	-0.3824	0.475	-1.593	0.324

5.8 Discussion and policy implications

Technology is considered a vital component in the production function by neoclassical theorists. The neoclassical theory which forms the framework of this study is associated with Robert Solow and Koopmans (1999). The theory posits that growth is dependent on labour force, technology, and the total capital stock of a country. To measure the growth and equilibrium of an economy, the theory adopts the concept of Cobb Douglas production function. This concept was adopted in the current study to underscore the net positive effects that new technologies and digital infrastructures have on crop productivity. Several studies in the past have explored the potential benefits of the use of digital technologies in agriculture, yet few have focused on how it relates to small holder farmers in Africa and its contribution to poverty reduction. By concentrating on small holder maize crop producers in South Africa, this study relied on panel data to examine the nexus between the application of digital technologies and improvement in crop performance.

While the results from this study confirm findings of other past studies, it distinctively reveals a more versatile and comprehensive approach to the analysis. For instance, it captures the

effects of climate variability on the mean and variance of maize crop production by small holder farmers in South Africa. The study revealed two critical findings in relation to farmer-preferred technologies. First, results show that drones, sensors, seed drills, smart irrigation and aerial images are among the top new technologies mostly deployed in farming practices in rural areas. Second, farmers adopt changes in cultivation practice with respect to the use of these technologies only when they have seen evidence of its positive net effect on production. This particular finding is in line with findings reported by Rotz et al. (2019) whose study explored the politics of digital agricultural technologies. It also reflects results published by Knierim et al. (2018) in their study on what drives adoption of smart farming technologies.

The statistical output also makes a strong case for technology adoption as having pronounced effects on aspects of yield. However, the study revealed that technology effects on yield variability may differ with regards to the frequency of technology usage and duration, all indicating significant positive coefficients. For instance, in places where seed drills and smart irrigation techniques are often used in cultivation practices, crop productivity appears to be high. In contrast, where these technologies are barely used, productivity seems low. This particular result is consistent with findings reported by Aboh, (2008) in a study assessing the frequency of ICT tools usage by agricultural extension agents in Imo State, Nigeria. In general, this study has shown a positive correlation between the application of digital agriculture technologies and increased crop performance as also reported in other studies (Evans 2018; Klerkx et al., 2019; McCampbell et al., 2019; Nguimkeu, & Okou, 2021).

Despite these findings, the analysis has shown that adoption of digital agriculture technologies by itself does not necessarily contribute to increased productivity. This means there are other basic factors such as farm size, quality of seeds and better farming practices among others that influence yield performance. Further studies on assessing the contribution of digital technologies on crop yields will therefore require complex research technique.

Findings from this study is subject to the usual limitations of regression analysis which include the issue of attribution. Other limitations were related to scope and data availability. The study scope was limited due to time and resources. In addition, data on crop performance from farmers were difficult to come by. These limitations need critical consideration in future studies. These limitations notwithstanding, the outcome of this research is reflective of the

general situation and condition in South Africa rural areas where maize cultivation is a predominant economic activity. Hence the weaknesses identified did not undermine the study's relevance and outcome.

The policy inference from this study is that digital technology is increasingly becoming an important solution to the many of the challenges in the agriculture sector. They are allowing farmers to maximise production capacity. The evidence is also clear among commercial farmers in South Africa. Meanwhile among small holder farmers, the adoption of technologies is still slow. To increase the uptake of smart farming technologies among local farmers will require the design of policies and programs that increase farmers ICT skills and ensures availability, accessibility and affordability of digital techniques. Policy makers should also create enabling environment that will allow the private sector to invest in agriculture smart technologies to increase its availability to small-scale farmers. Findings from this study also highlight the importance of increasing digital inclusion amongst farmers as a measure to increase their visibility in the wider agriculture value chain system.

5.9 Conclusion

This study sought to estimate the benefits of digital technology application on maize crop production with a focus on rural South Africa, using panel data from 2011 to 2021 from World Bank's open data source. The study employed stochastic production frontier framework which assesses technical efficiencies of production inputs in relation to outputs. The paper further adopted the cobb-douglas production function to estimate the relationship between variance of yield in relation to aggregate inputs. The study revealed two critical findings in relation to farmer-preferred technologies. First, results show that drones, sensors, seed drills, smart irrigation and aerial images are among the top new technologies mostly deployed in farming practices in rural areas. Second, farmers adopt changes in cultivation practice with respect to the use of these technologies only when they have seen evidence of its positive net effect on production.

The statistical output further showed a strong positive relation between technological adoption and yield increase. Notwithstanding these findings, it was noted that the mere adoption of digital agriculture technologies by itself does not necessarily contribute to

increased productivity. Therefore, to assess to holistic impact of digital technologies usage on crop performance it is important to consider factors such as farm size, quality of seeds and better farming practices among others. Against this backdrop, it is recommended that future studies exploring the nexus between digital technology application and crop performance must use larger sample with complex research technique.

5.10 Reference

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CHAPTER SIX: ESTIMATING THE IMPACT OF DIGITAL TECHNOLOGIES ON GOVERNMENT OPERATIONS, BUSINESS OPERATIONS AND GENERAL WELFARE. THE CASE OF SOUTH AFRICA

Boakye, A. (2023). 'Estimating the impact of digital technologies on government operations, business operations and general welfare'. The case of South Africa. African Journal of Science, Technology, Innovation and Development. https://doi.org/10.1080/20421338.2023.2296181.

6.1 Abstract

The shift towards digitalization is fundamentally transforming societies and changing lives. Meanwhile, many African countries are lagging on the dividends of accelerated digital technologies to address their developmental challenges. This is partly because of the dearth of evidence demonstrating how technological integration impact on economic growth and poverty reduction. By relying on a panel data for the period 2011-2021, this study empirically estimates the degree to which ICT adoption contributes to South Africa's economic competitiveness along four indicators: boosting productivity, accelerating business growth, increasing government operational efficiency, and creating opportunities for people. The data were analyzed using multivariate regression analysis. The findings indicated a strong positive correlation between the application of digital technologies and the improvement of business operations welfare improvement, and GDP growth. The findings suggest to policy makers on the need to prioritize interventions that drives investment in digital infrastructure. Given the net positive effects of ICT innovations, it is also recommended that policymakers focus on building ICT skills of its people, while ensuring a business-friendly environment that enables fast digital penetration in the economy.

Keywords: Poverty alleviations, inclusive growth, digitization, general welfare, South Africa

6.2 Introduction

Eradicating poverty in all its forms and dimensions has been one of the greatest challenges the world has grappled with over the years. A significant proportion of people worldwide still live in extreme poverty despite the remarkable progress made in combating poverty. According to a 2021 publication from the World Bank, about 689 million people, equivalent to 9.2% of the world's population live in extreme poverty with sub-Saharan Africa accounting for more than half of the global extreme poverty cases (World Bank, 2021).

Nonetheless, several African countries have made impressive gains in reducing poverty and improving general economic wellbeing. Today, many people in Africa have access to better education, water, electricity, sanitation, health, and jobs. Yet, new threats such as COVID-19 and climate change are beginning to reverse fortunes made in the fight against poverty and income inequalities. To address this problem requires a new way of thinking and approach. The ICT revolution presents a viable option for facilitating economic transformation and reducing the economic effect of COVID 19, thereby contributing to poverty reduction (Boakye et al., 2021). Innovations such as artificial intelligence, the Internet of things, data analytics and blockchain are shaping the way businesses are done in the agriculture, health, education, manufacturing, and service sectors (Boakye & Babatunde, 2020). They are contributing to improved efficiency and increased productivity.

The good news is that Sub-Saharan Africa has not been completely left out in the digitization drive. The widespread adoption and integration of ICTs in countries like Kenya and Ghana have reduced information and transaction costs, created new jobs, generated new revenue streams, conserved resources, and helped improve service delivery. Digital transformation in sub-Saharan Africa, for example, has been found to boost annual growth by almost 2% and reduce annual poverty by 1% (Ndulu et al., 2021). Meanwhile, not all countries within the region have benefited from the net positive effects of digitization on poverty reduction. In most countries, the adoption and integration of ICTs have been slow. Factors that account for the low ICT integration are many, however key among them are the lack of national ICT policies, poor infrastructure, and limited knowledge. In countries such as Liberia and Burundi, inadequate communication services and high cost and low ICT literacy remains major a major

challenge. To a significant degree, technology adoption is what makes the difference between a fast-growing developing economy and a slow growing one (World Bank, 2021). This is why it is important for policy makers to understand and have evidence on how technology adoption influence development.

Against this backdrop, this research demonstrates how digitization contributes to economic transformation, growth, and poverty reduction, with a focus on South Africa. In particular, the study purports to estimate the effect of adopting technological innovations on productivity and wellbeing. The rest of this paper continues as follows. Section 2 describes the status of poverty and economic growth in South Africa. Section 3 gives a snapshot of the state of digital innovation in South Africa. Section 4 explore relative literature on digitization and poverty reduction. Section 5 presents the methodology adopted in this study. Section 6 focuses on results. Section 7 provides discussion of the results and Section 8 gives the conclusion of the study.

6.3 Status of poverty and economic growth in South Africa

Poverty, inequality, and unemployment have persistently been the core challenges to South Africa's development agenda. For over two decades, the country has sought to respond to these challenges with a wide range of social and economic policies as well as initiatives that aim at ensuring fair distribution of resources (Biyase & Zwane, 2018). These measures can be traced back to the post-apartheid era when the then government made it a central objective to reduce poverty and inequality with the launch of the Reconstruction and Development Program. This program had the core goal of bridging inequality by investing in education, health, and other social amenities in poor communities. As an assessment of the program, 10 years after its implementation revealed positive outcomes. For instance, poverty levels declined from 33.8% in 1996 to 25.5% in 2006 (IDC, 2013). A further decline of 8% was witnessed between 2006 and 2014.

Despite this progress, the trend of poverty reduction was reversed between 2011 and 2015. In 2015, nearly half (49.2%) of the South African adult population fell below the upper-bound poverty line according to data from the Department of Statistics in South Africa (Biyase & Zwane, 2018). Today, it is estimated that nearly 55.5% of the population is living in poverty

(World Bank, 2021). Rural communities remain the regions with the highest poverty concentration. Female black South Africans are generally more vulnerable to poverty. An analysis of the poor shows that a typical poor household in rural areas is often headed by a single and economically inactive female black South African (Nwosu & Ndinda, 2018). The steady rise in poverty rates in South Africa since 2011 has been driven by a combination of international and domestic factors such as low and weak economic growth, continuing high unemployment levels, lower commodity prices, higher consumer prices as well as the recent COVID-19 pandemic.

Despite its poverty situation, South Africa's economy is regarded as one of the most robust economies in the world (Pabón & Leibbrandt, 2021). With a gross national income (GNI) per capita of USD6,040, the country is among the developed countries classified as upper-middle-income (World Bank, 2021). The South African economy is generally characterized by stable growth with relatively low taxes and tariffs, flexible exchange rates as well a controlled fiscal deficit. The political transition from the apartheid regime to democratic governance triggered robust growth and development owing to major adjustments made in the economy (Montle, 2021).

For instance, major factors such as the expansion of the labour market, an increased household expenditure and capital reallocation as well as growth in commodity markets which characterized the period between 1994 and 2008 saw the economy grow at an average rate of 3.3%. Between 2015 and 2017 real GDP growth averaged 0.80%, however with the advent of COVID 19, the economy fell by 8%, the worst ever since the end of the apartheid (World Bank, 2021). The impact of the COVID-19 pandemic has exacerbated the country's fiscal space due to unprecedented capital outflows and declines in domestic revenue.

6.4 State of digital innovation in South Africa

To understand the scope and nature of digitizing South Africa's economy, this section examines the structural changes that have taken place in the country over the past few decades. The significance of technological and ICT innovation as critical factors for building an inclusive society has been well recognized in South Africa for years. For decades, the country has launched ambitious ICT strategies and made major structural changes all geared toward

laying a solid foundation for sustainable development and ensuring that no one is left behind in the development process (Herselman et al., 2019).

From the introduction of the 1996 White Paper on Science and Technology, the creation of the Department of Science and Technology (DST) and the launch of the 2008 Ten-year Innovation Plan (TYIP), South Africa has demonstrated a strong commitment to making ICT development a national priority (Manda & Backhouse, 2018). For example, it has created a world-class research and education network called the South African National Research Network which provides broadband services to all South African institutions of higher learning as well as science councils and national research facilities (Mukwawaya et al., 2018). Significant progress has also been made in the application of innovation and technology in the health sector. For example, the South African Medical Research Council (SAMRC) in 2017 invested in over 30 innovation projects directed at developing new diagnostics, devices, vaccines, and other medical tools.

Despite these developments, South Africa still lags with digital transformation (Reddy et al., 2016; Saidi & Mongi, 2018). For instance, in 2018, the country scored 4.96 out of 10 in terms of the ICT development index and was ranked 92 out of 176 countries in respect of the level of innovation. In addition, the 2018 ITU's information society index placed South Africa 104th out of 144 countries in terms of access to fixed broadband (Kravchenko et al., 2019). Since 2011, South Africa has consistently imported more ICT products than it has exported. According to the latest publication from the Department of Communications and Digital Technologies, the digital economy is estimated to contribute only 2% of the country's GDP (Genesis Analytics, 2020).

In summary, despite progress made in promoting technology and innovation in South Africa, as shown by the level of structural changes and commitment made by successive governments, the level of technology and innovation in the country remains low relative to other advanced countries. There are several challenges that contribute to this situation. For instance, infrastructures to support the ICT/Telecommunication sector are limited despite investment from State Development Agencies. In addition, capital for innovation is currently insufficient to drive innovation to market. Currently, South Africa is a net import of technology. Meanwhile, the government has acknowledged the need for a stronger

promotion of digital technologies in business by raising the recognition of technology and innovation as crucial drivers for inclusive growth. With robust policies and commitment to act, South Africa can benefit from the prospects of digitization if it scales up investment in ICT infrastructure, takes decisive steps to invest in its human capital and apply technology-driven solutions across all sectors.

6.5 Relative literature on digitization and poverty reduction

Many scholars (Gruber & Koutroumpis, 2010; Katz & Koutroumpis 2014; Donou-Adonsou, Lim & Mathey, 2016; Haftu, 2019) hold the view that technological development drives long-term economic growth, productivity, and improvement in the standard of living. They particularly emphasized that it is progress in technology that differentiates fast-growing developing economies from slow-growing ones. Joseph Schumpeter (1928) was the first economist to have argued in favour of technological progress as a catalyst for economic growth (World Bank, 2018). Schumpeter provides that the diffusion of new ideas and production techniques throughout the economy creates a process of 'creative destruction' where weakening sectors are destroyed whiles new industries emerge. Thus, Schumpeter's view extends the threshold of the technological evolutionary concept beyond the simple application of innovative techniques to encompass the creation of new markets, new distribution systems and finding new sources for raw materials.

Building on Schumpeter's conceptual framework of technological transformation, Paul Romer (1986) in his study titled 'Increasing returns and long-run growth', indicated that technical progress is the main driver for economic growth (Landau & Rosenberg 1986). This growth, according to Paul Romer, can be seen in an increase in Gross Domestic Product (GDP), enhancement in labour productivity and acceleration in capital accumulation (Zhao, 2019). Thus, by reinforcing Schumpeter's position, Paul Romer provided that technical progress improves transformation of resources and diffusion of new ideas into products. In their book titled ''The positive-sum strategy: Harnessing technology for economic growth'', Landau and Rosenberg (1986) argued that leveraging technology for growth, however challenging it may be, is important for the success and prosperity of a company and nation, particularly during periods of low growth.

Interestingly, from the latter part of the 20th century till the earlier part of the 21st century, every new study on growth that emerged seemed to have implicated technological advancement in the growth of an economy. For example, in a cross-sectional study examining the effects of technological change on economic growth and development, Malecki (1991), found that technological progress contributes to local, regional, and national development. Similar observations were made by Jorgenson et al., (2000) who applied Jorgenson's production possibility frontier to describe the increased productivity growth the US experienced after 1995. Their findings revealed that the integration of computer systems in a firm's operations contributed significantly to the growth of the US economy. This was more evident in the average labour productivity which grew faster between 1995 and 1999 as a result of capital deepening which was induced by the fall in ICT prices.

