THE IMPACT OF BROADBAND INTERNET ON LABOUR PRODUCTIVITY IN AFRICAN COUNTRIES

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PREFACE

This paper is the final work in fulfilment of the requirements for the Master of Science in Business Administration at the University of Stavanger Business School. This thesis explores insights into the transformative potential of broadband connectivity in driving labour productivity growth across countries in Africa. The research is a collaborative effort of over six months, motivated by passion and interest in Internet economics.

The findings of this paper are expected to shed light on the positive outcomes of broadband Internet across various country sectors, and uncover the tangible benefits and transformative power of digital connectivity. By harnessing the potentials which broadband Internet connectivity offers, African countries can unlock new avenues of digital innovation, drive sustainable development and productivity growth.

We wish to express our profound gratitude to everyone who in one way or another, contributed to the success of this research, and in a special way, appreciate our supervisor, Anders Åkerman for his guidance and knowledge sharing. Furthermore, we thank Jonathan Muringani for his contributions in the period of writing, and Tom Broekel for offering statistical support and feedback in our analysis.

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SUMMARY

This study investigates the impact of broadband Internet on labour productivity in Africa, focusing on 34 countries. The research is estimated using a quantitative approach, by utilizing a fixed-effect panel regression model to analyze panel data obtained from the World Bank Indicator, from the period 2005 to 2020. The fixed-effect approach controls for country-specific heterogeneity and time-invariant unobserved factors, to produce more reliable estimates and enhance the robustness of the findings.

The findings show compelling evidence of a positive and significant effect of broadband Internet on labour productivity in African countries. The result suggests a 0.11 percent increase in the logarithm of labour productivity for each percent increase in broadband across the countries. Broadband Internet accessibility enhances workers' access to information and increases knowledge acquisition, improves workers' collaboration and cohesiveness notwithstanding geographical barriers, and stimulates e-commerce opportunities.

The findings of this study emphasize the significance of promoting broadband connectivity as an agent of economic growth, and for continued investment in broadband Internet infrastructure in Africa. Institutions, policymakers and stakeholders should prioritize strategies aimed at expanding broadband accessibility and affordability, to further harness the gains in labour productivity.

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1. INTRODUCTION

"Acquiring technology is still a dream for the majority of Africans who do not live in the capital cities and are not part of the elite."

Jensen, Mike

This statement was made in his paper written in the year 2000, and to date, Africans are hoping for the realisation of that dream. The low adoption of digital technologies and the lack of connectivity in remote and rural areas are disadvantages for the poor and small businesses, and this remains a major challenge (Guermazi et al., 2022). In 2017, only 22% of people in the African continent had access to the Internet, hence the digital economy Initiative for Africa and the African Union aim to make the continent digital by 2030 (*Digital Economy for Africa Initiative*, 2023). The Internet as a "self-organising and complicated system" evolved in the 1960s and was used by a restricted few, experts and scientists (Pastor-Satorras & Vespignani, 2004) and on time sharing Terminal (Campbell-Kelly & Garcia-Swartz, 2013). Due to its enormous advantages today, the Internet links more than 100 million hosts and is expanding at a rate unmatched by any other form of communication. The Internet may be seen as one of the most symbolic successes of consistent investment in fundamental and applied science research (Pastor-Satorras & Vespignani, 2010). The success of the Internet is due to its worldwide broadcasting capability that allows the interaction between individuals without regard for geographic location and distance.

The Internet has been employed in various work institutions such as health, education, financial, and banking among others to achieve their objectives, and the Internet-based interventions have been used by many instructors to achieve their work targets (Amarnath et al., 2023). Likewise, other user applications have helped several institutions to achieve their business objectives effortlessly, especially the banking industry, government agencies (Bertschek & Niebel, 2016), and most recently the work from home during the corona crisis which made it possible for most schools and institutions to work towards achieving their objectives. The Internet has changed workplaces significantly, contributed to improving labour productivity and changed the demand for employee skills and qualifications (Bertschek et al., 2013).

Implementing ICT-related investment policies has become a subject of interest for national, regional, and local governments in developing countries, especially in the context of reducing cost of ICT-related products and raising wages of workers. Similarly, high-speed Internet, a key technological innovation, has been in contest among scholars as a major component of social transformation and economic development (Akerman et al., 2015). The digital era has been the focus of many articles, books, and intellectual contributions. Its impact on development has stimulated considerable attention to the economic and social channels through which ICT would increase incomes, improve productivity, and reduce poverty (Baker et al., 2020). However, most recent broadband-related studies do not distinguish which specific aspect of the Internet technology is most associated with productivity, and the shortfall of adequate data availability on what the Internet is used for, disrupts the ability to establish a discrepancy between the impact of access (Van Dijk, 2017), connectivity, and objective of use termed the digital divide (Hargittai, 2003). Hence, there is a need to utilize the users of the Internet, or the volume of investments on the Internet as variables, to study the impact of the Internet in terms of productivity or economic growth (Baker et al., 2020).

Broadband technology has dispersed unevenly across countries, thereby making it an interest to evaluate economic indicators in areas with greater and lower broadband expansion and usage. Given the fast-growing adoption and the increasing usage of web browsers since the late 1990's, Internet technology has garnered significant attention with respect to their economic implications. Various literature has explored the microeconomic impacts of the Internet on market structure, market behaviour, and firm performance across industries, households, and individuals (Belleflamme, 2001; Goel & Hsieh, 2002; Haucap & Heimeshoff, 2013). On one hand, many argue that Internet market, Internet-based firms' investment (Haucap & Heimeshoff, 2013) broadband access, and investment in broadband infrastructure will increase productivity and economic growth (Abrardi & Cambini, 2019; Baker et al., 2020; Fabling & Grimes, 2021; Kolko, 2012; Najarzadeh et al., 2014; Nurmilaakso, 2009; Whitacre et al., 2014). Some contend that the gains will have a long-run impact on the economy (Abrardi & Cambini, 2019; Howell & Grimes, 2010). On the other hand, some empirical studies suggests that Internet and Internet-based investments do not have any significant impact on productivity and growth (Belleflamme, 2001; Bertschek et al., 2013; Gallardo et al., 2021). Until recently, very little dependable and useful broadband infrastructure data has been available in the study of the benefits of broadband and ICT-based infrastructure, while assessments of programs designed to improve broadband access and adoption are quite insufficient (Whitacre et al., 2014).

In Sub-Saharan Africa, 60 percent of the population has mobile phone coverage and subscription. Mobile phone subscriptions rose by 49 percent annually between 2002 and 2007 as compared to 17 percent per year in Europe (ITU, 2023), which models the macroeconomic theory of catch-up hypothesis holding that developing countries potentially tend to grow faster than the developed countries (Abramovitz, 1986). Additionally, Alzouma, (2008) argues that returns from ICT are not fully optimised in Africa due to illiteracy and poverty. Potential explanations to explain the slow economic growth and productivity of workers in many parts of Africa, Asia, and Latin America in the past few decades are skill-biased technological change (SBTC) and features of international trade (Acemoglu et al., 2005; Hjort & Poulsen, 2019). While many studies focus on the effects of ICT on labour productivity and economic growth in developed countries, to our knowledge, only but a few like Aker & Mbiti, (2010), Hjort & Poulsen, (2019), have made attempts to evaluate the interventions in developing countries. They find positive effects of the fast speed internet on employment rates in Africa.

Based on this, our aim is to address certain questions regarding the Internet advancement and development in developing countries by formulating the research question:

What is the impact of broadband Internet on labour productivity in African countries?

Developing economies lack systematic and reliable labour market and firm-level data, especially in the poor regions where the economic environment is dynamic and unstable (Hjort & Poulsen, 2019). Our objectives are to examine the impact of the broadband Internet on labour productivity in developing countries by additionally finding if the use of the Internet, and adoption of high-speed internet affect labour productivity in African region. Is it worthy to invest in the adoption of high-speed Internet, ICT-based infrastructure, and ICT development in developing countries by policymakers? What kind of technological investment program should be adopted and implemented by developing countries, seeing the effect of such a program in developed countries? Since developing institutions suffer from weak institutional policy and design, would the findings obtained from this study and high-speed internet programs, implemented in developed countries be applicable to them?

Understanding the specific attributes of broadband associated with labour productivity, would be of valuable contribution to a body of existing literature, and it would be of importance in the next wave of policy measures towards broadband development in developing countries. Furthermore, determining the effect of broadband on economic outcomes is expected to guide policymakers in the decision-making process towards future public investments on broadband and ultra-fast broadband infrastructures. In this study, we try to analyse the impact of broadband Internet on labour productivity by using a fixed-effect panel regression analysis on economic panel data for the broadband usage on labour productivity, and control for other factors that contribute to growth such as human capital, demographic and institutional variables. The data was obtained from the World Bank Indicator, to assess the impact in 34 countries of the African region from the period 2005 to 2020.

Our findings show a 0.11 percent increase in log transformed labour productivity for each percent increase in broadband Internet used in selected African countries. However, given that labour productivity could be influenced by other factors having strong exponential power on labour productivity, our results after controlling for the other factors shows a 0.06 percent increase in the logarithm of labour productivity for every one percent increase in broadband Internet used. Robustness of the model was controlled for, and regression model test was also conducted.

In other words, broadband Internet is with numerous advantages that affect growth (Czernich et al., 2011), and many developed countries and businesses have advanced because of fast broadband Internet (Acemoglu et al., 2014; Akerman, 2015; Hjort & Poulsen, 2019). Developing countries are not able to benefit from this because of low Internet infrastructure and non-availability of certain amenities like electricity, required human capital, and inadequate policies favouring the use of the Internet (Niebel, 2018).

In subsequent sections, the theorical framework forms the section 2, section 3 summarises the relevant literature in this study, section 4 introduces the methodology and the regression models, section 5 discusses our data and variables, section 6 presents the results with its interpretation and discussion, and finally we concluded in section 7.

2. THEORETICAL FRAMEWORK

2.1.THE INTERNET

The global internet is described as "a giant oak from a tiny plant". To better understand why information system work as they do, we need to have an insight into how they evolved (Campbell-Kelly & Garcia-Swartz, 2013). Information and Communication Technology (ICT) is a widely used term that provides conceptual understanding to the application of digital resources. ICT enables firms to redesign their business processes and better their products and services (Bertschek et al., 2013) as a general-purpose technology (Bresnahan et al., 2002). There is no universal scholarly definition for ICT as apparently, the sequence of the diverse definitions and applications of ICT is characterised by a variety of contexts. Although the primary definition of Information and Communication Technology (ICT) revolves around devices and facilities that promote the transfer of information through digital means (Zuppo, 2012). Bertschek et al., (2013) defined broadband Internet as Internet access provided at a certain high level of speed. In the United States, the Federal Communications Commission (FCC) to date defines wireline "Broadband" using an upstream/downstream standard of 25/3 Mbps (Ford, 2018). Furthermore, Net Impact Study defines the Internet business solutions as any initiatives that combines the Internet with networking, software, and computing hardware technologies to improve existing business process or create new business opportunities (Varian et al., 2002).

Prior to the internet's take-off in the 1990s, several isolated networks were available in the early 1960s. The catalyst for the integration of these networks into a whole on a global scale was the Transmission Control Protocol (ARPANET). In the 1970s, there was the development of commercial networks, and their emerged desktop personal computers with numerous forms of network provision for online services such as email services, consumer networks, and others. The Internet experience took shape from these activities (Pastor-Satorras & Vespignani, 2004). The Internet, which existed as an "**internet**," in the early 1960s was the interconnection of networks, and till now, the **Internet** is the network of networks operating under TCP. The Internet (World Wide Web) has gone through various stages and until now its success is a result of its global broadcasting capabilities, which enable interactivity among people regardless of their location or distance (Pastor-Satorras & Vespignani, 2004).

There are two main sides to the development of the Internet: the first is the conceptual development, which is the store of global information made accessible to everyone. The second is the technological development, which is the networking of computers, made possible for everyone to access global information. The Internet is a network communication system without a central authority, which is made possible by the intricate interaction of hardware infrastructures, connection architectures, and communication protocols (Pastor-Satorras & Vespignani, 2004). Knowledge, productivity, and experience are overly dependent on open, dynamic, interactive, and complicated Internet access, leading to a new paradigm (the Internet of Things and the Internet of Everything) that has created a data-driven society (Serrano et al., 2022). Based on this premise, we cannot talk about the impact of the Internet without elaborating on the bigger picture of Information and Communications Technology (ICT).

The Internet has evolved over decades and contributed to efficiency in education, social, political, and economic development on a cross-country level. The advent of advanced Internet has revolutionised, notably in the economic aspect (Birba & Diagne, 2012; Serrano et al., 2022), and curbed drawbacks while reducing costs with international trade, finance and various sectors of private businesses and public services (Bojnec & Ferto, 2012). A variety of reports by international institutions have emphasised on how the Internet has positively impacted the economy globally, by promoting GDP growth, improving the standard of living, facilitating business modernization, empowering consumers, and driving the growth of micro-multinationals (Manyika & Roxburgh, 2011). ICT advancement offers the potential to improve firm's productivity and labour performance (Wang et al., 2020). According to the OECD Ministerial Declaration, "WE DECLARE that, to contribute to the development of the Internet Economy, we will stimulate investment and competition in the development of high-capacity information and communication infrastructures, and the delivery of the Internet-enabled services within and across borders." (Enck & Reynolds, 2009).

While many recent studies have attempted to evaluate the significant impact of Broadband and ICT solutions on productivity, growth (Whitacre et al., 2014), and financial performance (Nurmilaakso, 2009), some do not see the impact. The productivity paradox was originally stated by Solow, (1956) who posits that you can see the computer age everywhere but in the productivity statistics (Nurmilaakso, 2009). Although the World Bank has adopted strategies to develop the ICT sector; thereby providing financial and technical support to many developing nations, recommend public-private partnership (PPP), finance the construction of necessary infrastructures, and manage access services wherever public authorities are faced with high budget deficits (Baker et al., 2020), there exist an inequality of the economic and social impact of the Internet on a cross-country level. The Internet as a cost-reducing and efficiency-optimization technology has shown positive effects in various ways, to include improving bilateral and international trade while reducing logistics costs (Freund & Weinhold, 2004; Y. Kim & Orazem, 2017; Wang et al., 2020), lowering inflation rates (Choi & Hoon Yi, 2009; Meijers, 2014; Wang et al., 2020), leading to favourable results, increasing revenue and reducing cost in developed countries (Najarzadeh et al., 2014; Varian et al., 2002). It is required to take into consideration the direct and indirect effect of the Internet network, particularly in the online market. Due to the endless diffusion of high-speed Internet networks, Internet access and Internet-based services are available to more people than ever (Paunov & Rollo, 2016), and have evolved transactions for businesses and final consumers (Haucap & Heimeshoff, 2013). Ultra-fast broadband (UFB) as a General-Purpose Technology (GPT) has the potential to stimulate productivity gains and foster substantial economic growth massively across various key economic sectors (Abrardi & Cambini, 2019). This is attributed to their ability to complement both product and process applications.

Apparently, the precise and distinct quantification of these effects remains unclear within the existing economic literature (Abrardi & Cambini, 2019). High-speed Internet connectivity contributes to improving modern life, entertainment, social life, education services, health-care services, and a host of other services. These uses produce measurable public and private benefits. In other words, broadband and broadband-related technologies reduce cost of sending and receiving data, invariably raising overall output and productivity (Kolko, 2012). The Internet promotes data accessibility and interchange (Pastor-Satorras & Vespignani, 2004), and the network effect suggests that the more people consume the internet, the greater the value derived for an individual (Campbell-Kelly & Garcia-Swartz, 2013).

2.2. OVERVIEW OF THE INTERNET IN AFRICA

The wave of the Internet in the world commenced in the 1960s (Pastor-Satorras & Vespignani, 2010), while Africa saw the light of submarine internet cables in the 2000s (Hjort & Poulsen, 2019). Most African nations' telecommunications infrastructure falls considerably behind that of South Africa, the continent's industrial leader (Oyelaran-Oyeyinka & Adeya, 2004). Telephone cables were the main source of internet transmission decades before a consortium of investors - African governments and multinationals built submarine internet cables from Europe. The larger fibre cables connecting internet traffic across the country virtually formed the backbone of the national telecom in all countries, with commercial telecommunications occasionally adding branches to it. (Hjort & Poulsen, 2019).

African nations relied on X.25 IPSS and 2400 baud modem Unix-to-Unix Copy (UUCP) networks for intercontinental and internet-work computer communications in the 1990s (Oyelaran-Oyeyinka & Adeya, 2004). Before the implementation of complete Internet Protocol (IP) gateways, several Fido nets were also deployed in various nations. Most African nations set up their initial internet Gateways using satellite connections which were provided via satellites and Very Small Aperture Terminal (VSAT) ground stations (internet society). Compared to other technologies, the applications were sluggish and used a low bandwidth to operate, taking up to 16 seconds to request a web page (Oyelaran-Oyeyinka & Adeya, 2004). There were about 560 public Internet Service Providers (ISPs) in Africa in the middle of 2002, covered by Intelsat, the biggest commercial satellite service provider in the world but, North and Central Africa were covered by Thuraya (Oyelaran-Oyeyinka & Adeya, 2004).