By examining the post-1995 productivity performance of the individual US industries that either produce IT, use IT, or are relatively isolated from the IT revolution, Stiroh (2002) discovered that U.S. productivity revival reflected gains in most industries that either produced or integrated Information Technology in their operations. Some recent studies have also confirmed the positive link between technical progress and development. For instance, in a study which applied an econometric approach to estimate the contribution of different types of ICT investments in 26 industries in 18 OECD countries, Spiezia (2013) found that the estimated contribution of ICT investments to value-added growth in the business sector varies from 1.0% a year in Australia to 0.4% a year in Japan. The study further revealed that ICT producing industries account for no less than two-thirds of total factor productivity (TFP) growth in Germany, Slovenia and the United Kingdom, about 60% in the United States and just below 50% in France and the Netherlands.

In Denmark, the Czech Republic and Italy, TFP increased in the ICT producing industries, whereas it decreased for the total business sector. Using annual time-series data over the period 1980 to 2010 to estimate the impact of ICT investment on economic growth and energy consumption in Japan, Ishida, (2015) discovered that ICT investment contributed to a moderate reduction in energy consumption, and long-run stability in GDP. Using instrumental variables-Generalized Method of Moments approach in examining the impact of technological developments on economic growth in 47 countries in Sub-Saharan Africa, Donou-Adonsou et

al. (2016), discovered that both the Internet and mobile phones usage contributed significantly to the GDP of most Sub-Saharan African countries. In a study of the effect of Education, R&D and ICT on economic growth in high-income countries, Saidi and Mongi (2018), found a bidirectional relationship between education, internet users and mobile cellular telephone, while there is a unidirectional relationship from internet users to economic growth and research and development and from the mobile cellular telephone to economic growth and research and development in the long run.

In light of the above evidence, it is likely to assume that the nexus between technological progress and economic growth points to a single direction. Yet this is not the case. Indeed, findings from studies in some developing countries suggest otherwise. One popular study that dispelled any doubts that technology improvements contribute less to economic growth was Jalava and Pohjola (2002). Jalava and Pohjola (2002) study employed an augmented variant of the neoclassical growth model to examine the impact of ICTs on growth in 39 countries. The results revealed no positive association between ICT advances and economic growth. A similar observation was made by Bollou and Ngwenyama (2008) who investigated the total factor productivity of the ICT sectors in six West African countries from 1995 to 2002 and found a rather declining level of TFP growth in ICT sectors of these economies. Despite these contrary findings, it is worth noting that the existing evidence concerning the negative relationship between technological developments and growth is relatively limited. In most cases, the arguments put forward by these scholars do not seem to undermine the potential of technological progress but rather focus on the scale of its contribution to realizing development goals such as poverty reduction and reducing inequalities.

6.6 Methodology

The Digital Adoption Index (DAI) and Network Readiness Index (NRI) were used as indicators to estimate the level of digital integration in South Africa as well as to measure the degree to which digitization has been leveraged to increase the country's competitiveness. The DAI is a global index which is used to measure countries' level of digital adoption across government operations, private business activities and public commercial service delivery. The average DAI of a country depicts the level of digital impact on four broad areas of development: boosting

productivity, accelerating business growth, increasing government operational efficiency, and creating opportunities for people. The NRI equally provides a framework for assessing ICT's impact on a country's economy. The computation of the digital adoption Index is based on sub-indexes focusing on governments, businesses, and the people. These sub-indexes are allocated equal weight expressed as DAI (Economy) = DAI (Businesses) + DAI (People) + DAI (Governments). Unlike the DAI, the network readiness index measures; 1) the extent to which a country's political, business, and regulatory environment allows ICT to thrive, 2) the availability of ICT infrastructure to drive ICT adoption; 3) the degree of ICT usage by people and 4) the impact of ICT on the economic and social sector. This study explores the various dimensions of both the DAI and NRI to assess and ascertain ICT impacts on individuals' welfare, business growth and government operations. The data used in this study were sourced from the World Bank Development Indicators, Digital Adoption Index reports and the Network Readiness Index Reports published by the World Economic Forum. All the data used are yearly reported and are consistent among all the identified sources. The data covers the period from 2011 to 2021.

Table 1: Variables Description

Representation	Variable definition	Sources
Y	Gross domestic product	World bank
C	ICT stock	World bank
LI	local infrastructure	World bank and ITU
TA	Technology availability	ITU
L	Labour contribution	World bank
K	Capital contribution	World bank
GoV	Government Services Delivery	
BuS	Business Operations	
PW	Peoples Welfare	Department of Social Welfare, South Africa
ΔlnY	Change in gross national output	World Economic Forum Network Readiness Index

ΔlnC	Change in ICT stock	World Economic Forum Network Readiness Index
ΔlnK	Change in physical capital stock	World Bank Ease ofDoing Business Index
ΔlnGOV	Improvement in Government Service Delivery	World Bank Growth and Development Index
ΔlnBuS	Improvement in business operations	World Bank Ease of Doing Business Index
ΔlnPW	Improvements in peoples welfare	World Bank Growth and Development Index

Table 1 describes the different variables used in the model as well as sources where these were retrieved. Data on national output, capital stock and labour were sourced from World Bank country reports on economic and social indicators. Data on ICT stock and technological availability were sourced from published reports by the United Nation's specialized agency of the International Telecommunication Union. For most of the data which focuses on change in business operations, government service delivery and the welfare of people, the World Bank Growth and Development Index, World Bank Ease of Doing Business Index and the World Economic Forum Network Readiness Index served as the main sources. All data used in this analysis are annual information published by the identified institutions.

6.6.1 Empirical model

The empirical model of this study applies the conceptual framework of Cobb and Douglas (1928) production function where growth is expressed as a function of physical and human capital, labour and the level of technological progress. The adoption of this model to estimate the ICT impacts on poverty alleviation and inclusive growth follows the footsteps of other scholars (Haftu, 2019; Solomon and van Klyton, 2020; Boakye et al., 2021). The model is expressed as $Yit_{=}f(A_tK^aL^{a1}C^{a2})$ where Y = output; A = total factor productivity, L= labour K= capital stock and C=ICT capital. The a represents the share of factor inputs. This growth production function is extended by assuming that the technological capacity which is denoted

by A is influenced by investments in digital tools (I), local ICT infrastructure (LI) and technology availability (TA). Hence *A* is transformed into:

$$A_t = I_{it} + LI_{it} + TA_{it}$$

The specification of this model is based on two main motivations. First, within empirical literature, this model is among the commonly used measures of technology diffusion in relation to GDP growth, poverty reduction and social inclusion. Second, the model takes into consideration human capital, level of ICT infrastructure and labour productivity which are key elements for economic growth. To measure the elasticity between the variables, the log form is applied to equation (1): $LogY_{it=} \alpha + LogI_{it} + LogLI_{it} + logTA_{it} + \beta LogK^{a} + \beta LogL^{a1} + \beta LogC^{a2} + \varepsilon_t$

The values in Equation (3) can be interpreted as follows: α represents the elasticity of output/growth with respect to physical capital and human capital, while β represents the output with respect to labour, capital stock and ICT stock. It is further assumed that the dependent variable Y and the technological progress (A) are exogenous variables and as such grow at time-variant rate g(it) while (ε) represents a random error. By using the autoregressive distributed lag (ARDL) modelling approach, the estimation of the stationarity test can be expressed as

$$\ln Y_{t=} \alpha + \alpha tT + \beta 1 \ln I_{it-1} + \beta_2 \ln LI_{it-1} + \beta_3 \ln TA_{it-1} + \beta 4 \ln K^{a} + \beta_5 \ln L^{a1} + \beta_6 \ln C^{a2} + \sum i=1(n-1) \gamma 1 \Delta \ln I_{it-1} + \sum i=1(n-1) + \gamma 2 \Delta \ln LI_{it-1} + \sum i=1(n-1) + \gamma 3 \Delta \ln TA_{it-1} + \sum i=1(n-1) \gamma 4 \Delta \ln K^{a} + \sum i=1(n-1) \gamma 5 \Delta \ln L^{1-a} + \varepsilon_t$$

In this model (equation 4), the dependent variable (Y_t) is examined through the long-term and short-term relationship with technological progress. βi represents long-term parameters, γ_i, short-term parameters, *T,* time trend, and ε, is random error. The error term in equation ε_t covers extraneous fixed factors, q, that measures the unobserved constant change in production, a time-specific impact (λ_t) and an idiosyncratic error term.

$$\varepsilon_t = q + \Delta_t + u_t$$

The ICT capital stock (C) is estimated using indicators such as internet access; availability of physical and ICT infrastructure; broadband networks, online services data, smartphones, and computer usage, among others. C is further proxy using change in government operations (GOV), improvement in business activities (BUS) and better people welfare (PW). A new model

is therefore derived and is given as:

$\ln\Delta Y_{t=} \beta_1 \Delta \ln BUS_{it-1} + \beta_2 \ln\Delta GOV_{it-1} + \beta_3 \ln\Delta PW_{it-1} + \beta 4 \ln K^{a} + q + \Delta_t + u_t$

These changes in government operations, business activities and people's welfare represent the core variables of interest in this study.

6.7 Empirical results

6.7.1 Testing for stationary

To test for stationarity in the time series, a unit root test was performed on each variable in the model. The data were fitted into a linear multivariate time series model to examine the eigenvalues from the specification. The purpose of this exercise was to determine whether a long-run relationship among non-stationary variables can be established. In doing so, it was assumed that the null hypothesis which is indicated as: economic growth and ICT progress are independent will contain unit root (non-stationarity) whiles the alternative hypothesis that growth is dependent on ICT progress will have no unit root (stationarity). The unit root test was carried out using Augmented Dickey-Fullry (ADF) tests with intercepts. Results as shown in Table 2 indicate that the variables were non-stationary at all levels. This means the variables responded to change in times and seasons.

Table 2: Unit root tests of variables

Variable	Model	T-statistics	Probability	Integration results
In(C)	Trend and intercept	-2.456432	0.03202	1(0)
In(K)	Trend and intercept	-1.433747	0.26408	1(0)
In(L)	Trend and intercept	-1.028343	0.58234	1(0)
In(TA)	Trend and intercept	-2.045674	0.09695	1(0)
In(GoV)	Trend and intercept	-1.332543	0.04745	1(0)
In(BuS)	Trend and intercept	-2.108829	0.95846	1(0)
In (PW)	Trend and intercept	-2.605714	0.36574	1(0)

6.7.2 Estimating the variability in the dataset

To determine the degree of variability in the dataset, we performed regression analysis to estimate the variations (V). As a rule of thumb, if the V is > or = 1, it shows a relatively high variation, while a V is < 1 represents a low variation. In other words, the higher the variation, the greater the level of dispersion around the mean. The variations as reported in Table 3 shows a relatively low level of dispersion exists among the data set as the values indicate less than one.

Table 3: degree of variability among the data set

Variables	Mean	Coefficients of variations
ΔlnY	0.494	0.034
ΔlnC	0.240	0.048
ΔlnK	0.356	0.020
ΔlnGOV	0.103	0.083
ΔlnBuS	0.534	0.007
ΔlnPW	0.428	0.091

6.7.3 Estimating the impact of digital technologies on government operations

To determine whether the adoption of digital technologies improves government operations in its service delivery, we performed regression analysis using indicators such as availability and easy access to internet services, availability of broadband networks and the degree on online services used in transaction government business. The estimation was based on the following assumptions:

Hypothesis 0: Adoption of ICT innovations has no significant effect on government operations.

Hypothesis 1: Adoption of ICT innovations has a significant effect on government operations.

Table 4 presents the results from the analysis. The relationship of the selected independent variables in relation to the dependent variable indicates a positive correlation (0.26045; 0. 63756 and 0.34368 for internet access; broadband and online services respectively). This means a unit change in digital technology adoption causes a unit improvement in government

operations. The error-correction was also negative (−1.00345), as expected, and this was found to be significant as indicated in Table 7. From the results of the probabilities, the null hypothesis that the adoption of ICT innovations has no significant effect on government operations is rejected at the 95% confidence level in addition to the no serial correlation found at the 95% confidence level. The S.E regression tests and the adjusted R-square values all fall within the range of $p < 0.10$, $p < 0.05$. This implies that the null hypothesis that the adoption of ICT innovations has no significant effect on government operations can also be rejected.

Table 4: ICT innovation usage and change in government operations

Dependent variable: ΔlnGOV **Included observation: 30**				
Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	-1.74685	0.247432	-3.03055	0.0006
Log of Internet access	0.26045	0.109358	2.095827	0.0045
Log of broadband networks	0. 63756	0. 044548	5.073414	0.0295
Log of online services	0.34368	0.038645	2.45823	0.00493
R-squared	0.00574	Mean.dependent var		1.3626
Adjusted R-squared	0.61952	S.D.dependent var		0.0411
S.E. of regression	1.75436	Akaike info criterion		0.0363
Sum squared resid	0.30727	Schwarz criterion		1.0847
Prob(F-statistic)	0.28606			
CointEq(−1)	-1.00762	0.175290	-2.20585	0.0072

6.7.4 Estimating the impact of digital technologies on business operations

Table 5 presents results from the analysis focusing on the impact of ICT innovations on business operations. The p values of the R-squared (0.03556) and adjusted R-square (0.64175) indicate

a significant correlation between the variables. This implies that the adoption of ICT innovations in commercial business operations leads to better efficiency and high productivity. The results from the S.E regression tests and the adjusted R-square values all fall within the range of $p < 0.10$, and $p < 0.05$. This means we can reject the null hypothesis "adoption of ICT innovations has no significant effect on improving business operations". This finding corresponds with findings by Solomon and van Klyton (2020), who conducted a broad-based study on the impact of digital technology on Africa's economic growth.

Table 5: Regression results on ICT innovations usage and change in business operations

Dependent variable: ΔlnBus **Included observation: 30**				
Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	-3.04325	0. 67303	-1.04734	0.0019
Log of Internet access	0.44512	0.03735	4.04645	0.0053
Log of broadband networks	0.11946	0.73836	5.38430	0.0893
Log of online services	0.87304	0.03573	3.046384	0.0836
R-squared	0.03556	Mean var		1.2645
Adjusted R-squared	0.64175	S.D.var		0.0710
S.E. of regression	1.25669	Akaike info criterion		0.0035
Sum squared resid	0.053112	Schwarz.criterion		0.9381
Prob(F-statistic)	0.12096			
CointEq(−1)	-1.00265	0.40736	-1.11255	0.00185

6.7.5 Estimating the impact of digital technologies on welfare

Table 6 presents results from the analysis focusing on the impact of ICT innovations usage on welfare improvement. Welfare improvement in this sense is measured by quick and easy access to better health and education services due to the adoption of ICT innovations. From

the table, a positive correlation can be observed between the variables under consideration. This means the availability and use of ICT services contribute to better welfare particularly in the areas of improving access to education and health services. The error correction is also negative (-0.507), as expected, and this was found to be significant. This implies that we can accept our hypothesis that "adoption of ICT innovations has a significant effect on improving welfare". This finding is consistent with that which is reported by Wossen et al, (2017) and Ehiakpor (2019).

Table 6: Regression results on ICT stock and welfare improvement

Dependent variable: ΔlnPW **Included observation: 30**				
Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	-1.62105	0.22085	-1.03736	0.0010
Log of Internet access	0.05073	0.21630	2.45012	0.0007
Log of broadband networks	0. 71282	0.19968	5.36364	0.0065
Log of online services	0.46664	0.30558	2. 40314	0.0072
R-squared	0.02084	Mean dependent var		1.3267
Adjusted R-squared	0.70371	S.D. dependent var		0.0502
S.E. of regression	1.223045	Akaike info criterion		0.0122
Sum squared resid	0.24636	Schwarz criterion		1.1544
Prob(statistic)	0.04324			
CointEq(−1)	-0.50754	0.13451	-1.06312	0.0086

6.7.5 Effects of ICT innovation usage on GDP growth

The output in Table 7, shows CointEq(−1) to be -1.00345. This suggests that short-term errors are corrected over time to achieve long-term equilibrium. What this means is that the impact of ICT innovations on economic growth cannot be determined within a short-term period. However, we can assume that a relatively quick adjustment in the GDP growth rate can occur when the rate of ICT penetration in both government and private operations increases. By focusing on the critical value of regression-residual based on the co-integration test, the value of the Sum squared residual is 0.2034 at a probability of 0.0043. This suggests a higher critical value over the absolute value of the t-statistic. We can therefore conclude that growth in the economy and ICT innovations are co-integrated and have a long-run relationship. The result is in line with previous studies conducted by Boakye et al., (2021).