Moves were made to increase the network internationally; Twenty-one countries were to be connected in 2008 by the East Africa Submarine Cable System (EASSy). In estimation, African nations have installed more than 1.39 million kilometres of terrestrial fibre lines, 936,000 of which were up and running in 2018. However, fibre-optic networks may not have reached every corner of Africa, especially in the continent's landlocked interior nations.

2.3. LABOUR PRODUCTIVITY

Productivity is an important factor affecting the overall performance and output of the economy for both developed and developing nations. It is noteworthy that firms' innovation activities in turn lead to labour productivity, thereby causing growth and competitiveness (Bertschek et al., 2013), by modifying and redesigning their business processes to enhance products or services. Output is measured by firm's performance, and firm's performance measured in terms of labour productivity and realised product and process innovation (Bartel et al., 2007; Cardona et al., 2013). Although some scholars argue that Electronic Data Interchange (EDI) does not necessarily increase revenue (Mukhopadhyay et al., 1995; Venkatraman & Zaheer, 1990), it can optimise cost thereby, increasing financial performance (Lee et al., 1999; Mukhopadhyay et al., 1995). According to OECD 2003, broadband access is widely considered to be a productivity-enhancing factor (Grimes et al., 2012). In a study by Varian et al., (2002), between the period from 1988 to 2001, it was estimated that the utilisation of the Internet has resulted to a remarkable cost reduction of 163.5 billion USD, and a substantial boost in income of 522.9 billion USD across firms in the United States, United Kingdom, Germany, and France (Nurmilaakso, 2009).

One of the seven hypotheses put forward by Belleflamme, (2001) in explaining the productivity paradox is that you may not see computers everywhere, but in the industrial sector where it is mainly seen, output is poorly measured (Howell & Grimes, 2010). The computer offers a wide range of benefits that the standard economic statistics in its ability should not be constrained to capture. Griliches et al., (1994) contends that the measurement challenge is of twofold: one being that the investment in computers occurs in the service industrial sectors where productivity is prominently hard to measure, while the other being that the nature of the benefits from computers often makes them hard to evaluate (Belleflamme, 2001). Furthermore, he asserts that whether we see computers everywhere, some of the economic inputs are not statistically accounted for. Economists have been counting new innovations on an arithmetic scale in attempt to confirm the productivity paradox, but they ought to be looking at the logarithmic scale, which proposes to turn out every greater number of new things to keep the current rate of new things up to the rates of the past (Belleflamme, 2001).

2.4. GROWTH IN PRODUCTIVITY

Some researchers use proxy technology as Total Factor Productivity (TFP), known as the "residual". Residual is any other factor in the production framework that is not being captured directly in the production process (Jones, 2018). Analysis of TFP and Gross Domestic Product (GDP) per capita in several nations, indicates that a significant amount of the variations in GDP per capita may be attributed to TFP (Greenhalgh & Rogers, 2010). According to the Solow model, a steady exogenous technological progress is the cause of the steady positive long-term rise in GDP per person, mirroring the truth about many developed countries' robust long-term growth (Solow, 1956; Sørensen & Whitta-Jacobsen, 2010). "An easy kind of technological change is that which simply multiplies the production function by an increasing scale factor" (Solow, 1956). Technological progress and the production function yields numerous results as for a given quantity of capital and labour, it can lead to larger quantities of output, lead to better version of a product, creation of new products and variety of products (Blanchard, 2016). Increased knowledge, better, and more sophisticated techniques make employees and the tools they use more productive (Burda & Wyplosz, 2013). One of the driving factors of economic growth in the United States can be attributed to advancement in technology, and the main reason explaining the gap between the United States and Europe in the 1990s (Kretschmer, 2012).

According to a study by Van Ark et al., (2008), labour productivity declined in Europe from 2.4 to 1.5 compared to the US in the 2000s, due to little emergence of the knowledge economy, caused by some factors such as lower growth from the investment in ICT, and a small share of technology producing firms in Europe, hence the Internet can be seen as part of technological progress that is sustaining growth.

3. RELEVANT LITERATURE

3.1. REVIEW OF LITERATURE

Productivity is the ultimate engine of growth in today's global economies according to OECD (2015). It may be induced by efficient business processes, the use of new digital technologies, and the facilitation of innovation enabled by Ultra-fast Broadband (UFB) networks (Abrardi & Cambini, 2019). There is a growing impact of mobile Internet on labour productivity growth, and economic growth. Other forms of Information and Communication Technologies, such as mobile phones, Internet use, and broadband adoption, are the main drivers of economic growth in developing countries over the recent period from 2007–2016 (Bahrini & Qaffas, 2019). In the past two decades, scholars have embarked on examining the relationship between macroeconomic variables (such as productivity, economic growth, inflation and international trade), and the ICT, - broadly represented by the Internet users, telecommunication expenditure, broadband, mobile phones and personal computer (Oliner et al., 2008; Whitacre et al., 2014), but in the last decade, the economic effects of the Internet have been studied independently (Najarzadeh et al., 2014). Maurseth, (2018) argues that the most advantages of the Internet were in the early decades and not in recent times. A fundamental aspect of most economic activity and transactions is the Internet (Najarzadeh et al., 2014). However, there is controversy about the impact of Information technology (IT) on firms' performance and labour productivity. Since the second half of the 1990's, many scholars are devoted to finding the contribution of IT to output or productivity growth, as economists have attributed the event of robust growth in the U.S. productivity, to the unprecedented investment and development of the Information Technology (Wei-Te Hsieh & Goel, 2019).

On one hand, some researchers report a positive (Akerman et al., 2015; Baker et al., 2020; Bartel et al., 2007; Bojnec & Ferto, 2012; Czernich, 2014; Fabling & Grimes, 2021; Ghosh, 2017; Haucap & Heimeshoff, 2013; Kolko, 2012; Wang et al., 2020; Whitacre et al., 2014) and statistically significant impact of the Internet on productivity and growth (Najarzadeh et al., 2014; Nurmilaakso, 2009) including voice telephony (Czernich, 2014). Expanding broadband infrastructure has been found to facilitate economic growth, total factor productivity in global economies (Abrardi & Cambini, 2019), particularly in low density areas. However, it does not necessarily lead to significant increase in telecommuting or other forms of home-based work (Kolko, 2012). Amidst these, some studies show positive results for earlier periods and negative results in a subsequent period (Maurseth, 2018; Oliner et al., 2008). Najarzadeh et al., (2014) reported a positive and significant effect of the Internet on labour productivity, GDP per employed person will increase by $14.6 when the number of Internet users increases by one percent holding other variables constant like education expenditure, per capita health expenditure, trade, and gross capital formation as a percentage of GDP. Major gains in productivity are being seen across all industries but especially in those that use IT extensively (Acemoglu et al., 2014).

The deployment of UFB yields both direct and indirect positive effects on economic activities. Due to the intricate nature of technology, and the challenges involved in implementing it within organisations, Information Technology (IT) as a single factor in some cases can yield positive outcomes, while others may result in negative returns. Consequently, when considering all systems collectively, the positive impact of the effective systems might be negated by poorly designed systems. Fast Internet access is conceived to be a productivity-enhancing factor (Howell & Grimes, 2010). As the Internet speeds have increased through the development in technology, many argue for the importance of investment in fast broadband infrastructure to enhance beneficial economic spill overs (Enck & Reynolds, 2009; Fabling & Grimes, 2021), prompting government initiatives for the promotion of investment in UFB infrastructure to complement private sector development (Howell & Grimes, 2010). Van Ark et al., (2008), argue that labour productivity declined in Europe from 2.4 percent to 1.5 percent compared to the US in the 2000s due to lower growth from the investment in ICT, and a small share of technology-producing firms in Europe. After the 2000s, the significant role played by IT was smaller, industrial reorganisation and cost-cutting in response to profit concerns, appear to have enhanced productivity development (Oliner et al., 2008).

Germany's federal government allotted an extra €400 million to scale up Germany's high-speed internet work, earmarking approximately a total of €4.4 billion for this purpose in 2021 (Chen et al., 2020). In a study conducted by Mukhopadhyay et al., (1995) to estimate the dollar benefits of improved information exchanges, using Electronic Data Interchange (EDI), Information technology yields individual benefits exceeding $100 for Chrysler company, resulting in a spectacular annual savings of $220 million for the company when applied across the entire system.

Another study by Bertschek & Niebel, (2016) finds a substantial impact of mobile internet use on business production after accounting for potential endogeneity bias, using instrumental variable estimates. Mobile internet connectivity can enhance communication and information flow even further while lowering associated expenses, and having access to the internet while on the go is linked to a 20% increase in labour productivity. Kim et al., (2021), also discovered that mobile ICT significantly boosts national production in emerging nations. Earlier studies looked at the impact of high-speed (Grimes et al., 2012), fast broadband (Czernich, 2014) on productivity, and finds that there is 7 to 10 percent boost in firm productivity from the adoption of broadband and this is significant across urban and rural regions, and high and low-knowledge sectors.