Table 7: Impact of digital technology use on GDP growth

Constant	**-0.97532**	**0.124664**	**-2.02753**	**0.0019**
ΔlnC	0.10742	0.022464	5.02684	0.0095
ΔlnK	0.38470	0.027485	3.00864	0.0113
ΔlnGOV	0.63440	0006466	1.33544	0.0065
ΔlnBuS				
ΔlnPW				
R-squared	0.00076	Meandependent var		0.1196
Adjusted R-squared	0.00187	S.D. dependent var		0.0024
S.E. of regression	1.00433	Akaike info criterion		0.01954
Sum squared resid	0.2034	Schwarz criterion		0.0043
Prob(F-statistic)	0.09433			
CointEq(−1)	-1.00345	0.03375	-1.07044	0.0034

6.8 Discussion

Digital technologies have gained prominence within the last decade. The invention of new tools such as cloud platforms, search engines, data analytics and artificial intelligence among others have created avenues for improved operations and service delivery. In some instances, digital technologies have increased productivity, boosted growth, and fostered better decision making. While many advanced countries have capitalized on the potentials of the digital economy, a greater number of economies in Africa still lagged in the digital transition. Despite their rapid spread, the impact of these digital technologies on government operations, business operations and general welfare is poorly understood and measured in South Africa.

This paper therefore attempted to explore the linkages between digital technologies and productivity. In particular, the paper used panel data to explain the difference in operational efficiencies attributable to digital technologies. When government operation was correlated with digitization, the findings revealed a strong positive relationship, indicating that the more government activities are digitized, the better their service delivery. The dividend enjoyed from a digitized government operations include reduced cost of coordination, increased inclusion as people get access to services at their convenience and better communication. The result agrees with findings by Ebrahim and Irani (2005) who's study focused on e-government implications on government business as well as Wandaogo (2022) who's research revealed that governments use of ICTs improves their effectiveness in both developing and developed countries.

In terms of digital technologies impact on business operation, results from this study revealed a strong positive linkage, meaning as business activities are digitally transitioned, business operations get improved. Indeed, digitizing business operation allows better management, increased operational transparency and enhanced customer experience. Perhaps the greatest benefit comes from lowering cost and thus raising efficiency and labour productivity. This finding is supported by that of Rachinger et al (2018), who's study on digitization and its influence on business innovation revealed that digitization has major impact of firm value propositions.

Finally, the results from this study suggested a positive and significant effect of digitization on people's welfare and long-term economic growth. This finding is largely consistent with previous literature on drivers of economic growth and productivity (Donou-Adonsou et al. 2016; Ndulu et al., 2021). The expansion of global trade, openness and urbanization in our current time can all be related to advances in innovations. Certainly, living standards would have been lower were it not for new and advance technologies. Even though the greater impact of digitization has been seen more in advanced countries that developing countries, government in lower economy countries who embraced digitization in its early stage of introduction have recorded remarkable progress in their economic performance.

Findings from this study are subject to the usual limitations of economic growth regression analysis which include the issue of attribution. Nonetheless this study provides a strong justification for policy makers to prioritize initiatives that encourage quick adoption and integration of smart technologies in economic operations. Indeed, the benefits of digital technologies will not be realized unless it is complemented with improved business climate good governance and human capital investment.

6.9 Conclusion

A country's level of innovation adoption broadly mirrored its overall economic development and poverty reduction. As this research has shown, technology has a strong role to play in advancing society. The study revealed a strong correlation between the application of digital technologies and improvement of business operations and government service delivery. The analysis further revealed a positive link between the use of technology and the general improvement of people's welfare. The value of adopting technology or digitizing the economy is immediately reflected in the strong correlation that technology has on indicators such as GDP growth and inclusion. Given the net positive effects of ICT innovations, it is recommended that policy makers focus on building ICT skills of its people, ensuring business friendly environment that enables digital penetration in the economy and creating an ecosystem that drive investment in digital infrastructure.

6.10 References

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CHAPTER SEVEN: ACHIEVING INCLUSIVE GROWTH IN HEALTH THROUGH DIGITISATION: THE CASE OF SOUTH AFRICA

8.1 Abstract

For many years, there have been several efforts by successive governments in South Africa to close health access gap, yet a large section of the population still struggles to obtain quality care. The advent of digitisation heralds a new hope of transforming the country's health systems to achieve better outcomes. Meanwhile, there has been slow attempts by government to seize this opportunity to improve healthcare delivery and ensure that no one is left behind. This is largely due to the lack of deeper understanding of the potentials of digitisation particular in the health sector. This paper attempts to underscore the benefits of digitising healthcare delivery to achieve inclusive health with a focus on South Africa. By so doing, the researchers analyse opportunities and barriers to the adoption of digital technologies in the country. The paper argues that leveraging digital technologies to achieve inclusive health depends on developing and implementing the right set of policy mix.

Key words: digitisation, inclusive health; South Africa.

8.2 Introduction

The ongoing digital revolution is yielding substantial dividend to all sectors of the economy, but the health sector has seen the most prospects. From rural to the national level, digital technologies are helping to transform how healthcare is delivered, administered, and managed. Digital tools such as e-visits, e-prescriptions and remote monitoring are enabling a shift from treatment in primary care clinics and hospitals to home care. Furthermore, eHealth is supporting critical health functions in the areas of health reporting and disease monitoring and surveillance.

Despite these prospects, many African countries have been slow to embrace digitisation as tool to transform their health sector (USAID, 2016). In Ghana for instance, there is a general lack of understanding on how digital technologies can create value and promote health inclusiveness in the country (Boakye & Babatunde, 2020). Understanding the opportunities ehealth present can help form the basis for increased investment in digital health technologies to effectively power growth across all sectors and to the benefit of all.

The experiences of emerging markets and developed countries show that digitization and smart technologies are important drivers of improved efficiency, high productivity, and inclusive growth. In recognition of the crucial role technology and innovation has on development process, South Africa has seen substantial investment in digital solutions for its agriculture sector in recent years. From the use of drones to sensors, digital solutions are fast transforming South Africa's agriculture landscape. Meanwhile little effort has been made to scale up the application of smart technologies in the health sector. For instance, compared to the agriculture sector, there have been slow private investments in digital health. As a result, health outcomes have been generally poor compared to other countries and with large population, those in remote areas struggling to access basic healthcare.

Against this background, this paper analyses the relationship between the adoption and up scaling of digital technologies and inclusive health growth. It focusses on South Africa context but draws on examples of good practice from other countries where many healthcare providers lead the field in their adoption of digital health technologies. The document also analyses opportunities and barriers to the adoption of digital technologies in the country. The

intention is to provoke discussion and provide policy makers with practical solutions to achieve inclusive health.

The paper is organised as follows: Section 2 discusses the significance of the study and research questions. Section 3 presents the methodology adopted in this study while Section 4 assesses the state of digital innovation in South Africa. Section 5 examines health inequality in South Africa and Section 6 presents the opportunities of digitisation to achieve inclusive health. Section 7 offers a snapshot of evidence on the relationships between digital health technologies and inclusive growth in health and Section 8 delves into the challenges to digital health application in South Africa. Section 9 provides policy recommendations to foster digitisation for health transformation and inclusive development in South Africa and Section 10 contains concluding remarks.

8.3 Significance of the study and research questions

South Africa is known to be one of the most unequal countries in the world. Disparities in access to education, employment and health can easily be traced along racial, gender and geographical lines. Inequalities in South African healthcare find expression in various degrees of quality of services, utilisation, accessibility, attainability, and distribution of health facilities. For many years, there has been several efforts to close the health access gap, yet a large section of the population still struggles to obtain quality care. The advent of digitisation heralds a new hope of transforming the country's health systems to achieve better outcomes. Meanwhile, there has been slow attempts by government to seize this opportunity to improve healthcare access and ensure that no one is left behind within the broad spectrum of healthcare delivery. This is largely due to the lack of deeper understanding of the potentials of digitisation particular in the health sector. This paper attempts to underscore the benefits of digitising healthcare delivery to achieve inclusive growth with a focus on South Africa. In doing so, the paper attempts to address the following questions:

1. What are the opportunities of digitisation to achieve inclusive health in South Africa?
2. What the challenges to digital health application in South Africa
3. What polices can government adopt to foster digitisation for health transformation in South Africa?

8.4 Methodology

In order to address the above research questions, our analysis integrates the concepts of interpretive approach. This method is based on the notion that social reality is not singular or objective, but rather influenced by human actions, experiences, and social contexts, and is therefore best studied by reconciling the subjective interpretations of its various participants. The approach was adopted because it enabled the researchers to understand that social reality is better interpreted through sense-making process rather than a hypothesis testing process. We started our analysis by first mapping out prominent digital health technology platforms that have emerged to support health systems. We laid out the potentials they hold in respect to improving health and social care services delivery. Documents were reviewed using an analysis framework to classify key issues discussed in the texts, gaps in literature, research findings and the methods adopted by the researcher. Overall, 30 documents (22 publications/ reports and 8 health policies) were included in the review. The final product offers recommendations to foster digitisation for inclusive health and health transformation in South Africa?

8.5 State of digital innovation in South Africa

To understand the scope and nature of digitising South Africa's economy, this section examines the structural changes that have taken place in the country over the past few decades. The significance of technological and ICT innovation as critical factors for building inclusive society has been well recognised in South Africa for years. For decades, the country has launched ambitious ICT strategies and made major structural changes all geared toward laying a solid foundation for sustainable development and ensuring that no one is left behind in the development process (Herselman et al., 2016).

From the introduction of the 1996 White Paper on Science and Technology, the creation of the Department of Science and Technology (DST) and the launch of the 2008 Ten-year Innovation Plan (TYIP), South Africa has demonstrated a strong commitment to making ICT development a national priority. For example, it has created a world class research and education network called the South African National Research Network which provides broadband services to all South African institutions of higher learning as well as science councils and national research facilities (Mukwawaya et al., 2018). Significant progress has

also been made in the application of innovation and technology in the health sector. For example, in the South African Medical Research Council (SAMRC) in 2017 invested in over 30 innovation projects directed at developing new diagnostics, devices, vaccines and other medical tools.

In spite of these developments, South Africa still lag behind with digital transformation (PwC South Africa, 2020). For instance, in 2018, the country scored 4.96 out of 10 in terms of ICT development index and was ranked 92 out of 176 countries in respect of level of innovation. In addition, the 2018 ITU's information society index placed South Africa 104th out of 144 countries in terms of access to fixed broadband (ITU, 2018). Since 2011, South Africa has consistently imported more ICT products than it has exported. According to the latest publication from the Department of Communications and Digital Technologies, the digital economy is estimated to contribute only 2% of the country's GDP (DCDT, 2020).

In sum, despite progress made in promoting technology and innovation in South Africa, as shown by the level of structural changes and commitment made by successive governments, the level of technology and innovation in the country remains low relative to other advance countries. There are a number of challenges that contribute to this situation. For instance, infrastructures to support the ICT/Telecommunication sector are limited despite investment from State Development Agencies. In addition, capital for innovation is currently insufficient to drive innovation to market. Currently, South Africa is a net import of technology. Meanwhile the government has acknowledged the need for a stronger promotion of digital technologies in business by rising recognition of technology and innovation as crucial drivers for inclusive growth. With strong vision, robust policies and commitment to act, South Africa can benefit from the prospects of digitisation if it scale up investment in ICT infrastructure, takes decisive steps to invest in its human capital and apply technology-driven solutions across all sectors.

8.6 Health inequality in South Africa

This section briefly discusses the complex problem of structural health inequalities in South Africa. It does this by focusing on the key drivers and historical dimensions of health inequality in the country's health care. South Africa is known to be one of the most unequal countries

in the world. Inequalities can easily be identified along racial lines, ethnicity, gender and geographical location (Ataguba, & Alaba, 2012). Similar with education and employment, health inequality in South Africa is a general reflection of the persistent socio-economic, racial and political disparities the country has experienced over the years.

Inequalities in health care arise along various dimensions: distribution and provision of care; availability of services and health infrastructure; and accessibility of quality services. South Africa's history of colonialism and Apartheid stand prominent in the establishment of structural inequalities in South African health care (Burger & Christian, 2020). Economic segregation which stood as a hallmark of the apartheid system led to the creation of numerous health measures and policies meant to privilege the few white populace and disadvantaged the large African populace (Harris et al., 2011). Consequently, the health needs of the larger population were underserved, and the health interest of various population groups were met unequally (von Fintel & Richter, 2019).

When apartheid gave way to a democratic transition in the 1990s, several structural changes were made, and new health reforms were created to bridge the inequality gaps in the distribution of health/social services. For instance, the introduction of the National Health Insurance System in South Africa was a key milestone in mitigating inequalities in health outcomes. Combined with the launch of other social welfare programs such as free primary health care and unconditional cash transfer, these measures contributed to increased health distribution and access in country. However, years after end of apartheid, systemic lapses, insufficient funding, and weak policies have deepened health inequalities resulting in situations where provinces with white majority receive more healthcare funding and better access compared to provinces with black majority where access to health services are generally inadequate. The urgent need for deliberate strategies to equalise the prevailing health access disparities and discrepancies cannot be overemphasised.

8.7 The opportunities of digitisation to achieve inclusive health in South Africa

Digitisation is what occurs when digital technologies are applied to solve problems. The benefits of digitisation range from increased productivity and job creation to enhanced wellbeing. However, the degree to which these benefits are within reach depends on

understanding the capabilities of digital transformation. Technological innovations present a large and unexploited potential for transforming the health sector of South Africa to achieve inclusive health (Mckinsey, 2019). Although immense progress has been made towards this course, limited efforts have been made to upscale the application of digital solutions to the health sector. This is largely due to general misunderstanding and the lack of awareness on digitisation and the opportunities that it presents (DCDT, 2020).

Digital health is currently changing health-care delivery, and it is at the core of responsive health management in many countries. It is important to mention that the core of providing health is based on using information and communication to support the delivery of health services, conduct research and manage health systems. Information and communication technologies (ICTs) provides significant benefits in ways that do not only increase efficiency but also improve health accountability (Sanya et al., 2018).

The term 'digital health or ehealth' is broadly define by the World Health Organisation as the use of information and communication technologies to provide treatment for patients, train healthcare professionals, track and monitor diseases (WHO, 2017). Digital health tools involve various technologies, such as mobile applications, biometric skin sensor, short messaging service, interactive voice response, health management information systems, mobile diagnostic devices, wearables, drones, and big data analytics. It also encompasses a whole range of components such as mobile health (mHealth), electronic health records (EHRs), and telehealth, telecare.

Digital platforms such as eHealth make use of tools like mobile phone-based health (mHealth) applications, telemedicine systems, or eLearning programmes, and includes the digitization of a country's Health Management Information System (HMIS) or Health Information System (HIS). Mobile health or mHealth describes services and information provided through mobile technology (Kampmeijer et al., 2016). mHealth has emerged rapidly in Africa countries due to the large penetration of mobile phones and the lack of modern health infrastructure. The opportunities for mhealth to promote inclusive health in South Africa can be found in the areas of promoting health education and awareness programmes, allowing real-time monitoring of an individual's health, enabling data collection for surveillance and public

health in rural areas and supporting diagnostic and treatment support, communication for health-care workers in remote settings.

Telemedicine or (telehealth) on the other hand signifies the use of ICT to increase access to care, improve patient outcomes and share medical information. It involves the use of video technology by specialists and consultants to support patients remotely. Telemedicine fosters inclusive heath by reducing costs of transportation and increasing convenience of patients in obtaining care (Thabrew et al., 2018). Health information systems is another aspect of digital health that facilitate gathering, aggregating, analysing, and synthesizing data from multiple sources to report on health situation and trends (disease burden, patterns of risk behaviour, health service coverage and health system metrics).

Internet of things and Big Data technology are increasingly becoming prominent in the delivery of health. Internet of things is a form of distributed computing that is based on network of objects that are embedded with electronic hardware and have internet access. Healthcare big data refers to collecting, analysing and leveraging consumer, patient, physical, and clinical data that is too vast or complex to be understood by traditional means of data processing.