Additionally, there exist a potential positive causal relationship between broadband availability/adoption, and employment rate as findings reveal that broadband is an important contributor to employment rate and reduction of unemployment (Akerman et al., 2015; Chen et al., 2020; Hjort & Poulsen, 2019; Jayakar & Park, 2013; Shapiro & Hassett, 2012; Whitacre et al., 2014), and have some effect on firm size (DeStefano et al., 2018). Broadband adoption in firms complement skilled workers (Akerman et al., 2015) and affects employers' relative demand for skilled and unskilled positions. The adoption of 4G wireless technology by a 10 percent increase in the US economy, could add more than 231,000 new jobs within a year (Shapiro & Hassett, 2012). Similarly, in Africa the increase of overall employment and particularly in skilled occupations is significantly more pronounced compared to rich countries (Hjort & Poulsen, 2019).

On the contrary, Fabling & Grimes, (2021) do not agree that Ultra-fast broadband (UFB) increases employment, potentially due to outsourcing which is absorbed in firms with initial low computer intensity. The use of industrial robots and process innovation leads to a significant increase in labour productivity, and an adverse effect on employment, as there is a reduction in employment due to robotization and innovation (Ballestar et al., 2021). In the future, workplaces will have a far less role for labour as IT-powered devices displace workers on a larger scale which is also evident in the labour share of national income of many developed and developing countries (Acemoglu et al., 2014). Through the labour market, broadband internet might have a beneficial impact on economic growth without lowering the unemployment rate (Czernich, 2014).

In response to the economic turmoil caused by the COVID-19 pandemic, the European Union (EU) took a significant measure in March 2021 by unveiling a fresh initiative – "Digital Compass 2030", aimed at promoting digitalization and widespread implementation of digital infrastructures. The objective of these steps is to enable businesses and individuals to thrive in a digitally advanced future that prioritises human well-being, sustainability, and overall prosperity (Abrardi & Cambini, 2019). Although the massive investment made in IT promises enormous potential for enhancing growth, reducing unemployment, and improving labour force performance, some scholars argue that the investment made in improving fast-fibre networks are still small (Abrardi & Cambini, 2019; Falk & Hagsten, 2021), and it may not generate returns to the extent anticipated by the investors (Howell & Grimes, 2010). They further contend that there is a spill-over effect of broadband availability, especially in areas where there is lower establishment of broadband, and access of broadband infrastructure (Falk & Hagsten, 2021).

Some other empirical findings also show that ICT do not only have a significant impact on daily life, but on production statistics, and on the possibilities and effectiveness of how businesses manufacture and distribute products and services (Pradhan et al., 2018). In the firm level, they prefer IT investment in product-differentiation rather than in the cost-reduction technologies, practically explained to be a productivity paradox in a study by Belleflamme, (2001). Investments in the Internet market and Internet-based firms is heterogeneous and characterised by a large degree of Schumpeterian competition where one dominant player follows the other (Haucap & Heimeshoff, 2013). Broadband Internet has proven to be significant for organisational and product innovation, help firms to enhance business procedures and to create new and better versions of existing goods and services in its expansion stage, and it has a significant role in e-commerce (Bertschek et al., 2013), which may lead to greater market share and improved communication and coordination across production lines and customers (Czernich, 2014; DeStefano et al., 2018).

Furthermore, the Internet benefit to firms is that as the telephone network develops, business expenses decrease, and production will rise for individual companies and individual economic sectors (Roller & Waverman, 2001), and it will reduce business production cost (Y. Kim & Orazem, 2017; Paunov & Rollo, 2016). Paunov & Rollo, (2016) argued that Internet usage across industries has a favourable impact on the average firms' productivity and capital expenditures. On average, enterprises with lower levels of innovation, such as single-plant operations, non-exporters, and businesses situated in small agglomerations, have higher returns to productivity. In their Quantile regression findings, productivity increase from Internet-enabled knowledge access only benefits the most productive businesses. Businesses with productivity levels below the median do not gain as much. Quantile regression results show that the most productive small businesses outperform bigger firms in terms of payoffs, even though company sizes do not appear to affect productivity increase for the average firm. The adoption of new IT-enhanced equipment helps in producing a customised product, and there is improved efficiency of the production stages (Bartel et al., 2007). Bloom et al., (2013) show that productivity growth occurred in sectors that were either into IT Production or in intensive use of IT. They also realised that US multinationals in IT sectors experienced higher productivity growth in Europe compared to non-US multinationals, but the growth in sectors that use IT intensively was not that great. As a result of lower broadband prices as well as increased innovation and entrepreneurship, broadband adoption has a beneficial impact on economic development (Ghosh, 2017).

Some other studies in explaining productivity relatively to Broadband, find insignificant and no causal effect between broadband indicators and productivity variables (Bertschek et al., 2013; Ford, 2018; Gallardo et al., 2021; Haller & Lyons, 2015). The benefits of the Internet in terms of productivity would not be universally similar because of the complexity of what the Internet is used for. Some earlier studies relied on cross-sectional or short-time series data, due to inadequate data on broadband deployment and availability (Jayakar & Park, 2013), and the potential delay in realising the business value of IT, utilising data that covers only a limited time-period may not fully reflect the importance and impact of IT investments (Mukhopadhyay et al., 1995). Although the advantages of broadband Internet seem to be widely acknowledged among policy makers, the empirical evidence on these benefits are inconclusive (Bertschek et al., 2013).

Business performance may have an impact on broadband consumption; they account for the fact that infrastructural investment occurs in prosperous regions or nations first, which implies that the investment choice depends on the region's or country's economic capacity (Bertschek et al., 2013). Ultra-fast Broadband is a key enabling factor for flexibility in work patterns, such as smart-working, and teleworking which can be associated with higher productivity (Cambini et al., 2023), and labour force participation. Fibre-based networks are considered the most resilient, secure, and reliable infrastructures to support all the infant digital technologies, and they thus represent a key asset for the economic success and recovery for the European Union (Cambini et al., 2023). Increased government investment in faster broadband networks in advancement of private sector willingness to invest, invariably invokes new growth and general-purpose technology theories in the long run (Howell & Grimes, 2010). While some argue that the gains of investment in fast broadband networks will only be perceived in the long-run, advanced Internet technology is associated with wage growth in areas of high population density and IT-intensive industries (Forman et al., 2012).

3.2. COMPLEMENTARITIES OF THE INTERNET

Information technology, new work structures, and new goods and services are three separate innovations at the business level that skilled labour is complementary to (Bresnahan et al., 2002). It's possible that developing and emerging nations are unlikely to reap as much from ICT investments as established nations will, due to a lack of absorptive capabilities such as an adequate amount of human capital or other complementary elements like Research and Development (R&D) expenditures (Kenny, 2003; Niebel, 2018). Not having access to certain amenities (such as stable power supply) may prevent less developed countries from benefiting from the use of the Internet. Even with access to the Internet, the barriers to utilising the new technology will result to low Internet usage. Additionally, the basic ability to read is necessary for effective Internet use, and one-third of adult individuals in low-income countries lack that educational skill (Kenny, 2003). According to (Bertschek et al., 2015), the most important technical developments in developed countries over several decades have been the expansion and technological upgrades of telecommunication and broadband infrastructure.

Given the sharp upturn in popularity and use of Internet technologies across industries, households, as well as individuals, the economic impact of the Internet and usage have gradually gained interest. In addition to the increased demand for bandwidth, telecom operators and Internet providers are faced with the need to upgrade their legacy networks, by investing in the renowned "Next Generation Access" (NGA) broadband networks based on fibre-optic technology (Abrardi & Cambini, 2019).

4. METHODOLOGY

4.1. EMPIRICAL STRATEGY

In this study, we used a fixed-effects panel regression analysis to examine the relationship between labour productivity as the dependent variable, broadband as one explanatory variable, and other explanatory variables that can contribute to labour productivity which includes human capital, institutional quality, and demographic variables. The fixed effect panel regression model is chosen as befitting for this panel data analysis that contains series of observations collected over time for multiple entities such as firms, individuals, households, states, or countries.

Panel data, also known as longitudinal or cross-sectional time-series data, is a dataset widely used in social science and econometrics, that tracks or observes behaviour or entities across time. Baltagi & Heun Song, (2006) explained 'panel data' to mean a set of datasets on the same individual over periods of time. It allows control for variables that cannot be observed or measured, or control for variables that change over time but do not change across entities such as national policies etc.

The fixed-effect panel regression, also called the within estimator is acclaimed to be the "gold standard" (Schurer & Yong, 2012) and most reliable estimation method for a wide variety of specifications common to real world data (Bell et al., 2019; Greene, 2011). It is a statistical method used to observe the relationship between variables in a set of panel data while controlling for unobserved heterogeneity across entities by including individual-specific fixed effects. It explores the relationship between predictor and outcome variables within an entity and helps to address potential omitted variable bias, while accounting for time-invariant factors that may influence our dependent variable but are not included in the model. By including entity-fixed effects, the analysis focuses on within-entity variations over time, allowing for the identification of the causal impact of the explanatory variables on labour productivity. The difference between this model and Ordinary Least Square (OLS) regression is that OLS regression does not consider heterogeneity across entities or time.

4.2. EMPIRICAL MODEL

In this form of regression, it can be executed using various statistical techniques such as the Least Squares Dummy Variable (LSDV) method, First-difference estimator, Covariance model, but we use the Fixed-Effects/Within estimator for this analysis. Our regression model is specified as:

$$\ln(Y_{it}) = \beta_0 + \beta_1.\text{In}X1_{it} + \beta_2.\text{In}X2_{it} + \beta_3 X3_{it} + \beta_4.\text{In } X4_{it} + \varepsilon_{it} \quad (4.1)$$

Based on equation 4.1 Our objective is to estimate β_1, the effect on Y_i of a change in X_i holding others constant. Having individual specific intercepts can be understood as the fixed effect of entity *i*, called fixed effect model. An equivalent representation of our model is therefore rewritten in equation 4.2 as the following explained regression model:

$$\text{Log(Labour productivity)} = \beta_0 + \beta_1 * \text{log(Broadband)} + \beta_2 * \text{log(total population)} + \beta_3 * \text{CPIA} + \beta_4 * \text{log(Education)} + \varepsilon \quad (4.2)$$ [1]

Where:

- log(Labour productivity) denotes the dependent variable being the natural logarithm of the labour productivity measure.
- log(Broadband) denotes the main explanatory variable of interest which is the natural logarithm of the fixed broadband variable.
- log(Total Population) denotes one of the control variables representing the natural logarithm of the total population variable which accounts for potential influence of population size on labour productivity.
- CPIA meaning Country Policy and Institutional Assessment, represents the institutional quality variable, being another control variable that captures other relevant institutional factors that may affect increase or decrease in labour productivity. The CPIA score is a rating from 1 (low) to 6 (high) as a measure that reflects the quality of

[1] In our regression model, the properties of our data include missing variables and observations with zero values. We applied a log-transformation to address issues of skewness. Due to the missing observations and zero values, we added +1 after log-transformation and still obtained the same result. We removed the missing values and zero values from our observation to avoid potential distortion of the distribution of our data, interpretation challenge, bias in the magnitude of the transformed values, and alteration of the statistical properties of the transformed variable. This change produced an unbalanced data sets used for the regression analysis.

a country's governance and institutional territory; this is the design and implementation of government policy by the central government to deliver services effectively. It consists of property rights, quality of public administration, budgetary and financial management, efficient mobilization of revenue, transparency, accountability, and corruption in the public sector.

- Log(Education) is another control variable which is a proxy for the effect of human capital on labour productivity. We took the natural logarithm of the education variable to account for the impact of educational levels on labour productivity. This variable contains secondary education pupils enrolled in public and private schools.
- β_0 represents the intercept term, while β_1 to β_4 represent the regression coefficients associated with their respective variables.
- ε represents the error term capturing unobserved factors that may affect Labour productivity and random variation.
- i and t are the entity or country index and the time index.

The regression analysis will be implemented using the fixed-effects panel regression model. We use the Fixed-Effect (FE) model when we only want to analyse the impact of variables that vary over time by exploring the relationship between predictor and outcome variables within an entity/individual. Each entity has its own peculiar characteristics that may or may not influence the predictor variables, and to control for this bias we implore the within estimator. The assumptions are that Fixed-effects model removes the effect of those time-invariant characteristics to assess the net effect of the predictors on the outcome variable, and that those time-invariant features are individually unique and should not be correlated with other individual features.

We aim to determine the impact of the control variables on the dependent variable while controlling for entity-specific fixed effects. The regression coefficients of the respective variables will provide information on how the change in the explanatory variable affect the dependent variable, while considering the constant differences among the entities to assess their statistical significance and reliability.

Control variables such as total population, CPIA, and Education[2] were included to account for potential confounding factors that may affect labour productivity independent of broadband. The reason for this choice of variables as our control variable is because we are left with few solid variables that contains meaningful data due to unavailability of data on other forms of variables that can influence labour productivity for specific period. The natural logarithmic transformation of the selected observable variables makes interpretation more intuitive, shows the elasticity coefficients of the variables, and cater for issues of non-linearity, skewness, and heteroscedasticity. A percentage change in the independent variable leads to a certain percentage change in the dependent variable.

Non-linear relationships can lead to biased parameter estimates and incorrect inferences, skewness can affect the assumption of the regression model, which can lead to biased standard errors and invalid statistical inferences. Heteroscedasticity violates the assumptions of homoscedasticity, and can lead to inefficient parameter estimates, biased standard errors, and unreliable hypothesis tests. To capture and approximate nonlinear relationships more effectively, mitigate skewness, stabilize the variance, and eliminate issues of heteroscedasticity, the significance and magnitude of the regression coefficients will be assessed to determine the impact of broadband Internet, total population, CPIA, and education on labour productivity. Robust standard errors will be employed to account for the potential heteroskedasticity and correlation within the entities over time.

4.3 MODEL STATISTICAL TEST

According to (Wooldridge, 2010), pooled OLS is used when each month/period/year of a set of panel data comprises of different sample. On the other hand, fixed effects or random effects models are to be used when the same set of individuals/states/countries/entities/firms is observed across different periods. We conducted a Lagrange Multiplier Test (also known as the Honda Test), to ascertain the presence of individual effects in the panel data model. Our test result indicates a normal test statistic value of 36, which is quite large, and an associated p-value of 2.2e-16, suggesting compelling evidence against the null hypothesis of no individual effects. This implies

[2] Which will be explained in detail in the section 5.2

that the pooled OLS is not suitable, implying that we are observing the sample over different periods. We therefore conclude that there are significant individual effect or differences present in our model (**Appendix 1**). It is important to account for these individual effects to obtain accurate and reliable estimates in the panel data analysis.

Although the Random Effect (RE) model promises to cater for everything that the Fixed Effect (FE) model does, according to Monte-Carlo simulations (Bell et al., 2019), FE remains the widely acclaimed default, and recommended method for time-cross-sectional and panel data (Bell et al., 2019). To decide which type of panel regression (fixed or random effects panel regression) to use, we conducted a Hausman test where the null hypothesis is that the preferred model is random effects, and the alternative hypothesis is that fixed effects are to be chosen (Greene, 2011).

In this specific test, the result shows a chi-squared statistic of 0.19 with 1 degree of freedom. The associated p-value test is 0.66, which is greater than the common level of significance (0.05). Based on this test result, it suggests that the preferred model is the RE model. However, we chose to proceed with the FE model. Our reason is based on the nature of the data and variables we intend to observe in this study, the interpretability of our model and other underlying assumptions of our research. The FE model focuses on within-individual variation over time, it is suitable for unobserved individual-specific effects and can control for these individual-specific effects while capturing time-invariant heterogeneity across countries. FE model further helps to control omitted variable bias while assuming that the effects of the independent variables are constant across countries.

4.4. TEST FOR GOODNESS-OF-FIT (GOF) OF THE MODEL.

We conducted an F-test to examine the significance of the individual effects and time effects in the fixed-effects panel regression model. In the F-test for the individual effects, the null hypothesis (H0) is that there are no significant individual effects in the model while the alternative hypothesis (H1) is that there are significant individual effects in the model. We obtained an F-statistics of 136, p-value of 2.2e-16 which is extremely small, indicating the presence of strong evidence to reject the null hypothesis and that there are significant individual effects in the model. Additionally, in the F-test for time-effects, the null hypothesis (H0) indicates no significant time effects in the model, whereas the alternative hypothesis (H1) is that there is a significant effect in the model. The test shows an F-statistic of 1.14, and a p-value of 0.32, which is above the normal significance level of 0.05. It implies that there is not enough evidence to reject the null hypothesis, suggesting that there are no significant time effects in the model. Summarily, our F-test for individual effects indicates that there are significant individual effects in the model, while the F-test for time effects suggests that there are no significant time effects. We therefore draw from this result to use only the individual fixed-effects panel regression model for this analysis (**Appendix 2**)