Big data has become more influential in healthcare due to three major shifts in the healthcare industry: the vast amount of data available, growing healthcare costs, and a focus on consumerism. Big data enables health systems to turn these challenges into opportunities to provide personalized patient journeys and quality care (Stratton et al., 2017). These technologies allow health professionals to bring care closer to patients' home, empower patients to assume control of their own health and offer clinicians and researchers the tools to plan, give care and design effective treatments.

Understanding these applications, their benefits as well as how they are used is necessary to bridge health inequity gaps in South Africa. The South African governments can for instance, facilitate better use of these applications by providing better ICT infrastructure, building a skilled labour force, and eliminating regulatory obstacles to the adoption and adaptation of digital solutions.

8.8 Empirical evidence on the relationships between digital health technologies and inclusive growth in health

There is a large body of evidence on the relationship between digital health technologies and inclusive health (Garrity, 2015; Baker, Xiang & Atkinson, 2017; Krüger & Niemi, 2012; Boakye & Babatunde). Some of these research highlights new channels through which digital health technologies foster structural transformation and inclusive health (Boakye & Babatunde, 2020). For example, important complementarities have been identified between investments in digital health and increased the economic efficiency of service provision (Stroetmann, 2018). In addition, ICT-related changes in hospitals, clinics and care homes are typically part of a process of experimentation and research, for which those who embraced them often report improvement in health care delivery. Economies with a policy framework that allows this process of creative destruction usually benefits from ICT opportunities than economies where such changes are more difficult and slower to embrace (WHO, 2019).

Available literature suggests that positive health outcome occurs through structural changes involving investing and adopting digital health solutions (Stroetmann, 2018; Boakye & Babatunde, 2020). Investments in digital health technologies in particular, have been found to have both social and benefits. For instance, a study assessing the benefits of eHealth in 11 public and private healthcare delivery centers of varying sizes and settings (rural/urban) revealed that investment in e-Health contributes to 50%-80% reduction in medication errors, increase the use of formulary and generic drugs by 30% and increase patient screening and preventive healthcare procedures by 40% (Abolade & Durosinmi, 2018).

Trends in IoT-based healthcare have also been widely explored in recent times with much of this research focusing on the development of platforms, new services and applications, interoperability, and security, among others (Hanson, Puplampu & Shaw, 2017; Bagula et al., 2018). In addition, policies and guidelines that allow easy and quick deployment of the IoT technology in the medical field have been examined in several countries, meanwhile the potentials of IoT technologies in the healthcare field remains in its infancy. At present, the pace of development in the whole digitisation ecosystem is increasing at an exponential rate, however experts wonder whether these developments could lead to little or complete transformation of the healthcare industry.

With regard to inclusive health, the evidence available suggests that technological innovation in health plays a crucial role in determining whether or not the health care delivery in a society is inclusive. To the extent that new health technologies allow remote treatment they make healthcare more inclusive (Boakye and Babatunde, 2020). Innovation in the health sector can also have a positive impact on wellbeing if it gives rural people better access to health information (Krüger & Niemi 2012; Venkatesh et al., 2016). For example, the rapid spread of mobile telephones in Africa has been credited with giving people living in remote areas better access to health services. A study conducted in rural Tanzania by Krüger and Niemi (2012) revealed how telemedicine is enabling paediatric care to be offered to patients in remote areas. In rural India, Venkatesh, Rai, Sykes and Aljafari (2016) discovered that the use of eHealth kiosks had contributed to better infant health and mortality. In Lebanon, one study revealed that eHealth facilitates equitable access to primary healthcare for those living in rural and refugee settings (Saleh et al., 2018).

Other scholars suggest that IoT technologies could be used to provide better access to healthcare for those living in rural areas by allowing remote monitoring of non-critical patients at home rather than in hospital, thereby reducing strain on hospital resources (Qudah & Luetsch,2019; Hashiguchi, 2020). The authors further provide that mobile health technology has the power to give patients in remote areas the opportunity to assume more control over their health thereby making them less dependent on health workers for health information. All the evidence point to the fact that digital health technologies are essential for sustaining inclusive health.

8.9 Challenges to digital health application in South Africa

The main opportunities for digital solutions to positively impact the South African health sector reflect the structural constraints the country face in pursuit of its health commitments and targets. The core challenges faced are substantial and complex, and include limited digital infrastructure, low skills, and policy issues. Investment in digital infrastructure is critical to meet the new demand for virtual health services and achieve inclusive health. In order to improve connectivity and enhance health access in urban and rural areas requires substantial investments by government and private enterprises, yet insufficient resources and funding is a common concern for all ehealth projects in South Africa (Myllyoja et al., 2016). For instance,

basic infrastructure such as internet, hardware and electricity supply are expensive and inaccessible to a large proportion of the population.

Another notable challenge to the successful application of ehealth solutions in South Africa is the issue of privacy and security of personal health information. Provision of health care is laden with complex issue of confidentiality, privacy, and security. The introduction of digital health solutions need not undermine the essential values that underpin the trust relationship between doctor-patient. Protecting personal health information that is gathered using electronic devices is critical for up scaling demand for eHealth services in urban and remote areas.

Low technological capacity of a large part of South African population is equally a critical hindrance to the country's ability to fully advance ehealth application to achieve inclusive health. The South African National Research Foundation (NRF), for example highlights the maintenance and development of knowledge and skills for digitisation as an important challenge. Health care staff must be skilled to use new technologies. The lack of appropriate skills and expertise to oversee a digitisation health project is a serious concern in South Africa.

It is worth noting that Strong legislation, policy, and compliance are essential for building resilient systems for technology penetration and innovation in a country. However, in South Africa, there is a lack of flexible regulatory environment that enables fast deployment and adaptation of innovation. In addition, there are inadequate rules governing data storage, privacy, and confidentiality. These challenges do have implications for confidence depose in the use of digital technologies in the country. Long term strategic plans coupled with strong vision and complemented by robust policies and political will are critical success factors to smooth role out of digital health projects.

8.10 Policies to foster digitisation for health transformation and inclusive development in South Africa

The depth of health care inequality in South Africa offers a solid justification for upgrading the country's health systems along a new and innovative path to ensure that no one is left behind. Indeed, digitisation of healthcare has shown to be good enabler for better healthcare and improved public health systems. The ability to successfully leverage digital technologies

to achieve better health outcomes and foster inclusive growth however depends on developing and implementing the right set of policy mix.

For South Africa, the first step is the need to develop a national ehealth strategy that bridge the access and usage gap. Across the country, ehealth technologies vary among provinces by demographic and geographic categories, raising concerns about the inclusiveness of health care delivery. Notable challenges typically include a combination of lack of high-quality and affordable internet infrastructure; and a shortage of skills personals needed to succeed in the digital health ecosystem. Developing national digital health strategies that are robust, but flexible enough to adapt to local settings, is the first step to closing the health care access and usage gaps. The process of developing and drafting the strategy should involve all relevant actors and stakeholders, to ensure prior agreement on major goals, concrete objectives, appropriate implementation structures and resources.

Increase domestic expenditure on Research and Development is another recommended action. It is crucial to point that R&D is essential to the extent that it can effectively foster technological learning and build innovation capacities in a country. One of the biggest concerns identified by medical practitioners in South Africa is the limited evidence on outcomes of ehealth service. Lack of evidence means a lack of trust in digital health technologies and consequently low patronage. To build trust means to develop strong privacy and security arrangements and clear governance structures for the use of personal health data. Conducting cost-benefit analysis to identify required changes for ehealth care provision is another useful way of overcoming this concern.

Given that ICT infrastructure and fixed line or mobile phone connectivity is a challenge in rural South Africa, it is important that the government continually invest in digital health infrastructures to meet existing and future health demand and help bridge digital divides. Promoting availability, accessibility and affordability of ICT infrastructure, devices, and connectivity through increased investment in a low-cost, high-speed broadband is a sure way to go. A critical area for policy action involves establishing national broadband plans that address the key barriers to the deployment of high-speed networks and services, particularly in rural areas.

Another dimension to be considered as policy action is improving health literacy levels through training and capacity development. Understanding the usefulness of ehealth technologies and its application is the first step towards acceptance. Training and sensitisation are important factors for facilitating acceptance and use of new systems among health practitioners in remote areas. Health professionals who experience difficulties in understanding and using digital health technologies, may have negative perceptions about its usefulness, and would be less likely to accept these interventions (Boakye & Babatunde, 2020). Training and capacity building can eventually contribute to shaping their digital literacy, reduces anxious about making errors and encourage the usability of digital systems and devices.

8.11 Conclusion

This paper examined the state of health transformation, digital innovation, and inclusive growth in health in South Africa. The paper elaborated on the opportunities of digitisation to achieve inclusive health in South Africa and points to a common challenge that the country face as it aspires to expand ehealth application. The paper argued that leveraging digital technologies to achieve better health outcomes and foster inclusive growth depends on developing and implementing the right set of policy mix. These policy mix as discussed in the paper include developing a national ehealth strategy that bridge the access and usage gap; increasing domestic government expenditure on R&D; investing in the development of digital health infrastructures to meet existing and future health demand; and improving health literacy levels through training and capacity development.

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CHAPTER EIGHT: SUMMARY CONCLUSION AND POLICY RECOMMENDATIONS

9.1 Summary conclusions

This research has applied a comparative analysis technique to examine the readiness and capacity of Ghana and South Africa to embrace the digital economy and ensures inclusive digital transformation as pathways to addressing poverty and promoting inclusive growth. Guided by the conceptual framework of neoclassical theories, the study reviewed key trends of technology adoption in Africa and identified key policy issues for discussion among policymakers and social partners. The nature of this research project took the form of publications. A total of six articles covering diverse topics but grounded in digitisation and its relation to development problems were published in internationally accredited journals.

The first article which explored the impact of technological progress and digitization on Ghana's economy analysed a time series data covering the period 2009–2019. In this article, technological progress and economic growth inter-dependency was analysed in two steps. First, the relationship was tested by Augmented Dickey–Fuller method. A significant relation was found between technological progress and investments in ICT infrastructure. Technological progress and GDP relation was then tested in the next step. Consequently, a long run relation was observed between the two variables by using Engel Granger and Error Correction Models. The results indicated that adopting technology or digitising the economy has the impetus of driving sustainable growth and development in Ghana.

In the second article, the researcher analysed evidence from South Africa to assess the process of alleviating poverty and achieving inclusive growth through digital innovations. By exploring extensive literature, this article showed evidence on how digitisation contributes to economic transformation, growth, and poverty reduction. In particular, the study revealed how adopting technological innovations impacts productivity and general wellbeing. The paper argues that leveraging digital technologies to achieve economic and inclusive growth depends on designing and implementing the right set of policy mix. This policy mix includes, establishing the right regulatory framework; investing in digital skills acquisition through

training and capacity building; prioritising spending on research and development; and finally investing in ICT infrastructure.

In the third article, the research project focused on examining the role of internet of things (IoT) to support health services in rural communities. This research was relevant and timely particular because of global health catastrophe that world experienced in year 2019 and 2020. The COVID-19 pandemic unleashed harsh economic difficulties on many countries and reversed progress made in reducing extreme poverty. The pandemic also exposed the fragile state of health systems in many African countries including Ghana and South Africa and highlighted the importance of leveraging digital tools to promote inclusive health.

The research project investigated and identified appropriate mechanisms by which IoTs technologies could be leveraged to mitigate health burdens in poor communities with emphasis on enhancing remote monitoring of patients' health, increasing access to health information, training of healthcare professionals and reducing out-of-pocket health expenditure. The point of departure of this study was that internet of things health technologies can help bridge the health divide between rural and urban healthcare centres. This operational concept was established based on evidence drawn from developed and developing countries where digital health tools have been successfully implemented to increase access to quality health service.

Most importantly, the study outlined various roadmaps for building and implementing resilient digital health systems in rural communities. These roadmaps focused on expanding ICT connectivity, forging strategic partnerships, training healthcare professionals, and developing favourable legislation to attract private sector investments in digital infrastructure.

The fourth article analysed a panel data for the period 2011- 2021, to estimate the relationship between the application of agriculture technologies and maize yield in rural South Africa using a stochastic production frontier framework and Cobb-Douglas production function. The stochastic production frontier model was estimated using simple ordinary least square, maximum likelihood estimation and probit regressions. The analysis adopted a three-stage procedure which began with the specification of regression model, the calculation of

least residuals squares of the explanatory variables and finally the estimation of the variances in the functional forms of output levels. The study revealed two critical findings in relation to farmer-preferred technologies. First, results show that drones, sensors, seed drills, smart irrigation and aerial images are among the top new technologies mostly deployed in farming practices in rural areas. Second, farmers adopt changes in cultivation practice with respect to the use of these technologies only when they have seen evidence of its positive net effect on production. The statistical output further showed a strong positive relation between technological adoption and yield increase. Notwithstanding these findings, it was noted that the mere adoption of digital agriculture technologies by itself does not necessarily contribute to increased productivity.

The fifth article analysed the impact of digital technologies on government operations, business operations and general welfare using evidence from South Africa. The study revealed a strong correlation between the application of digital technologies and improvement of business operations and government service delivery. The analysis further revealed a positive link between the use of technology and the general improvement of people's welfare. In addition, study concluded that the value of adopting technology or digitizing the economy is immediately reflected in the strong correlation that technology has on indicators such as GDP growth and inclusion.

The sixth article focused on promoting inclusive growth in health through digitisation, using evidence from South Africa. The study specifically highlighted opportunities and barriers to the adoption of digital technologies in the country. The paper argued that leveraging digital technologies to achieve better health outcomes and foster inclusive growth depends on developing and implementing the right set of policy which include developing a national ehealth strategy that bridge the access and usage gap; increasing domestic government expenditure on R&D; investing in the development of digital health infrastructures to meet existing and future health demand; and improving health literacy levels through training and capacity development.

9.2 Policy recommendations

The results from this research project provides a strong basis for outlining a number of forward-looking policy recommendations needed to drive the transitioning from traditional models of operations to a digitised ecosystem. The extensive diagnosis carried out in this research project has revealed the weaknesses in government systems, deficiencies in policy and regulatory frameworks and institutional capacity limitations which impede progress towards digitisation. At the same time the study has highlighted varied potentials of digital tools that with the right set of policy mix they could be leveraged to fast-track progress towards addressing poverty and promoting inclusive growth. The study has argued that mainstreaming technological innovation is not only crucial to addressing the transformation and inclusive challenges that many countries experience but also can help to achieve better development outcomes. Against this backdrop, this section presents some policy measures that could be implemented to effectively promote digitisation in Ghana and South Africa.

Increase investment in research and development: There is no argument about the integral role that research and development play in promoting technology and innovation. Research and Development offer a wide range of gains in the areas of fostering technological learning, building institutions innovative capacity and facilitating diffusion of knowledge that are essential for promoting inclusive growth. One important avenue that government can adopt is to prioritize investment in higher education institutions by offering research grants to stimulate R&D projects.

Strengthen linkages between higher education and domestic firms: Higher education institutions are key producers of knowledge and skills. However, often times there is a weak collaboration between universities and industries, a situation that often results in skills mismatch and lack of knowledge transfer. Building a strong linkage between higher education and domestic firms is useful to the extent that it creates avenues for knowledge spillovers into domestic firms. It also offers the possibility for graduates to acquire the skills needed to be participate effectively in the labour market. An important pathway to foster this linkage is to have the CEO of big industries to sit on the Board of Directors of higher education institutions.

Reform regulatory frameworks and create favourable business environment to encourage entrepreneurship: Entrepreneurship is an important enabler of innovation. Entrepreneurship facilitates the adoption and implementation of new techniques. Policies that support innovation and digital start-up entrepreneurs are necessary increase access and reduce cost of using digital solution. To unleash the innovative capacity of entrepreneurs requires the creation of conducive business environment. For instance, through investment in infrastructure, elimination of regulatory barriers to business registration, tax incentives and trainings, government could stimulate entrepreneurship ideas among young people.

Develop technology and innovative policies that are coherent and inclusive. The study has revealed the lack of disconnect between ICT policies and broader development policies in Ghana and South Africa. When ICT policies are not coherent with the broader development policies, it leaves a vacuum in measuring the impact of ICT adoption on development outcomes such as poverty reduction. One way to foster coherence is to align ICT policies with educational policies to enhance upskilling among youth to support digital uptake. Moreover, when it comes to access to digital solutions and ICT in general, women tend to be disadvantage. To address this problem, policy makers may need to adopt targeted strategy to increase women access to ICT tools. These targeted strategies could be in the form of offering educational scholarships for women to receive ICT training or enhancing women access to credit to enable them afford ICT tools.