Furthermore, we conducted a three-type Lagrange Multiplier Test to assess the presence of individual fixed effects, time effects, or two-ways effects in our model and panel data. The test statistics for Individual fixed effects is 36.22, with a p-value of 2.2e-16. The Alternative hypothesis is significant, which indicates strong evidence against the null hypothesis of no individual effects. This suggests that there are significant unobserved characteristics specific to each entity unit that systematically affect the dependent variable beyond observed variables included in our model (**Appendix 4**)

The test statistic for the time effect is -0.99, with an associated p-value of 0.84. The alternative hypothesis is significant hence, it does not provide evidence against the null hypothesis of no time effects. The p-value is relatively large (0.84) suggesting that there is no strong evidence to assume the presence of time effects in the model. Therefore, the test evidence suggests that the observed variables in the model adequately explain the variation over time (**Appendix 4**)

The two-ways effect (individual and time effects) test statistics is 25, with an associated p-value of 2.2e-16. This test provides a strong proof against the null hypothesis of no two-way effects. This implies that there are significant unobserved characteristics specific to each individual unit and time that systematically affect the dependent variable beyond observed variables incorporated in the model. Summarily, our findings imply the importance of accounting for individual fixed effects and the interaction between the individual and time effects when analyzing the panel data (**Appendix 4**)

4.5. HYPOTHESIS STATEMENT

Our research hypotheses statement is as follows:

H0: **The use of broadband Internet has no impact on labour productivity in African countries.**

H1: **The use of Broadband Internet has an impact on labour productivity in African countries.**

5. DATA AND VARIABLES

5.1. DATA

Based on our research topic, we are using secondary data from the World Bank Group (a combination of five institutions). This is very vital and relevant for this study because it is convenient, and the World Bank group's aim is to support and partner with governments of developing countries and invigorate the private sector in developing countries. The World Bank Indicator (IBRD – IDA) (World Bank, 2021) is the World Bank's compilation of relevant, high-quality, and cross-country comparable data on global development for 217 economies in 1400 times series. The final data set for our empirical analysis consists of an unbalanced panel dataset for 34 African countries with 326 observations in the period 2005 to 2020. This unbalanced nature of our data set is due to missing values that could influence or bias our model results, and the unavailability of data for some countries.

The unbalanced panel data caused by many omitted observations implies that not all countries (entities) have observations across all years. Although it is ideal to perform a fixed-effect panel regression with a balanced panel dataset to avoid omitted variable bias, this is not always the case, as the model can still be executed with an unbalanced panel dataset (Bell et al., 2019; Fairbrother, 2014).

5.2. DESCRIPTION OF VARIABLES

5.2.1. Labour productivity

According to a study by Ahmad et al., (2003), labour productivity growth can be derived by dividing a quantity index of output (GDP) by a quantity index of labour input, which could be total employment, total hours, or any quality modified measure of labour input. They emphasized the validity of all the alternatives, but these options do provide varying levels of accuracy. Our dependent variable is labour productivity, which is the quantity of goods and services that can be produced by one worker (Mahmood, 2012) as measure of economic growth, derived by dividing the total output (GDP variable) by the total number of employees (Employment total variable), all taken from the World Bank Indicator (World Bank, 2022). We log-transformed the labour productivity variable to avoid skewness in the distribution. Due to the lack of availability of other input measures such as hours worked across countries, they would have to be standardized or adjusted across all African countries to give a much more uniform measure (Ahmad et al., 2003) which will be difficult in our case.

Gross Domestic Product (GDP) measured in US dollars was obtained from the World Bank's national accounts data and the OECD's (Organization for Economic Co-operation and Development) national accounts data files. This is the gross value added by all producers in the economy, which includes product taxes and excludes subsidies, depreciation of assets, and depletion and degradation of natural resources, were not taken into consideration. A single year official exchange rate was used to convert all domestic currencies into US dollars; in cases where this was not applicable, an alternative conversion factor was used. Countries such as Angola, Burundi, the Democratic Republic of the Congo, Eritrea, Ethiopia, Ghana, and Nigeria that have dual or multiple exchange rates have an “alternative conversion factor” - PA.NUS.ATLS was used as a weighted average of the different rates in practice. This was done to give a more accurate comparison across countries and a true reflection of the economic reality of those countries. The reporting period is the calendar year (CY), while some countries, like Ethiopia and Ghana, have theirs in the fiscal year (FY), which ends June 30, and July 7 respectively.

Employment total variable was obtained from the International Labour Organization (Labour Force Statistics database- IFS) by the World Bank Group. It is obtained annually through labour force surveys and household surveys, which are supplemented by official estimates and censuses. These include people of 15 years and older (considered to be the working age population), who were engaged in an activity that produced an economic outcome for a pay and include all forms of employment, either on a part-time basis or for a very short period.

5.2.2. Broadband Internet

The source of our broadband variable was the World Bank indicator (World Bank, 2021), which they obtained from the International Telecommunication Union (ITU), and World Telecommunication/ICT Indicators Database. This is fixed broadband subscriptions to the public Internet and includes cable modems, Digital Subscriber Line (DSL), fiber to the home, satellite, and terrestrial fixed wireless broadband. This measurement excludes mobile Internet and captures all transactions without considering the mode of payment. This includes both residential and organizational subscriptions.

For the explanatory variables, we follow Akerman et al., (2015) by adopting data on fixed broadband subscriptions, which is a measure of access to the Internet connectivity as our main explanatory variable, and we chose this due to its potential influence on labour productivity. Throughout this study, broadband is defined as internet connections at downstream speeds equal to, or greater than 256kbit/s. We included control variables to account for the potential effect on labour productivity, and to isolate the specific effect of fixed broadband. Our aim is to control confounding factors and obtain more accurate, isolated, and specific estimates of the cause-and-effect relationship between broadband Internet and labour productivity. They are also log-transformed to control for skewness of the measurement variable.

To ensure the validity and robustness of our study, we draw upon the existing literature and studies on economic growth and productivity (Barro, 1991; Beck et al., 2000; Sala-i-Martin et al., 2004). These studies provide a solid foundation of variables and factors that have been established as key drivers of labour productivity. However, our choice of variables are limited by data availability, constraining us to those core variables with meaningful data, available for specific time periods.

Labour productivity could be influenced by many other extraneous variables that could have strong explanatory power aside from the use of the Internet. Hence, we control for relevant variables such as human capital (proxied by number of enrollments in secondary education), population, and institutional quality (proxied by Country Policy and Institutional Assessment – CPIA score)

5.2.3. Population

Population is the total number of all residents in a country irrespective of legal status. It was obtained from many sources such as the United Nations Population, census reports and other statistical publications from national statistical offices, among others, by the World Bank Group (World Bank, 2021). These are estimates mainly from the national population censuses and are extrapolations based on demographic models for the years before and after the census. The values are in mid-year.

In this study, total population was chosen as one of our control variables because of the controversial relationship between population growth and economic growth (Peterson, 2017; Thuku[1] et al., 2013). Population growth, migration characteristics, age structure and other population dynamics can relatively influence labour productivity. Larger populations may have different characteristics and dynamics that can affect labour productivity and economic growth. By including population as a variable in observing labour productivity, it can be informative in some contexts, especially when examining labour force structure, demographic trends, or making cross-country comparisons. It also enhances the internal validity of our study by limiting extraneous variables. Controlling population size ensures that any observed effects of broadband on labour productivity are not wholly propelled by population differences.

5.2.4. Institutional quality (CPIA- Country Policy and Institutional Assessment)

The regression model further features a fiscal policy variable and an effect of institutional factors proxied by the Country Policy and Institutional Assessment (CPIA) scores from the CPIA database in the World Bank Group (World Bank, 2021), which consists of property rights, quality of public administration, budgetary and financial management, efficient mobilization of revenue, transparency, accountability, and corruption in the public sector. The CPIA score is a rating from 1 (low) to 6 (high) as a measure that reflects the quality of a country's governance and institutional territory.

The World Bank carries out a performance assessment of every country annually, which focuses on 16 criteria further grouped into four main clusters: economic management, structural policies, policies for social inclusion and equity, public sector management, and institutions. Each cluster weighs 25 percent in the overall score, which they obtained by averaging the scores of the four clusters, and the score depends on the level of performance each year. The ratings reflect several observations and opinions based on the knowledge of the country and on other important publicly available measurements. To ensure that the scores are consistent across countries, it goes through two key processes; the benchmarking phase, which is done at the regional level, and finally the bank wide review process. The limitation is that the ratings are based on a country's economic outcome, such as economic growth, which are impacted by events the country has no control over rather than capturing the quality of policies within a country that are within the country's control.

To include the CPIA score as a control variable is to capture the potential influence of overall institutional quality on labour productivity. Good governance, political stability, and high institutional quality have proven to provide a viable environment for economic and productivity growth (Acemoglu et al., 2005; Levine et al., 2000; Rodrik et al., 2004; Wamboye et al., 2016). This is to help separate the specific effects of broadband from the broader institutional context in which it operates, and we did this by standardizing the CPIA score. The benefits of standardizing the CPIA score are for equal weighting, meaningful comparability, interpretation, and handling of outliers.