APPENDICES

Appendix A: Supporting Documents for Article One

Boakye, A*., Nwabufo, N., & Dinbabo, M. (2022). The impact of technological progress and digitization on Ghana's economy. African Journal of Science, Technology, Innovation and Development,16. https://www.tandfonline.com/doi/abs/10.1080/20421338.2021.1994239.*

Appendix A 1: Feedback from Reviewer 1:

The minor concerns:-

- ✓ In abstract the authors said this study analyzed the impact of technological progress and digitisation on the Ghana's economy using a panel data for the period of 2009–2019. However in conclusion they said that this paper, we study the growth impact of digitisation on Ghana's development by using annual time series data for the period 2000–2015.

- ✓ In abstract the authors said that the results indicate that adopting technology or digitising the economy has the impetus of driving sustainable growth and development. In particular it was noted that ICT investments drives high productivity rates and faster economic growth.it is better if they quantified the impact rather than narrating it while the authors used econometric model for analysis. Why not quantify the result?

The major concern:-

- ✓ The result in Table 5 shows GDP growth impact on technological progress. But the title and the overall objective of the paper is The Impact of Technological Progress and Digitisation on Ghana's Economy. How we can reconcile the two idea? I cannot find the result that shows the impact of technological progress and digitization on country's economy. Rather the result show the impact of counties economy (GDP growth) on technological progress (see result in table 5).

Appendix A 2: Confirmation of publication from Taylor and Francis:

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The impact of technological progress and digitization on Ghana's economy

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Appendix A 3: First request to publish my article in a book.

Dear Dr. Alex Boakye,

My name is Daniela Olari and I am editor at Eliva Press. I went through your list of recent publications and it is impressive. We are interested in publishing a book of your works, including this paper: "**The impact of technological progress and digitization on Ghana's economy**".

We specialize in publication and dissemination of academic books. The publication is free for our authors. You will retain copyrights and earn up to 50% royalties. In addition, the book will be distributed through Amazon, Lightning Source, Barnes and Noble, Book Depository and many more.

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Your reply would be greatly appreciated.

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Sincere regards,
Daniela Olari
Editor

daniela.olari@elivapress.com
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Appendix A 4: Second request to publish my article in a book.

Dear Dr. Boakye,

I hope my email finds you well during these challenging global times.

Please excuse the direct nature of this contact, however I would like to speak with you regarding your work on the The impact of technological progress and digitization on Ghana's economy study.

Research Outreach work in collaboration with research teams assisting with their Public Outreach activity, through means of a professionally produced series of publications and articles aimed at a broader audience.

I understand Public Outreach is a very important issue within the research community – where it is often difficult to obtain large numbers of views and interactions.

We are currently working on our June 2022 edition. This publication will feature a wide variety of science disciplines, including approximately 28 research articles. We would like you to be one of those featured.

My suggestion is that we might create a new article, possibly covering some basic details of the published paper I have seen online, or indeed, covering new ground or the wider scope of your work. This would be an entirely new article written and developed by Research Outreach, in close collaboration with you.

Research Outreach distributes all content, publications and your individual article, across major Social Media platforms, as well as our own website. Your work will be seen by a large and quantifiable global audience.

All content we produce is free to share and can be downloaded by any reader. Our website is entirely transparent and answers any questions you may have.

I have briefly looked over the details of your work and believe Research Outreach to be an effective platform to communicate your outreach requirements.

We publish under the Creative Commons Licence and you will own the copyright to your published material, and we can send you a separate PDF download, to be used on your web-page, at events, conferences, or as outreach material for students etc.

Please have a look at our website for examples of the publications we produce and further

detail on our objectives and services:
www.researchoutreach.org

I can assure you the entire process requires very little work on your part, less than 2 hours of your time to approve the content we create over a 10-week editorial process.

Some of the services we provide are paid for, this means there is a cost to you if you decide to take part. I would be delighted to explain this and our editorial process. I understand your time is limited.

Rather than writing any further detail, could we please find 5 minutes to discuss?

During our call, I can answer any questions you may have and explain in detail the requirements and cost for taking part and of course the benefits of doing so.

Thank you in advance,

Julian Barrett
Project Director
Research Outreach

M: +44 7968 123454 (UK Cell)
T: +44 1453 828 951 (UK)

W: www.researchoutreach.org
E: julian@researchoutreach.org

Appendix A 5: IBR results review

Result of Review

Article Title: The Extent to Which Digital Technology Influence Ghana's GDP Growth

Author(s): Alex Boakye, Mulugeta Dinbabo

Decision of Paper Selection

( ) A. Accept submission, no revisions required.

(*) B. Accept submission, revisions required; please revise the paper according to comments.( ) C. Decline submission; you may revise and resubmit for review.

( ) D. Decline submission.

What should you do next? (Only for accepted papers, A & B)

- ✓ Revise the paper according to the comments (if applicable).
- ✓ All authors must agree on the publication; please inform us of agreement by e-mail.
- ✓ Pay the Article Processing Charge of 300.00USD for the paper.
  - ✧ Please find payment information at: http://ibr-pay.ccsenet.org
  - ✧ Please notify the editorial assistant when payment has been made

Proposed Schedule for Publication (Only for accepted papers, A & B)

- ✓ Vol. 14, No. 7, July 2021, if you meet above requirements within 2 weeks.
- ✓ e-Version First: the online version may be published soon after the final draft iscompleted.
- ✓ You may also ask to publish the paper later, if you need more time for revision orpayment.

Additional Information (Only for accepted papers, A & B)

- ✓ You may download your article in PDF at: http://ibr.ccsenet.org
- ✓ You may contact us to request an e-book of the full issue in PDF, *free of charge*.
- ✓ To order print copies, please click “Order Hard Copies” on the journal’s website.

Evaluation	**Grade** Please give a grade of 5, 4, 3, 2, 1(high to low)
Overall evaluation of the paper	**3**
Contribution to existing knowledge	3
Organization and readability	4
Soundness of methodology	3
Evidence supports conclusion	3
Adequacy of literature review	4

Comments and Suggestions

(*) 1. Revise the paper according to *Paper Submission Guide*: http://ibr-author.ccsenet.org( ) 2. Picture(s)/figure(s) are not clear; 300 dpi is required.

( ) 3. Resize the table(s)/figure(s), to fit A4 paper size, and make all pages be vertical.( ) 4. Revise table(s) into three-line table(s).

( ) 5. Insert table(s) and figure(s) into the text, not after references.

(*) 6. Similarity index (checked by iThenticate) is high, please find the iThenticate report attached, revise to keep the Similarity Index ≤30% and single source matches are ≤6%.

( ) 7. Add DOI persistent links to those references that have DOIs, please see *Paper Submission Guide.*

( ) 8. Some typos and grammar errors need to be corrected. Maybe a colleague more fluentin English should read the manuscript to fine tune it before publication. You may arrange theproofreading by yourself. We will change a service fee if you ask us to arrange proofreading.

(*) 9. Complete the *Response to the Comments*, and send to us, along with the revised manuscript. (Template attached)

(*) 10. Each reference cited in the text must appear in the reference list, and each entry in thereference list must be cited in the text.

( ) 11. References should not be numbered, so citations in the text with numbers within brackets should be modified as with author's name and publication year. For example, (Smith, 1999), please see Paper Submission Guide.

(*) 12. The format of references section is not appropriate; please revise them according to the paper submission guide file.

❖ **Evaluation** (Please evaluate the manuscript by grade 1-5)

5=Excellent 4=Good 3=Average 2=Below Average 1=Poor

Items	Grade
Contribution to existing knowledge	3
Organization and readability	2

Soundness of methodology	3
Evidence supports conclusion	2
Adequacy of literature review	2

❖ **Strengths**

This can be a good study for Ghana economy looking the ICT perspective.

❖ **Weaknesses**

Writing structure need to be improved.

❖ **Suggestions to Author/s**

- Need to rewrite title
- Add key words
- Add some latest studies in Literature Review section.
- Can recommend some more policies in the light of research findings.
- (See more comments as attached)

Appendix B: Supporting Documents for Article Two

Boakye, A., *& Babatunde Olumide, O. (2021). The role of internet of things to support health services in rural communities. A case study of Ghana and Sierra Leone. Transnational CorporationsReview, 13(1),4350.* https://www.tandfonline.com/doi/abs/10.1080/19186444.2020.1849937

Appendix B 1: Publication confirmation from Taylor and Francis

The online platform for Taylor & Francis Group content

Author Services | FAQ | Twitter | Facebook

Dear Alex Boakye,

Congratulations, we're delighted to let you know that your final published article (the Version of Record) is now on Taylor & Francis Online.

The role of internet of things (IoT) to support health services in rural communities. A case study of Ghana and Sierra Leone

Want to tell others you're published? Use your free eprints today
Every author at Routledge (including all co-authors) gets 50 free online copies of their article to share with friends and colleagues as soon as their article is published. Your eprint link is now ready to use and is:

https://www.tandfonline.com/eprint/MNHVEPA7Z3NQJWTFJCAN/full?target=10.1080/19186444.2020.1849937

You can paste this into your emails, on social media, or anywhere else you'd like others to read your article. Author feedback tells us this is a highly effective way of highlighting your research. Using this link also means we can track your article's downloads and citations, so you can measure its impact. Find out more about **sharing your work**, how you can work with us to **highlight your article**.

Have you registered to access your Authored Works?
If you haven't already done so, now is the time to register for your **Authored Works**, our dedicated center for all Taylor & Francis published authors. Authored Works gives you instant access to your article, and is where you can go to see how many people have downloaded it, cited it and access your Altmetric data.

To access your Authored Works, you will need to register with the email address below:

alexboakye00@gmail.com

Once you've completed the **quick registration** you'll be sent an email asking you to confirm. Click on the

verification link and you can then login (using the above email address) whenever you want to by going to **Taylor & Francis Online**. Once you have logged in, click on "**Your Account**" at the top of the page to see the latest updates on your article.

Next steps
We'll be in touch as soon as your article is assigned to the latest issue of Transnational Corporations Review, but if you've any queries in the interim don't hesitate to **contact us**.

Kind regards,

Stewart Gardiner
Global Production Director, Journals
Taylor & Francis Group

Interested in insights, tips, and updates for Taylor & Francis authors? Be part of our researcher community on:
Twitter
Facebook
Taylor & Francis Author Services

Routledge

Please do not reply to this email. To ensure that you receive your alerts and information from Taylor & Francis Online, please add "alerts@tandfonline.com" and "info@tandfonline.com" to your safe senders list.

Taylor & Francis, an Informa business.
Taylor & Francis is a trading name of Informa UK Limited, registered in England under no. 1072954. Registered office: 5 Howick Place, London, SW1P 1WG.

Appendix B 2: Confirmation email of article accepted for publication.

Nov 07, 2020

Ref.: Ms. No. RNCR-2020-0044R2
The role of Internet of Things (IoT) to support health service delivery in rural communities. A case study of Ghana and Sierra Leone.
Transnational Corporations Review

Dear Mr Boakye,

I am pleased to tell you that your work has now been accepted for publication in Transnational Corporations Review.

It was accepted on Nov 07, 2020

Comments from the Editor and Reviewers can be found below.

Thank you for submitting your work to this journal.

With kind regards

Hugh Dang
Managing Editor
Transnational Corporations Review

Comments from the Editors and Reviewers:

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/rncr/login.asp?a=r). Please contact the publication office if you have any questions.

Appendix B 3: Peer Review Request Form

PEER REVIEW REQUEST FORM

(Contact: tncr.special@gmail.com)

Paper ID	RNCR-2020-0044
Paper Title	The role of Internet of Things (IoT) to support health services in rural communities. A case study of Ghana and Sierra Leone.

Reviewer's information (name with affiliation and email):

Qi Zhang, University of Ottawa, qzhan020@uottawa.ca

	Poor	Fair	Good	Very Good	Outstanding
Relevance of Topic			√		
Originality			√		
Conceptual Foundation		√			
Methodology Employed		√			
Usefulness of Findings			√		
Readability				√	

Recommendation to Editors:

	Accept as it is	Accept with (minor) changes	Accept with major changes	Reject
Recommendation		√		

Comments/suggestion to the author(s):

This paper studied the role of internet of things (IoT) technologies to improve health outcomes for the rural residents in Ghana and Sierra Leone. Author(s) highlighted some relevant health technologies to increase the efficiency of healthcare delivery in rural communities. This paper has good contribution that provides many insights to improve the healthcare system in Ghana and Sierra Leone by using IoT technologies.

Comment 1:

Introduction section, paragraph 2: "We draw lessons from developed countries…" There is a large gap between the economic and social development between the less developed countries and developed countries. In my opinion, the author(s) should show some successful examples on how the other less developed countries, or even developing countries implemented IoTs to their health care system. This is more convincing than lessons learned from developed countries. In the later section, author(s) provided examples from India. Therefore, here should add developing countries, rather than only developed countries.

Comment 2:

Introduction section, paragraph 3 and Section V: "…e-visits, e-prescriptions and remote monitoring." In general, audience may raise the questions about the accessibility of computer, internet and the high technology knowledge of rural residents in Ghana and Sierra Leone. Author(s) should provide evidence that how the infrastructure and knowledge training has been built or will be built to be able to support the new healthcare functions at residents' homes. In Section V paragraph 2, author(s) mentioned the accessibility of phones should support the access of health service and with higher quality of healthcare. However, there is no discussion about how it can benefit the residents given that they lack of infrastructure. For me, the discussion of mobile health and telehealth has conflicting statement. If the rural area cannot build road then how they can build mobile signal towers, or have stable internet coverage. Section V is lack of discussion on the supporting infrastructure the mobile health and telehealth in rural area.

Comment 3:

I understand the methodology of interpretive approach. However, I found the examples in Section V may not be able to convince the audiences to understand how accessible of high technology (e.g. drones) in rural areas. Is there any successful example in a similar country? It mentioned that drones to deliver medicines is less costly. The author(s) should provide some statistics to show evidence why drones is less costly. Roads can also contribute other basic development in rural area. Costly or not should be measured in a meaningful way.

Comment 4:

Section VII, paragraph 2, I found some statement in this paragraph echoed with my comments mentioned above. In other way, the statement in this paragraph conflicts with the statement in section V. For example, Section VII mentioned building network systems is costly. If building roads and network are both costly, then author(s) need to find some statistics to prove why building network is more feasible than roads.

Comment 5:

Author(s) covers complete perspectives of investigating the way to introduce IoT technology in rural area. However, the paper would be improved if the author(s) provides deeper discussion with examples that are detailed or convincing strategies/statistics from other countries as supporting evidence to show the feasibility of implementing IoT in rural area of Ghana and Sierra Leone.

Section V, paragraph 3:

Comments on Editing:

1. **Please make either "healthcare" or "health care" consistent through the entire paper.**
2. **Section II, paragraph 1, it should be healthcare delivery or health service delivery but not health delivery.**
3. **Section IV, paragraph 2, it should be 'launched'.**

<u>Suggestions to the editor(s):</u>

This paper is well written and with a new angle to explore the improvement of healthcare system in Ghana and Sierra Leone. With minor changes, I think this paper will contribute to the journal.

Other Notes:

Updated: December 2018

Appendix B 4: Feedback from reviewers

Decision: Major Revision Required

The research did well to highlight major health challenges in both Ghana and Sierra Leone and provided roadmap to addressing the issues. There are very useful points and contributions to literature in health economy. However, below are my concerns:

Introduction should be able to highlight the situation of things in Ghana and SL as regards to IOT and compare such with what is obtainable from Advanced countries and countries with efficient use of IOT in primary health delivery. Back up your arguments with data and references.

I also feel the section I and II should merged- introduction should be able to highlight the Significance of the study and research questions. The research gap should appropriately be established in this section and reinforced in literature review. From the introduction, one should be able to understand the intent of the research, research questions, research gaps and brief solutions. Readers should be able to picture the content of the paper from the introduction.

The status of health in Ghana and Sierra Leone:

Compare the "ratio of doctors to the population" in Ghana and Sierra Leone to what is obtainable from advance countries. This should be done for both countries under review.