5.2.5. Education

The education data was also obtained from the World Bank Group (World Bank, 2022), which they retrieved from the UNESCO Institute for Statistics (UIS) annually, mainly from the population census, household survey, and labour force survey. The education variable contains secondary education pupils enrolled in public and private schools. All the data were linked to the International Standard Classification of Education (ISCE) for comparison purposes. The limitation is that the data was measured by only taking the level of education attainment (years of schooling) into consideration and not the quality of education (learning achievement and other goals). Educational attainment is treated as a proxy for the stock of human capital (Barro, 2013).

Great emphasis has been placed on human capital as another important factor that majorly contributes to labour productivity and growth (Barro, 2013; Gyimah-Brempong et al., 2006; Najarzadeh et al., 2014) in Sub-Saharan Africa (Bloom et al., 2013). Moreover, countries with human capital accumulation represented by a well-educated workforce have varying advantages for their productivity growth (Wamboye et al., 2016). Highly skilled individuals are better equipped to perform complex tasks and contribute to higher levels of output per worker. Investors are drawn to locations with a skilled workforce that is more adaptable to technological advancements, thereby enabling efficient integration of new technologies into the production processes and providing competitive advantages. Using education as a control variable account for the potential influence of educational attainment, skills, and knowledge on labour productivity (Grossman & Helpman, 1993). Controlling education helps isolate the effect of broadband on labour productivity while holding educational factors constant. We use the number of people enrolled in secondary (high school) education as the data for education.

5.3. DESCRIPTIVE STATISTICS

Table 1 shows the descriptive statistics for the 34 African countries (**Appendix 5**) for the period 2005 to 2020 with variables explaining the effect of broadband on labour productivity in African countries. The average GDP is 30.7 billion US dollars, with minimum value of 149 million US dollars for Sao Tome Principe in the year 2007, and the maximum value of 574.1 billion US dollars for Nigeria recorded in the year 2014.

Broadband Internet as the main independent variable has an average of 46,080 subscriptions with minimum of 42 subscriptions for Djibouti in the year 2005, and a maximum of 1,135,608 subscription for Tanzania which was recorded in 2020. Djibouti had the highest labour productivity of 13,188 in the year 2005, and Ethiopia recording the lowest labour productivity of 200 in the year 2005 as seen in **Table 1**

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Table 1: Descriptives of variables from 2005 to 2020

Statistics	N	Mean	St. Dev	Min	Max
Labour product.	326	2,345.538	2,172.055	200.174	13,188.090
Broadband	326	46,080.090	128,452.300	42	1,135,608
Pop total	326	23,761,563.000	33,202,110.000	169,845	198,387,623
CPIA	326	2.975	0.458	2.000	4.000
Education	326	1,249,567.000	1,837,875.000	8,518	12,532,753
GDP	326	30,735,440,688.00	74,116,834,991.00	149,146,423.00	574,183,825,592.00
Emp total	326	61.002	15.354	22.126	85.866

To generate the statistical tables and summary statistics, the stargazer function, version 5.2.3, (Hlavac, 2022) was used. The dependent variable is labour productivity. They are log-transformed in the model to avoid skewness in the distribution and provide a more intuitive coefficient. For the explanatory variables, we focused on fixed broadband subscription, which is the number of people that have access to internet connectivity as our main explanatory variable. We included total population, CPIA score, and education as our control variables. These control variables were included to account for the potential effect on labour productivity, and to isolate the specific effect of broadband Internet to obtain more accurate estimates of the cause-and-effect relationship between broadband Internet and labour productivity.

By including these control variables, we intend to enhance the accuracy and reliability of the regression analysis, through minimizing the possible influence of confounding factors and obtaining more precise estimates of the causal relationship between Internet, proxied by fixed broadband subscriptions and labour productivity. **Figure 1** is the visualization of the correlation of our variables.

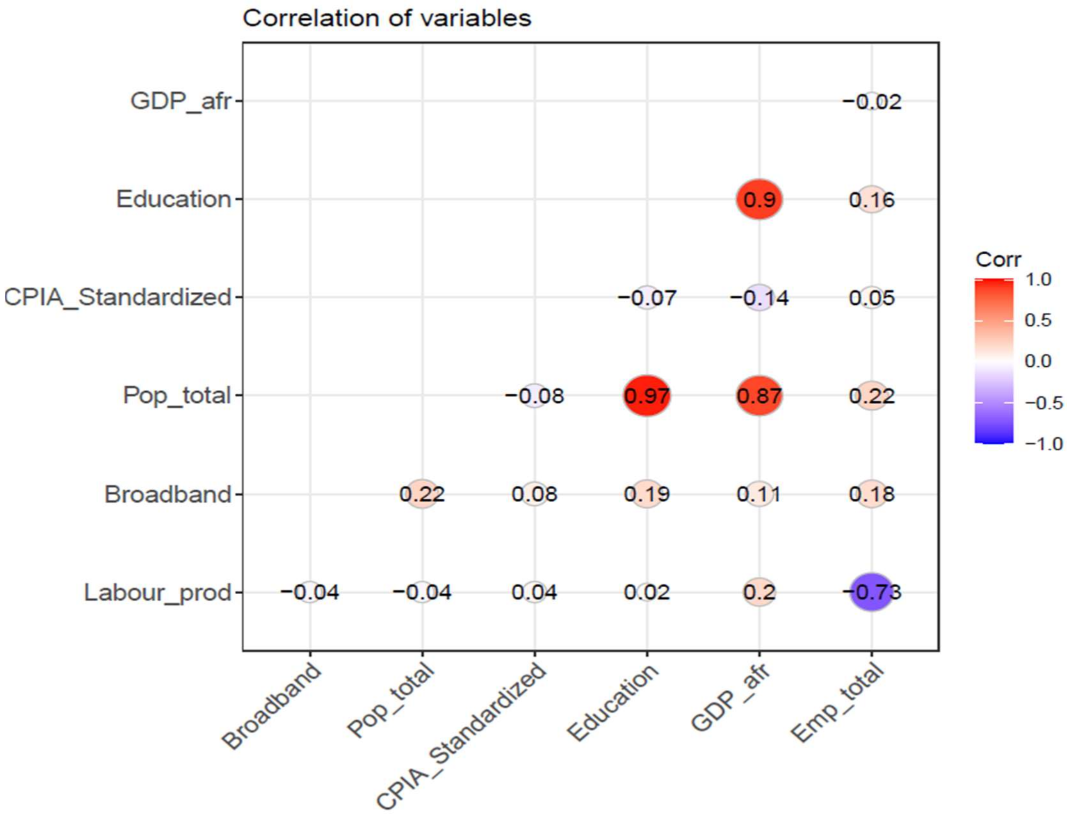

Figure 1: Correction of Variable

In **Figure 1**, education is strongly and positively correlated with gross GDP per capita[3] , when the human capital of a country increase GDP per capita equally increases. Population is positively and strongly correlated with education and GDP per capita, which implies that a higher population will lead to a higher number of people enrolled in school.

However, education is positive but weakly correlated with employment total, population total is also positively correlated with employment total although the correlation is weak. Broadband Internet is positive and weakly correlated with all the variables especially with institutional quality (CPIA) and GDP per capita. Labour productivity tends to be negatively correlated with broadband Internet, population total and employment total. This is because labour productivity is derived by dividing GDP by the population. Notably, the higher the population, the lower the labour

[3] GDP per capita is represented as GDP_afr, standardized Country Policy and Institutional Assessment score variable is labelled as CPIA_Standardized, total population is labelled as Pop_total, total employment is labelled as EMP_total, and labour productivity is represented by Labour_prod in **Figure 1**

productivity and a high share of population means higher employment total (shown by the positive correlation) which lowers labour productivity. Labour productivity is positively correlated with GDP per capita and education though the correlation is weak.

6. RESULTS, INTERPRETATION AND DISCUSSION

6.1. PRESENTATION OF RESULTS

Table 2: Model 1- OLS Regression:

	log(Labour productivity)
log(Broadband)	0.118***
	(0.023)
Constant	6.324***
	(0.209)
Observations	326
R2	0.077
Adjusted R2	0.075
Residual Std. Error	0.851 (df = 324)
F Statistic	27.188*** (df = 1; 324)
Note:	*p<0.1; **p<0.05; ***p<0.01.

The result is a presentation of the OLS model of our regression analysis. The dependent variable is the logarithm of Labour productivity while the independent variable is the logarithm of broadband.