"According to WHO estimates, the country has one of the world's highest maternal and child mortality ratio." What is the ratio? Compare both countries to advance countries.

Provide Health expenditure for both Ghana (was provided) and Sierra Leone and compare to advance countries.

In literature review, all the argument presented are with respect to development in developing countries, there is no where you presented an argument that a better use of IOT Technology or mobile health technology was able to improve health in developed countries.

Comparison with developed countries will help to "draw lessons from developed countries".

What does the health care contribute to economic development of the nations? Look at the contribution of healthcare to the economy of Ghana and Sierra Leone with comparison to developed nations of your choice. That will help you to project an increase in contribution of the health economy to the overall economy. Policy makers may be interested on this.

Since there is language problem, don't you think educating the populace will also help to adapt and adopt to the new technologies?

Be specific in your conclusions; use of etc. should be avoided.

I am not sure the reference method is appropriate with the journal requirements.

The author(s) may need to proofread the entire work and adjust some typographical errors and sentences.

Appendix C: Supporting Documents for Article Three

Boakye, A., & Dinbabo, M. (2021). Alleviating poverty and achieving inclusive growth through digital innovations. Evidence from South Africa. *Journal for Creativity, Innovation and Social Entrepreneurship Tshwane University of Technology (TUT-JCISE) Vol. 5, No. 2, 2021 - ISSN 2521-0270.* https://sarchi.org/wp-content/uploads/2022/04/135097-JCISE-Vol-5-Issue-2-2021.pdf

Appendix C 1: Referee report

Journal of Creativity, Innovation and Social Entrepreneurship (JCISE)

Is a peer-reviewed journal of the, DSI/NRF SARChI on Innovation Studies at Tshwane University of Technology

https://sarchi.org/jcise/

REFEREE REPORT

Please complete as comprehensively as possible, supplying full explanations where applicable. We expect within two weeks to submit the peer review by doing the refereeing. Kindly return the manuscript as soon as possible. The referee's name should not appear on this form.

Title of the Research Paper:

Alleviating poverty and achieving inclusive growth through digital innovations. Evidence from South Africa

Is the title appropriate and adequate?

Yes, it covers the context of the paper.

How significant is the research selected and who can benefit from the work?

The research is significant because it addresses real-life and contemporary phenomena i.e. poverty and innovation.

What is the original contribution of the submitted research paper?

Innovation is central in addressing the societal problems.

How has the research been done by evaluating the methods and the data used?

The research relied on desktop research which is appropriate in obtaining secondary data. Latest data were obtained, and all issues were well-articulated to paint a picture of the state of affairs regarding poverty and innovation in South Africa.

State the changes required making the paper publishable, if it has not successfully included meriting direct publication without major revisions. If revisions are essential, clearly state, how the author/authors can do them?

Minor editorial changes

Clearly examine how complete and consistent the references and bibliography are?

The references are current and up to date.

Are the research fully inclusive of what is expected to qualify publication?

Yes

State clearly reasons if the paper does not qualify for publication.

n/a

State clearly the reasons why the paper deserves to be published?

It accurately paints a picture of the state of affairs regarding poverty and innovation in South Africa.

If the paper is ready for publication, state what precise alterations are required?

In present form	
With minor editorial alterations	X
With major editorial alterations	
With minor alterations to content	
With major alterations to content	
Not at all	

Please provide any other comments after doing finally the review to the end

The paper can be published subject to minor editorial changes.

Appendix D: Supporting Documents for Article Four

Boakye, A. (2023). 'Estimating the impact of digital technologies on government operations, business operations and general welfare'. The case of South Africa. African Journal of Science, Technology, Innovation and Development. African Journal of Science, Technology, Innovation and Development, RAJS-2022-0188R2.... Article has been accepted for publication. Publication expected in early May 2023

Appendix D1: Confirmation email on article accepted for publication

Ref.: Ms. No. RAJS-2022-0188R2

Estimating the impact of digital technologies on government operations, business

operations and general welfare. The case of South Africa.

African Journal of Science, Technology, Innovation and Development

Dear Mr Boakye,

I am pleased to tell you that your work has now been accepted for publication in African Journal of Science, Technology, Innovation and Development.

It was accepted on Apr 21, 2023

Please note that this acceptance is subject to a routine originality check using Crossref Similarity Check™ software.

Once the originality check is complete, the paper will be forwarded to the Production Editor for copy editing and typesetting and you should expect to receive proofs for checking in due course. Any comments from the Editor and Reviewers can be found below.

Thank you for your contribution to African Journal of Science, Technology, Innovation and Development.

With kind regards

Angathevar Baskaran

Editor in Chief

African Journal of Science, Technology, Innovation and Development

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In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/rajs/login.asp?a=r). Please contact the publication office if you have any questions.

Appendix D2: Comments from the Editors and Reviewers

Date:	Jan 26, 2023
To:	"Alex Boakye" 3699295@myuwc.ac.za
From:	"" RAJS-peerreview@journals.tandf.co.uk
Subject:	(African Journal of Science, Technology, Innovation and Development) A revise decision has been made on your submission

Jan 26, 2023

Ref.: Ms. No. RAJS-2022-0188R1

Estimating the impact of digital technologies on government operations, business operations and general welfare. The case of South Africa.
African Journal of Science, Technology, Innovation and Development

Dear Mr Boakye,

Reviewers have now commented on your paper. You will see that they are advising that you revise your manuscript. If you are prepared to undertake the work required, I would be pleased to review a revision.

For your guidance, reviewers' comments are appended below.

If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript.

Your revision is due by Mar 27, 2023.

To submit a revision, go to https://rp.tandfonline.com/submission/flow?submissionId=&step=1. If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript.

If you have any questions or technical issues, please contact the journal's editorial office at RAJS-peerreview@journals.tandf.co.uk.
Yours sincerely

Angathevar Baskaran
Editor in Chief
African Journal of Science, Technology, Innovation and Development

Comments from the Editors and Reviewers:

Suitability or appropriateness for publication in AJSTID
Reviewer 1: This paper is suitable for the journal. It addresses a problem that may be of interest to the large audience of AJSTID. However, it is not appropriate for publication in its current form. I suggest a minor revision.

A concise, coherent and clear Abstract
Reviewer 1: The Abstract is concise, coherent and clear. However, there still remains a potential mismatch in describing one of the methodologies of the paper.

A clear explication of the research questions/ hypotheses
Reviewer 1: The research questions/hypotheses are clear.

Sound review of the relevant literatures
Reviewer 1: The literature is quite extensive. I recommend that authors include a review of studies on factors responsible for slow adoption of ICT in African Countries.

Based on sound and robust data
Reviewer 1: The data description is not adequate. Hence, I am not able to adjudge the soundness and robustness of the data. Authors have presented sources of the data, period covered and variables accessed. Because different variables were sourced from different sources, I am not aware if their levels matched. For example, it is not clear whether data sourced from various outlets are hourly, daily, weekly, monthly or yearly, and whether they are consistent across board. You may think of one possibility, for instance, data from the World bank platform may be yearly and data from other sources may be monthly. In general, the size of the data is not expressly revealed.

I have raised this concern in the last round of review. I suspect these might not have been passed to authors. This time around, I have included this concern in my comments to the authors.

A rigorous conceptual/analytical framework
Reviewer 1: Conceptual frameworks are clearly described and justified.

An incisive analysis/ discussion of results
Reviewer 1: Results are mostly reported, but discussions remain scarce around potential drivers of insight/conclusion drawn from results.

Effective use and assessment of the findings for theory and policy
Reviewer 1: It is not clearly stated.

Good structure and presentation (Overall organization, Tables, Charts/ Figures well integrated in the discussion and the English language)
Reviewer 1: The organization of the paper needs some improvement. Readers cannot differentiate between Sections and Subsections. Moreover, Section titles should be in bold letters and the paper should include section number.

PLEASE ADDRESS THE FOLLOWING COMMENTS

Reviewer #1: The authors have tried on improving this paper. However, there still remains certain concerns that they failed to address. Please see below:

Abstract: The Augmented Dickey-Fuller method, mentioned in the Abstract, is only used to test for properties of the time series data. It is not best to emphasize such method in the Abstract as this is not the main approach underlining the main results of this paper. You may

want to withdraw that sentence from your Abstract or rephrase by making reference to the appropriate approach, upon which the major result is based.

The organization of the paper needs some improvement. Readers cannot differentiate between Sections and Subsections. Moreover, Section titles should be in bold letters and the paper should include section number.

Page 3, paragraph 1: "In most countries, the adoption and integration of ICTs have been slow." The adoption and integration of ICTs may be slow due to many reasons. Authors should review studies on factors responsible for slow adoption. Ensure to find the ranking of these factors to justify the underlined claim: "This is largely due to the limited evidence showing how digital innovations are transforming economies, reducing poverty and improving overall wellbeing."

Page 4, paragraph 1: "For instance, major factors such the expansion of the labour market...." You miss "such as"

The sentence "where Y ...." that follows Equation 1 should be moved to a new line. In "The coefficient represents...." I don't understand "a coefficient" as far as the equation is concern. It is not clear. I raised these concerns in the first round of review.

Using "............1" is not a standard way of formatting equations. Please adopt the standard practice.

Page 8: "α0" i.e., alpha0 looks very unprofessional. Make the 0 a subscript instead or otherwise the current form simply means α multiply 0.

Equation 4: the first t right after the equality sign means what?

Page 10: "CV is >/= 1,..." writing greater than or equal to as ">/=" is not acceptable. Please learn how to format mathematical symbols in Microsoft word.

Page 11, Paragraph 1: How significant is R-squared value of 0.02975. To the best of my understanding, the value suggests that your model explains only 2.9% variations. That seems to be a poor result and if you must retain that result, you need to justify why the R-squared value is very low.

In the last round of review, I recommended that the discussion of results be improved. The authors did not make any attempt in this regard. I would say your results are mostly reported, but discussions remain scarce around potential drivers of insight/conclusion drawn from results.

The data description is not adequate. Authors have presented sources of the data, period covered and variables accessed. Because different variables were sourced from different sources, I am not aware if their levels matched. For example, it is not clear whether data sourced from various outlets are hourly, daily, weekly, monthly or yearly, and whether they

are consistent across board. You may think of one possibility, for instance, data from the World bank platform may be yearly and data from other sources may be monthly. In general, the size of the data is not expressly revealed.

What is the use of your findings for theory and policy making? It is not clear how Public Policy-makers can use your findings to improve on governance.

I have recommended a major revision in the last round of review. However, the authors' attempt at addressing my concerns still falls short of meeting my expectation. I like to invite them to revise one more time, ensuring due diligence in addressing those concerns raised above.

APPENDIX F: Supporting documents for Article Five

Boakye, A. Estimating agriculture technologies' impact on maize yield in rural South Africa. *SN Bus Econ* **3**, 149 (2023). https://doi.org/10.1007/s43546-023-00530-4

Appendix F1: Confirmation email on article accepted for publication

Date:	13 Jul 2023
To:	"Alex Boakye" alexboakye00@gmail.com
From:	"SN Business & Economics (SNBE)" roopika.dhayanithy@springer.com
Subject:	Your Submission SNBE-D-22-01038R3

Dear Mr Boakye,

We are pleased to inform you that your manuscript, "Estimating agriculture technologies' impact on maize yield in rural South Africa", has been accepted for publication in SN Business & Economics .

You will receive an e-mail in due course regarding the production process.

Please remember to quote the manuscript number, SNBE-D-22-01038R3, whenever inquiring about your manuscript.

With kind regards,
Cintia Hua
Managing Editor
SN Business & Economics

Comments to the author (if any):
We are happy to confirm that your paper has been accepted for publication. You will receive a proof for approval in the coming weeks. Please approve your proof speedily to ensure there are no delays to your paper being published. Assuming no delays, we would expect your paper to be published in approximately 4-5 weeks.

****

Please note that this journal is a Transformative Journal (TJ). Authors may publish their research with us through the traditional subscription access route or make their paper immediately open access through payment of an article-processing charge (APC). Authors will not be required to make a final decision about access to their article until it has been accepted.

Authors may need to take specific actions to achieve compliance with funder and institutional open access mandates. If your research is supported by a funder that requires immediate open access (e.g. according to Plan S principles) then you should select the gold OA route, and we will direct you to the compliant route where possible. For authors selecting the subscription publication route our standard licensing terms will need to be accepted, including our self-archiving policies. Those standard licensing terms will supersede any other terms that the author or any third party may assert apply to any version of the manuscript.

Find out more about compliance: https://www.springernature.com/gp/open-research/funding/policy-compliance-faqs

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_____

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/snbe/login.asp?a=r). Please contact the publication office if you have any questions.

Appendix F2: Feedback from first review

Date:	09 Jan 2023
To:	"Alex Boakye" alexboakye00@gmail.com
From:	"SN Business & Economics (SNBE)" roopika.dhayanithy@springer.com
Subject:	Major Revisions requested SNBE-D-22-01038

Attachment(s): Revision_Due.ics

Dear Mr Boakye,

I am writing to inform you that we have received the reports from our advisors on your

manuscript, 'Estimating the impact of digital technology on maize yields for poverty reduction and inclusive growth in rural South Africa', which you submitted to SN Business & Economics .

The review process was overseen by an associate editor and independent reviewers.

The editor has requested 'major revisions', the full details of which are outlined at the bottom of this letter. You are also kindly requested also to check the website for possible reviewer attachment(s), if applicable.

We invite you to evaluate the comments carefully and if you feel you can address the issues identified, we would welcome a revision. A revision would be sent out again for review, but I cannot guarantee it will be accepted for publication.

A judgement on suitability for publication would be based on whether the editor and reviewers conclude their initial comments have been addressed satisfactorily, and to what degree they feel your paper meets the journal's criteria for acceptance.

If you would like to revise your paper, we suggest a resubmission deadline of 28 Feb 2023, although you would, of course, be welcome to resubmit sooner. If you require longer, however, please let us know so we can update your manuscript record on our submission system.

When submitting your revised manuscript online, please include the following:

- A rebuttal letter with a point-by-point response to each of the editor's and reviewers' comments and a clear description of any changes made in the revised paper. If you have not made changes in response to any of the feedback, please provide full reasoning.
- A marked-up version of the revised manuscript with the changes highlighted in colour. Please do not include track changes or comment boxes.

Please upload your files here:

https://www.editorialmanager.com/snbe/

Your username is: ********

If you forgot your password, you can click the 'Send Login Details' link on the EM Login page.

We look forward to receiving your revised manuscript by 28 Feb 2023.

In order to add the due date to your electronic calendar, please open the attached file.

With kind regards,

Neda Ghatrouei

Assistant Editor

SN Business & Economics

Comments to the author (if any):
Reviewer #1: The paper deals with an interesting issue in the current context to digital technology's contribution to agricultural productivity in general and maize yields in particular.
I suggest minor revisions along the following lines: (i) The discussion needs to be put first in the general context of macroeconomics of technical change and Solow or Romer growth model--at least for a theoretical framework; (ii) Some stylized facts or descriptive statistics need to be provided in Section 2 and general applicability in other countries in a nutshell;, as the current one is inadequate (iii) one of the important mode of farmers' communication -- as mentioned-- is IVR, SMS for controlling adversities such as lack of inputs and financial debacle or collateral damage; (iv).page 7 --the equation is not clear and how SFA analysis comes into picture is not analyzed or motivated technically. Table 2 should go in front rather than in the results section. A table listing Explanatory variables and sources of data would add more value and that should be added. Moreover, Educational variable or absorption of technology is a primary determinant. That's not considered.; (v) Section plans and numbering and writing styles need to be improved via checking English grammar, styles and presentations.

Thank you.

Reviewer #2: 1. In the Introduction section, please clarify the justification for this research. The problem statement is not well organized and not clear to the reader. Please revise the entire introduction part and make it clear based on your applied methods and research keywords. You are also requested to add the overall and specific objectives of your research at the end of the introduction part. I think the research gap is not properly highlighted in the background of your research. You have mentioned a significant number of previous studies, but how does your study differ from them? Please revise this part if possible. Please identify the apparent research gaps by going through the existing research and your value addition (novelty) to the existing research.
2. Please revise the title of your study. I did not find anything related to poverty reduction or rural South Africa.
3. In the Materials and Methods section, I would recommend revising your methodology based on your research objectives. You clarified your research methods nicely, but it would be easy to understand if you redesigned this section sequentially (objective-wise). You are also requested to add a research framework (flow of your research with applied methods) to understand the overall research flow at a glance.
4. Please add limitation of your research.
5. Please revise the following sections: (i) Overview of crop production in South Africa (ii) The potentials of modern technologies in crop production (iii) What does literature reveals

about technology adoption and increase in crop yield? and (iv) Estimating the contribution of technological progress in crop yield. It is too elaborate and detailed. It should be more concise and well connected with the present study. I will recommend making it a single section with some graphical representation.

General notes from editor:

*CLARITY OF LANGUAGE

We consider that the clarity of the English in your paper needs to be improved to enhance readability. We ask you to arrange a thorough proofread/edit to enhance the clarity of the language. These resources may be useful:

● Exploring this collection of free resources offering advice on writing in English (https://www.springernature.com/gp/researchers/campaigns/english-language-forauthors);
● Asking a colleague to review your manuscript for clarity;
● Using a professional language editing service where editors will improve the English to ensure that your meaning is clear and identify problems that require your review. Two such services are provided by our affiliates Nature Research Editing Service (http://www.authorservices.springernature.com/) and American Journal Experts (http://www.aje.com/). Springer Nature authors receive 10% off their first submission to either service.
Please note that the use of a language editing service is neither a requirement for publication in this journal, nor does it imply or guarantee that the article will be selected for peer review or accepted.

* CRITERIA FOR PUBLICATION

All papers submitted to the journal are assessed against a set criteria for publication. Papers that fall short in meeting these will not be considered for publication. We strongly recommend giving consideration to these criteria, listed below, before resubmitting. These points should be clear to any reader of your paper. Where needed, please modify your paper to ensure that these features are evident and well developed.

● Pose a clear and valid research question;
● Be academically sound in methodology and analysis;
● Provide appropriate evidence or reasoning for the conclusions;
● Make a contribution to the literature—irrespective to magnitude;
● Be presented in an intelligible fashion and in standard English.

* ARTICLE TITLE

Titles should be descriptive of the main findings, giving the reader a clear sense of the paper's content, and should not exceed 150 characters (including spaces). We discourage

the use of active verbs; punctuation is not allowed.

We invite you to consider rewording your title to enhance its clarity and impact.

* ABSTRACT

The article's abstract plays an important role in clearly conveying the parameters and key features of a study. We feel your abstract could be strengthened. Please take this opportunity to proofread your abstract to ensure it is clear, well-structured and contains appropriate levels of detail.

Abstracts can take different forms and we are happy for authors to adopt a structure that best conveys the essence of the paper in question.

That said, a suggested generic formula is as follows:
* Background context (e.g. for the general reader);
* Specific knowledge gap the work aims to fill and/or the research question explored;
* Methods/approach used in the study;
* Key findings, conclusions or observations (where possible findings should be given in context or, if applicable, quantified);
* Implications or applications of the work.

A general reader should have a clear impression from the abstract of the novelty and significance of the work, and how it builds on existing scholarship.

Please do not include any subheadings - all abstracts must be one paragraph of text only.

Abstracts should not exceed 200 words.

___

Please note that if we feel the above issues have not been satisfactorily addressed on resubmission we may decide that your paper is not
suitable for peer review.

_____

REVISING YOUR PAPER

When revising your paper do keep in mind how your work fully meets all the below criteria for publication. Please make revisions as appropriate to ensure all of these are fully satisfied and apparent to the general reader.

To be publishable in this journal a paper must do the following:

1. Pose a clear and valid research question;
2. Be academically sound in methodology and analysis;
3. Provide appropriate evidence or reasoning for the conclusions;
4. Make a contribution to the literature—irrespective to magnitude (we do not consider abstracts and internet preprints to compromise this);
5. Be presented in an intelligible fashion and in standard English.
Key sections:

Please ensure all the following sections are included in the final paper, as appropriate (the sections marked * are mandatory for all papers; if a section is not relevant, please do not include it):

Funding (information that explains whether and by whom the research was supported).
*Conflicts of interest/Competing interests (include appropriate disclosures)
*Availability of data and material (data transparency)
Code availability (software application or custom code)
Authors' contributions (optional: please review the submission guidelines from the journal whether statements are mandatory).
Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full. Please do not include any mention of referees or editors.
Ethics/informed consent: For research involving human participants, authors MUST identify: (a) the committee that approved the research, (b) confirm that all research was performed in accordance with relevant guidelines/regulations, and (c) include at the end of their manuscript statements (named 'Ethical statement' and 'Informed consent') confirming that informed consent was obtained from all participants and/or their legal guardians.

Rebuttal letter

When submitting your revision, please include a rebuttal letter in which you clearly outline point-by-point how you have addressed all of the feedback given by the editor and referee(s).

If you have not made changes in response to any feedback or you disagree with it, you should still provide a comment explaining your reasoning.

Writing a rebuttal letter
The response to the reviewers' comments is one of the most important parts of your revised manuscript submission. This is where you should describe the work you have done in revision, and clear up any points of misunderstanding from the first round of review. Writing an effective response helps the reviewers and the Editor assess your revised manuscript, and it is important to make the most of this opportunity to showcase how your paper has improved and developed.

If the rebuttal letter is not clearly structured or information is lacking it will be returned to

you for amendment.

Letter structure

● We request you use a point-by-point response format. That is, you provide a specific response to each point made by each reviewer. This allows the reviewer and the Editor to easily see how you have addressed each issue that was raised;
● While point-by-point detail is critical, it is also important to provide a concise overview of the most important revisions made. This should be provided as an introduction to the more detailed response, with the purpose of telling the reviewer and Editor what you focused on when revising the manuscript.
● Tips and suggestions
● Mark all revisions in your paper in colour or bold text. If you use multiple colours for different referees, make clear in the letter to which referees each colour refers.
● In your overview, be sure to address any points that were specifically flagged by the Editor in the decision letter;
● When writing your point-by-point response, include all of the reviewers' comments as they provided them. After each reviewer comment, provide your response before moving onto the next;
● Make sure to respond to all points. If you were unable to address a particular point, provide a clear and well-reasoned rationale for why;
● You may not agree with all of the reviewers' points, and it is fine to provide your perspective on the issues raised provided you keep the tone of your response professional and constructive and your arguments grounded in academic reasoning;
● While specificity is important, so is brevity in presentation. Please keep your responses concise and to the point;
● Rather than including figures or replicating blocks of text from the manuscript in your response, point to the specific place in the revised manuscript that contains the relevant information.

****
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Appendix F3: Feedback from second review

Date:	23 Jun 2023
To:	"Alex Boakye" alexboakye00@gmail.com
From:	"SN Business & Economics (SNBE)" roopika.dhayanithy@springer.com
Subject:	SNBE-D-22-01038R2 - accepted but needs final editing
Attachment(s):	Revision_Due.ics

Dear Mr Boakye,

We have now completed an assessment of your paper, Estimating agriculture technologies' impact on maize yield in rural South Africa, which was submitted for publication in SN Business & Economics .

I am delighted to inform you that we would be happy, in principle, to publish your paper in the journal, subject to some final minor amendments.

We therefore invite you to revise your paper one last time to address any remaining issues. At the same time we ask that you ensure your paper meets all our formatting requirements. A list of all requests is at the foot of this message.

If the editor and/or reviewers have requested changes to the text (beyond minor language, formatting or style issues), please provide a rebuttal letter detailing point-by-point any changes made. If you have not made changes in response to any of the feedback, please provide full reasoning.

While re-submitting, please check the filled in author data carefully and update them if applicable; they need to be complete and correct in order for the revision to be processed further.

In order to submit your corrected manuscript, please access the following website:

https://www.editorialmanager.com/snbe/

We look forward to receiving the final version of your manuscript on or by: 07 Jul 2023.

In order to add the due date to your electronic calendar, please open the attached file.

With kind regards,

Cintia Hua

Managing Editor

SN Business & Economics

Comments to the author (if any):
Thank you for submitting your paper. I am happy to confirm that we consider your paper to be almost ready for acceptance for publication, subject to some final issues being resolved as outlined below. In particular, you need to change the data Availability Statement. Please find guidance below.

Before resubmitting, please can you ensure that all the below issues have been fully addressed (where appropriate). If any points are not resolved we will likely have to send your paper back to you.

Please check our submission guidelines carefully to ensure your paper meets all requirements (https://www.springer.com/journal/43546/submission-guidelines#Instructions%20for%20Authors_Title%20page)

Key points include:

FILE FORMATS: Ensure your submitted files are in an accepted file type: Article files: doc; docx; TeX. Figure files: psd; ai; eps; tiff; jpg; pdf (preferably vector enabled); png; ps; gif; ppt; pptx; bmp; vsd; cdx; svg; emf. We can accept figures which have been compressed into one of these formats where the contents of the folder are one of the other accepted file types listed: zip; 7zip; rar

TITLE PAGE: Ensure the first page of the paper contains all necessary information as outlined here: https://www.springer.com/journal/43546/submission-

guidelines#Instructions%20for%20Authors_Title%20page. Note that only those who fulfil our authorship criteria can be listed as authors (https://www.springer.com/journal/43546/submission-guidelines#Instructions%20for%20Authors_Authorship%20principles).

ARTICLE TITLE: Ensure the article title is clear and concise to maximise its impact and clarity. Titles should be descriptive of the main findings, giving the reader a clear sense of the paper's content, and should not exceed 150 characters (including spaces). We discourage the use of active verbs or redundant wordings such as 'Research on…', 'Review of…', 'Study of…'. Colons (:) or hyphens (-) may be included only if absolutely necessary – but separate subheadings are not permitted.

LANGUAGE: We ask you thoroughly check your manuscript text for spelling, grammar and clarity of expression. The journal's typesetting process does NOT involve copy-editing. As such, major issues should be attended to in this final round of revisions. If language issues are identified on resubmission we will return the paper to you so that they can be resolved.

If you need help with writing in English you should consider:
Exploring this collection of free resources offering advice on writing in English (https://www.springernature.com/gp/researchers/campaigns/english-language-forauthors);
Asking a colleague who is a native English speaker to review your manuscript for clarity;
Using a professional language editing service where editors will improve the English to ensure that your meaning is clear and identify problems that require your review. Two such services are provided by our affiliates Nature Research Editing Service (https://authorservices.springernature.com/) and American Journal Experts (https://www.aje.com/). Springer Nature authors receive 10% off their first submission to either service.
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* ABSTRACT: Take this opportunity to carefully proofread your abstract to ensure it is clear, well-structured, and contains appropriate levels of detail. Abstracts can take different forms and we are happy for authors to adopt a structure that best conveys the essence of the paper in question.

However, a suggested generic formula is as follows:

* Background context (e.g. for the general reader);
* Specific knowledge gap the work aims to fill and/or the research question explored;
* Methods/approach used in the study;
* Key findings, conclusions or observations (where possible findings should be given in context or, if applicable, quantified);
* Implications or applications of the work.
* Four to six keywords that can be used for indexing purposes.

A general reader should have a clear impression from the abstract of the novelty and

significance of the work, and how it builds on existing scholarship.

Abstracts should not exceed 250 words.

To conform to journal style, please avoid the inclusion of subheadings or reference citations.

DECLARATIONS: All manuscripts must contain the following sections under the heading 'Declarations'. If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section.

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Availability of data and material (data transparency) (see here: https://www.springer.com/journal/43546/submission-guidelines#Instructions%20for%20Authors_Research%20Data%20Policy).

Code availability (software application or custom code).
Authors' contributions (optional: please review the submission guidelines from the journal whether statements are mandatory).
Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full. Please do not include any mention of referees or editors.

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If references are missing from the bibliography or citations from the main text, then this will cause problems at the production/typesetting stage, resulting in your paper being returned to you, and delaying publication.

FIGURES AND TABLES: Ensure that all guidelines are followed for figures and tables (https://www.springer.com/journal/43546/submission-guidelines#Instructions%20for%20Authors_Tables and https://www.springer.com/journal/43546/submission-guidelines#Instructions%20for%20Authors_Artwork%20and%20Illustrations%20Guidelines).
Any images that are copyrighted must include in the figure legends relevant reuse

permissions.

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APPENDIX G: Ethical clearance form

UNIVERSITY OF THE WESTERN CAPE

ETHICAL CLEARANCE APPLICATION FORM
HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE
2019 FORM

PLEASE NOTE THAT THE FORM MUST BE COMPLETED IN TYPED SCRIPT. HANDWRITTEN APPLICATIONS WILL NOT BE CONSIDERED.

SECTION 1: PERSONAL DETAILS

1.1	Surname of Applicant:	Boakye
1.2	First names of applicant:	Alex
1.3	Title of Applicant: (Ms/ Mr/ Mrs/ Dr/ Professor etc)	Mr
1.5	Student Number: (where applicable)	3699295
1.6	Staff Number: (where applicable)	_____
1.7	Faculty:	EMS
1.8	Department / Unit /School / Institute:	ISD
1.9	Existing Qualifications:	Master's in Development Management
1.10	Proposed Qualification for Project (In the case of research for degree purposes)	: PhD

2. Contact Details

Tel. No.:	+27 749 419848
Cell. No:	+22586924686
E-mail:	3699295@myuwc.ac.za
Postal address	*Institute for Social Development,*

University of the Western Cape,
Robert Sobukwe Road 7535

(in the case of Student):

3. SUPERVISOR/ PROJECT LEADER DETAILS

NAME	TELEPHONE NO.	EMAIL	**Department / Unit /School / Institute**	QUALIFICATIONS
3.1 Mulugeta F.Dinbabo	+27 21 959 3855	mdinbabo@uwc.ac.za	ISD	PhD
3.2 Osden Jokonya	021 959 1610	ojokonya@uwc.ac.za	Department of Information Systems	PhD

SECTION 2: PROJECT DESCRIPTION

Please do *not* provide your full research proposal here: what is required is a short project description of not more than two pages that gives, under the following headings, a brief overview spelling out the background to the study, the key questions to be addressed, the participants (or subjects) and research site, including a full description of the sample, and the research approach/ methods

1. **Project title:** What does the digital revolution mean for poverty alleviation and inclusive growth in Africa? A case study of Ghana and South Africa**.**
2.
3. **Location of the study** (where will the study be conducted)

   Cape Town, South Africa

2.3 Objectives of and need for the study
(Set out the major objectives and the theoretical approach of the research, indicating briefly, why you believe the study is needed.)

Goal: The goal of this study is to review key trends of technology adoption and jobs creation in Africa as well as to develop an inclusive digital readiness framework for promoting inclusive economic growth, employment and development in Sub-Saharan Africa.

Objectives

1. To explore the dynamics of technological change in Africa

2. To describe the new emerging technologies and the windows of opportunities it presents

3. To explore the different strategies that Africa can use the emerging technologies to address its fundamental problems of poverty and food insecurity

4. To identify the common factors behind successful adaptation of digital technologies across all sectors.

5. To uncover the barriers that need to be overcome to facilitate inclusive digital transformation in the country.

2.4 Questions to be answered in the research

(Set out the critical questions which you intend to answer by undertaking this research.)

1. What are the determinants behind successful adaptation of digital technologies?
2. What are the barriers that hinder inclusive digital transformation?
3. What is the relationship between digitization and economic growth, employment and development?

Significance of the study

The world is undergoing a disruptive change characterized by advances in digital technologies that is set to impact on everything, including business dynamism, societal cohesion and the future of work. A significant transformation of global and regional labour market is forecast over the next decades (world economic forum, 2018). On the one hand, governments around the world are taking proactive measures by developing policies that aims to capture the technological potential for sustainable growth while mitigating against job displacement. On the other hand, organizations across all industries are adopting new technologies in their business operations to increase their competiveness in the global economy (Liao, 2017; Saturno, 2017). Yet many institutions and stats in sub-Saharan Africa are far behind from making optimal use of the recent emerging technologies and are ill-prepared for the impending disruption to jobs and skills brought about by the technological advances. In particular, there seems to be lack of understanding on how today's emerging technologies will transform societies, businesses and governance. A primary reason for this lack of in-depth understanding is the limited data available for reference (UNCTAD, 2018). Consequently, the extent to which Africa is prepared to participate in future global economy is low. Building on this context, this study will explore the various ways in which sub-Saharan Africa can capitalize on the growth of new technologies to address some of its fundamental problems such as poverty, migration and food insecurity. The goal of achieving food security through increasing agriculture productivity in Africa is of particular interest to the researcher since many African economies are largely dependent on Agriculture activities. Interestingly, agriculture is moving into a new phase of technology characterized by big data applications and the Internet of things which promises to trigger huge productivity gains (Lohr, 2015). The new phase includes cheap sensors and drones monitoring plants, livestock, water supplies, and weather, to provide detailed, real-time information. These precision farming technologies are highly relevant for Africa's agriculture sector (Dlodlo & Kalezhi 2015). In

addition advance Internet of things applications that based on sophisticated data analytics are being employed to address some of the challenges that farmers face (Lohr, 2015; World Bank, 2018). Yet the framework for adopting the Internet of things application to Africa's agriculture sector has not been widely explored. The steps to adoption of the Internet of things in African agriculture merit deeper analysis, given its potential impact. Finally, much of the literature on the application of digital technologies were drafted in the early 2000s when the level of ICTs was much lower and there were few visible success stories. This suggest that the most information available are outdated (World Bank, 2018). There is therefore a need for more timely research on the usefulness of digital technologies in the region.

2.5 Research approach/methods

This section should explain how you will go about answering the critical questions which you have identified under 2.4 above. Set out the approach within which you will work, who your research subjects will be, how they will be chosen and located and what you will expect them to do.

Research design

A research design is a plan, structure and strategy of investigation in order to obtain answers to research questions (Babbie & Mouton, 2001; Craig, 2009). According to Kumar (2011), a research design must ensure that the procedures undertaken obtain valid, objective and accurate information about the research topic. Although there are several ways of classifying research designs, Kumar (2011) notes that they fall into three general categories, namely experimental, quasi-experimental and nonexperimental. In this study, a nonexperimental research design which involved the use of secondary data will be adopted. There are essentially two reasons why this approach is favoured. The first reason is for the purpose of cost and time efficiency. Second, for feasibility, as it will not be possible to either randomly select respondents or manipulate the variables (technological progress/economic growth) employed in this study.

Research methodology and data source

This study shall adopt a mixed methods approach of scientific investigation. The quantitative part of this research will focus on analysing annual data from two data sources-- World Bank

databank and the United Nations Development Programme. The databank of the World Bank in particular constitutes a data source for both the dependent and independent variables (GDP and technical progress) of this study. It consists of time-series data on variety of topics in five-year intervals from 1960 to 1975 as well as annually since 1976 (available online). The databank which is an online visualization and interactive tool contains more than 200 growth statistics on 192 countries. Also included are statistics on internet access which comprise fixed and mobile broadband data, ICT investments and so forth. Additionally, it provides demographic and macroeconomic data for more than 180 countries. Concurrently, this interactive online database affords researchers the opportunity to create dynamic customized reports based on their selection of countries, indicators and years.

The UNDP annual report equally constitute relevant data source to aid this investigation. Specifically, it publishes report on nation's Human Development Index (HDI) which represent one of the primary dependent variables of this study. The Human Development Index is particularly considered to be a comprehensive measure of development than the traditional measures such as Gross National Product (GNP) and Gross Domestic Product (GDP). In contrast to these conventional measures of development, the HDI place emphasis on people, and seeks to incorporate their capabilities in gauging the development construct. The HDI summarizes mean outcomes in key development dimensions which include but not limited to health, knowledge, and living standards. For the purpose of this study, the researcher will analyse data collected over the period of 10years from 2008-2018 for Ghana and South Africa.

Quantitative analysis process

First, there will be a mapping of changes that has occurred within Africa's growth programs. In doing so, particular emphasis will be placed on comparing programs that integrate new technologies in African countries with that of developed countries. Then after, spatial regression models will be used to estimate the effect of technology diffusion on growth. The data for the study will be analyze using social science analysis (SPSS) (IBM SPSS Statistics Version 20).

Model Specification

Methodologically, the scope of this study falls under the cluster of studies dedicated to exploring factors that drive economic growth in developing countries. Studies of this genre

typically borrow from the neoclassical framework of Solow (1956) and Schumpeter (1992). Central to this conceptual framework is an aggregate production function which is derived from the Cobb and Douglas (1928) production function. Following in the footsteps of previous researchers (Njoh, 2018), the researcher will employ the following model in the present study:

$Y_{it=}f(A_tK_t^aL_t^{1-a})$…… 1 where A = total factor productivity, L= labor, K= capital

This growth production function is extended by assuming that the total factor productivity is influenced by technological progress which in turn is driven by investments (I), local infrastructure (LI), technology availability (TA). Hence *A* is transformed into:

$A_t = I_{it} + LI_{it} + TA_{it}$ ……..2

The specification of this model is based on two main motivation. First, within empirical literature, this model is among the commonly used measures of technology diffusion in relation to GDP. Secondly, the model takes into consideration human capital and labour productivity which are key elements for economic growth.

Empirical estimation

Test for stationarity

A unit root test on each variable in the models outlined in the previous sections will be performed using the Augmented Dickey- Fuller (ADF) test. ADF test is applied on each time series. Despite the preferences for other tests, such as the Dickey Fuller (DF) test and Philips-Perron (PP) test for testing the presence or otherwise of a unit root among other researchers, in this study the ADF will be applied because of its superiority when it comes to time series with autoregressive structure, as well as its reliability for ensuring white noise residuals (Ali et al., 2011). The process will involve first fitting the data to linear multivariate time series model and then examining the eigenvalues from that specification. The motivation is to test whether if a long-run relationship among variables that are non-stationary can be established. Therefore, once the unit roots are confirmed for the time series data, the next step will be to establish the existence of a long-run equilibrium relationship among variables. In so doing, it

will be assumed that the null hypothesis of the series test will contain unit root (non-stationarity) whiles the alternative hypothesis will have no unit root (stationarity). When the results obtained provide strong evidence that all the time series in levels are non-stationary, then the implication will be that they are integrated at an order of 0, i.e. *I* (0) at 5% significance level. This means the null hypothesis cannot be rejected for any of the variables under scrutiny. On the one hand, when the variables are found to be non-stationary in levels, their first difference will be considered. On the other hand, if the test rejects the null hypothesis at the first difference of the variables, it implies that they are integrated at an order of 1, i.e. *I* (1) at 5% significance level, which will imply that they are stationary.

Test for cointegration

After testing for unit roots, the next step is to test for co integration. The conintegration analysis will examine the existence of any possible long-run relationship among the dependent and independent variables. In doing so this study will capitalize on Johansen and Juselius's (1990) approach of co integration. There are few reasons why Johansen's co integration procedure is considered. First it is useful where the series are non-stationary. Second, it is an invariant test, which permits the existence of cointegration between the system variables without imposing bias on the estimates. Third, it can identify whether more than one cointegrating vector really exists.

Qualitative analysis process

The qualitative aspect of this research will employ content analysis. According to *Bryman (2011),* content analysis is a research technique for studying textual documents in a replicable and systematic manner with the aim of examining patterns in data. This technique is valuable in social science research because it offers opportunity to researchers to recover and examine the nuances of behaviors, perceptions, and trends. At the same time, it represents an important tool for bridging the gap between exclusive quantitative and qualitative research methods (Bryman, 2011). Content analysis equally allows researchers to analyze socio-cognitive and perceptual constructs that seems challenging when one adopt traditional quantitative methods (Bryman, 2011). In this study, the researcher will examine policy documents, published articles and government reports from both developing and developed countries. Using content analysis in this research is considered appropriate because it allows for the examination of relevant policy documents and other supplementary documents that are related to the research objectives. In addition, the large bodies of text related to this study

required content analysis as specific themes will be created in to standardise the analysis. It will allow the researcher to study the words in the text and to understand better the perspectives of the authors. The content analysis of treaties and policy documents in this research will be both manifest and latent. This means it will consider both the elements that are physically present and also interpreted the underlying structures in the physical data.

2.5.1 Use of Secondary Information/Data

	YES	NO
(a) Does the project involve **only** the use of information already collected by others (secondary data)? .	X	

(b) If you answered yes, to the above, there may be no need to complete the rest of the form. Motivate here why the data to be used means that there is no need for further ethical clearance (e.g. the use of publicly available census data).
This research will focus on analyzing annual data from two data sources-- World Bank databank and the United Nations Development Programme which are available in the public domain.

	YES	NO
(c) Indicate whether the secondary data you are using, was subject to ethical or legal clearance when it was initially collected		X

2.6 Proposed work plan

Set out your intended plan of work for the research, indicating important target dates necessary to meet your proposed deadline.

STEPS	DATES
Proposal submission	February 2020
Writing of literature review and theoretical framework section	March 2020-June 2020
Data retrieving and analysis	July – August 2020
Writing of final chapters	September2020-January 2021
Submission of final thesis for editing	March 2021
Reviewing and submission of thesis for examination	June 2021
Graduation	December 2021

SECTION 3: ETHICAL ISSUES

The UWC Research Ethics Policy applies to all members of staff, graduate and undergraduate students who are involved in research on or off the campuses of University of the Western Cape. In addition, any person not affiliated with UWC who wishes to conduct research with UWC students and / or staff is bound by the same ethics framework. Each member of the University community is responsible for implementing this Policy in relation to scholarly work with which she or he is associated and to avoid any activity, which might be considered to be in violation of this Policy.

All students and members of staff must familiarise themselves with, AND sign an undertaking to comply with, the University's "Code of Conduct for Research".

Provide a brief narrative account of what you see as the key issues concerning your responsibilities as a researcher in this project. If you are dealing with particularly sensitive issues, mention them here and provide details as to how you will cope with them in the relevant section of the form.
Ethical considerations are essential in research. They are norms that determine what is right and what is wrong in terms of the research process, more particularly relating to data collection. The integrity, reliability and validity of the research findings rely heavily on whether or not the researcher chooses to adhere to the ethical principles when conducting research. The research findings must be presented with maximum of accuracy, final results must be unbiased, and neutrality of the researcher must be maintained all along the research process. The researcher needs to ensure that the work s/he produces is honest, suggesting that the findings should be fair and credible, and the data collected should not be plagiarized, fabricated or forged. With regard to the present study, the researcher has taken clear initiatives to ensure that any misconduct, and/or academic dishonesty do not take place.
This study will only be undertaken after approval is granted by the University of the Western Cape Senate, the Economic and Management Sciences Faculty Board and the Institute for Social Development.

QUESTION 3.1

Does your study cover research which crucially involves or focuses on:	**YES**	**NO**
Children		X
Persons who are intellectually or mentally impaired		X
Persons who have experienced traumatic or stressful life circumstances		X
Persons who suffer from a serious chronic ailment		X
Persons highly dependent on medical care		X
Persons in captivity		X

Persons living in particularly vulnerable life circumstances		X

If "Yes", indicate what measures you will take to protect the autonomy of respondents and (where indicated) to prevent social stigmatisation and/or secondary victimisation of respondents. If you are unsure about any of these concepts, please consult your supervisor/ project leader.

QUESTION 3.2

Will the research involve any of the following:	**YES**	**NO**
Access to confidential information without prior consent of participants		X
Participants being required to commit an act which might diminish self-respect or cause them to experience shame, embarrassment, or regret		X
Participants being exposed to questions which are likely to be experienced as stressful or upsetting		X
The use of stimuli, tasks or procedures which may be experienced as stressful, noxious, or unpleasant		X
Any form of deception		X
Any other relevant risks		X

If "Yes", explain and justify. If appropriate, indicate what steps will be taken to minimise any potential stress/harm, and what referral processes will be put into place.

QUESTION 3.3

Will any of the following approaches be used for the research:	**YES**	**NO**
Questionnaire (survey)		X
Structured interview		X
Focus group		X

Open-ended interview		X
Other research method or approach		X

If your research involves questionnaires, surveys, structured interviews, or any quantitative research instrument, attach a copy. If it involves open-ended interviews or focus groups, provide a list of the core questions you aim to discuss with the interviewees.
N/A

QUESTION 3.4

Will the autonomy of participants be protected through the use of an information sheet and a consent form, which specify, in language that respondents will understand:	**YES**	**NO**
The nature and purpose/s of the research	N A	
The identity and institutional association of the researcher and supervisor/project leader and their contact details	N A	
The fact that participation is voluntary	N A	
The fact that participants are free to withdraw from the research at any time without any negative or undesirable consequences to themselves	N A	
That responses will be used only for the purposes of the research	N A	
(In the case of experimental or quantitative research) That anonymity will be ensured where appropriate (e.g. coded/ disguised names of participants/ respondents/ institutions)	N A	
(In the case of qualitative research) That respondents will be granted anonymity should they desire so; or else be identified by coded names (including their institutions and places of residence). (Motivation is to be provided if anonymity is not ensured.)	N A	
That respondents taking part in focus group discussions must undertake to maintain confidentiality with regard to what others say in those discussions	N A	
The possible risks to which participants may be exposed and benefits they may receive as a result of their participation in the research	N A	

A copy of the consent form and information sheet must be appended. If NO to any of the above: (a) please justify/explain, and (b) indicate what measures will be adopted to ensure that the respondents fully understand the nature of the research and the consent that they are giving.

QUESTION 3.5

Specify what efforts have been made or will be made to obtain informed permission for the research from appropriate authorities (including caretakers or legal guardians in the case of minor children)?
This study will only be undertaken after approval is granted by the University of the Western Cape Senate, the Economic and Management Sciences Faculty Board and the Institute for Social Development.

QUESTION 3.6

STORAGE AND DISPOSAL OF RESEARCH MATERIAL (including, for example, survey data and interview transcripts): **Please note that the research material should be kept for a minimum period of at least five years in a secure location by arrangement with your supervisor.** **How will the research data be secured and stored? When and how (if at all) will data be disposed of?**
N/A

QUESTION 3.7

Is this research supported by funding that is likely to inform or impact in any way on the design, outcome and dissemination of the research?	**YES**	**NO** **X**

If yes, this needs to be explained and justified.

QUESTION 3.8

Has any organization/company participating in the research or funding the project, imposed any conditions to the research?	**YES**	**NO** **X**

If yes, please indicate what the conditions are.

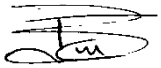
QUESTION 3.9

Do you, or any individual associated with or responsible for the design of the research, have any personal, economic interests (or any other potential conflict of interests) that could reasonably be regarded as relevant to this research project?	**YES**	**NO** **X**

If YES please provide full details:

SECTION 4: FORMALISATION OF THE APPLICATION

APPLICANT:

I have familiarised myself with the University's Code of Conduct for Research and undertake to comply with it. The information supplied above is correct to the best of my knowledge.
NB: PLEASE ENSURE THAT THE ATTACHED CHECK SHEET IS COMPLETED
DATE: 6/02/20. **SIGNATURE OF APPLICANT** 

SUPERVISOR/PROJECT LEADER/DISCIPLINE ACADEMIC LEADER

NB: PLEASE ENSURE THAT THE APPLICANT HAS COMPLETED THE ATTACHED CHECK SHEET AND THAT THE FORM IS FORWARDED TO YOUR FACULTY RESEARCH COMMITTEE FOR FURTHER ATTENTION:
DATE: 6/02/20 **SIGNATURE OF SUPERVISOR / PROJECT LEADER / DISCIPLINE LEADER**    Co-Supervisor: Pro. O. Jokonya  … Date: 6/02/20

RECOMMENDATION OF FACULTY RESEARCH COMMITTEE/HIGHER DEGREES COMMITTEE:
The application is (please tick): Recommended and referred to the Human and Social Sciences Research Ethics Committee for further consideration Not Approved, referred back for revision and resubmission Other: please specify: **NAME OF CHAIRPERSON OF FACULTY RESEARCH COMMITTEE:** **_____** **SIGNATURE: _____** **DATE _____**

RECOMMENDATION OF UNIVERSITY'S HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE:
NAME OF CHAIRPERSON OF FACULTY RESEARCH COMMITTEE: **_____** **SIGNATURE: _____** **DATE _____**

CHECK SHEET FOR APPLICATION

PLEASE TICK

1.	Form has been fully completed and all questions have been answered	X
2.	Questionnaire attached (where applicable)	NA
3.	Information sheet and consent form attached (where applicable)	NA
4.	Approval from relevant authorities obtained (and attached) where research involves the utilisation of space, data and/or facilities at other institutions/organisations	NA
5.	Signature of Supervisor / project leader	X
6.	Application forwarded to Faculty Research Committee for recommendation and transmission to the Research Office	X