The regression result in **Table 2** indicates that the logarithm of broadband has a statistically significant positive effect on the logarithm of labour productivity, with a coefficient estimate for log(Broadband) at 0.12. In the absence of broadband (when broadband is zero), log-transformed labour productivity is 6.3 percent. Based on the result, the coefficient is statistically significant at a 1% level, implying a positive and significant relationship between the explanatory and dependent variable (logarithm of broadband and logarithm of labour productivity respectively). We can expect on average a 0.12 percent increase in the log of labour productivity for each percent increase in broadband.

The R-squared value is 0.08, which indicates that about 8% of the variation in the logarithm of labour productivity is explained by the logarithm of broadband in this model. The adjusted R-squared value is slightly lower at 0.075, considering the number of variables and degrees of freedom.

Table 3: Model 2- Fixed Effect Regression

Model 2: Fixed Effect Regression

	Dependent variable:
	log(Labour productivity)
log(Broadband)	0.108***
	(0.008)
Observations	326
R2	0.401
Adjusted R2	0.331
F Statistic	194.482*** (df = 1; 291)

Note: *p<0.1; **p<0.05; ***p<0.01. The result is from a fixed effect regression model, examining the relationship between the dependent variable which is the logarithm of labour productivity, and the independent variable which is the logarithm of broadband usage. Our model is estimated using unbalanced panel data of 34 entities (countries), 16 years' period, and a total of 326 observations.

In **Table 3** the estimated coefficient for the log transformed Broadband variable is 0.11, which shows a positive and statistically significant relationship at 1% confidence level. This implies that on average, a one percent increase in broadband usage is associated with a 0.11 percent increase in labour productivity, holding all other factors constant. The R-squared of 0.4 suggests that approximately 40% of the variation in the log-transformed labour productivity can be explained by the variation in the log-transformed broadband usage, in the presence of individual-specific effects. However, the adjusted R-squared value is 0.331, indicating the fitness of our model to explain our data, after adjusting for the inclusion of other variables and the sample size. This suggests that the included independent variable – logarithm of broadband may not be capturing all the relevant factors that affect labour productivity.

Summarily, our result in **Table 3** Model 2 suggests that the logarithm of broadband has a significant and positive effect on the logarithm of labour productivity, after accounting for individual specific effects. To control other factors affecting labour productivity, we further examine the relationship between labour productivity and broadband, while holding other factors like population that can contribute to labour productivity constant.

We improved our model, and we obtained the result in **Table 4** Model 3:

Table 4: Model 3- Fixed Effect Regression

Model 3 - Fixed Effect Regression

	Dependent variable:
	log(Labour productivity)
log(Broadband)	0.072***
	(0.010)
log(Population total)	0.719***
	(0.145)
Observations	326
R2	0.447
Adjusted R2	0.381
F Statistic	117.358*** (df = 2; 290)

Note: *p<0.1; **p<0.05; ***p<0.01. The result is from a fixed effect regression model, examining the relationship between the 'dependent variable, log(Labour productivity), and the independent variables, log(Broadband) and log(Population total), estimated using an unbalanced panel data of 34 entities (countries), 16 years' period, and a total of 326 observations.

In **Table 4** Model 3, the estimated coefficient of the log-transformed broadband is 0.07, showing a strong positive statistically significant relationship at 1% level. This result implies that for each percent increase in broadband is accompanied by an approximate of 0.07 percent increase in labour productivity, holding other variables constant. The estimated coefficient of the log-transformed population total is 0.72, equally showing a strong positive and statistically significant relationship between log-transformed population total and log-transformed labour productivity at 1% significance level. This suggests that a one percent increase in the population is associated with 0.72 percent increase in labour productivity, holding all other variables constant.

Most of the R-squared value of our comes from the fixed effects, indicating that approximately 45% of the variation in the log-transformed labour productivity is explained by the independent variables incorporated in our model. The adjusted R-squared value of 0.38 accounts for the degrees of freedom in our model, showing a slightly lower estimate of the percentage of variation explained by the independent variables.

Our model suggests that both the log-transformed broadband variable and log-transformed population total variable have a positive significant relationship with the dependent variable, log-transformed labour productivity. The independent variables collectively have a substantial impact on the dependent variable.

Table 5: Model 4- Fixed Effect Regression

Model 4 - Fixed Effect Regression

	Dependent variable:
	log(Labour productivity)
log(Broadband)	0.066***
	(0.010)
log(Population total)	0.845***
	(0.147)
CPIA_Standardized	0.092***
	(0.027)
Observations	326
R2	0.469
Adjusted R2	0.402
F Statistic	84.953*** (df = 3; 289)

Note: *p<0.1; **p<0.05; ***p<0.01. The result is from a fixed effect regression model, exploring the relationship between the dependent variable, log(Labour productivity), and independent variables, log(Broadband), log(Population total), and CPIA_Standardized variable, estimated using an unbalanced panel data of 34 entities (countries), 16 years' period, and a total of 326 observations.

The estimated coefficient for the log-transformed broadband in model 4 **Table 5** is 0.07, showing a strong positive and statistically significant relationship between log-transformed broadband and log-transformed labour productivity at 1% level. This implies that for each percent increase in broadband will result to an approximated 0.07 percent increase in log labour productivity, while holding other variables constant.The coefficient estimate for the log-transformed Population total in this model is 0.85, which shows a strong positive and statistically significant relationship between the log-transformed broadband and log-transformed labour productivity at 1% level. The result suggests that a one percent increase in the population will give rise to a 0.85 increase in log labour productivity, while holding other variables constant. The estimated coefficient for the standardized CPIA is 0.09, equally showing a positive and statistically significant relationship between the standardized CPIA and log-transformed labour productivity at 1% level. The result indicates that a one percent increase in the CPIA is associated with an approximate 0.09 percent increase in the log of labour productivity, holding other variables constant.

From our model 4 result, the R-squared of 0.47 suggests that the model is a good fit for our analysis which comes from the fixed effect, indicating that approximately 47% of the variation in the log-transformed labour productivity is explained by the independent variables incorporated in our model. The adjusted R-squared value of 0.40 accounts for the degrees of freedom in our model, providing a slightly lower estimate of the percentage of variation explained by the independent variables. Based on this result in Model 4, the log-transformed broadband variable, the log-transformed population total variable, and the standardized CPIA collectively have a positive and substantial impact on the log-transformed labour productivity variable.

We further improved our model to incorporate all the variables assumed in this regression analysis as factors that can contribute to labour productivity growth, to evaluate the impact of broadband on labour productivity while taking into consideration all these other factors, and we obtained the result in **Table 6**.

Table 6: Model 5- Fixed Effect Regression

Model 5: Fixed Effect Regression

	Dependent variable:
	log(Labour productivity)
log(Broadband)	0.061***
	(0.010)
log(Population total)	0.125
	(0.232)
CPIA_Standardized	0.084***
	(0.026)
log(Education)	0.325***
	(0.082)
Observations	326
R2	0.496
Adjusted R2	0.431
F Statistic	70.885*** (df = 4; 288)

Note: *p<0.1; **p<0.05; ***p<0.01. This table shows an improved result of within effect regression model examining the relationship between the dependent variable, which is the logarithm of labour productivity, and multiple independent variables, to include the logarithm of broadband usage, logarithm of total population, the standardized CPIA index, and the logarithm of education level. The data used for the model is the same as in **Table 6**.

In **Table 6**, the estimated coefficient for our main explanatory variable, which is the logarithm of broadband, is 0.06, and it is statistically significant at 1% level. This suggests that on average, a one percent increase in the logarithm of broadband is associated with a 0.06 percent increase in logarithm of labour productivity, while holding other variables constant.

For the population total variable, the estimated coefficient is 0.13, though not statistically significant. This implies that on average, a one percent increase in the logarithm total population has a positive but small effect on the logarithm of log labour productivity, holding other variables constant. For the standardized CPIA variable, the estimated coefficient is 0.08, statistically significant at the 1% level. It suggests that a one percent increase in the CPIA index is associated with a 0.08 percent increase in log labour productivity while holding other variables constant. And for the education variable, with an estimated coefficient is 0.33, and statistically significant at 1% levels. The result for the education variable indicates that on average, a one percent increase in the education variable will cause a 0.33 percent increase in the logarithm of labour productivity, holding other variables constant. The R-squared value of 0.5 suggesting that approximately 50% of the variation in the logarithm of labour productivity can be explained by the chosen independent variables in our model, considering the individual-specific effects. In addition, the adjusted R-squared of 0.43 considers the number of variables and degrees of freedom in the model. It is lower than the R-squared and caters for the inclusion of irrelevant variables. Based on this, our findings indicate that broadband, CPIA and education have statistically significant effects on labour productivity, but population total do not have statistically significant effect on labour productivity although it is positive.

Table 7: Model 6- Fixed Effect Regression with Country and Year dummies

Model 6- Fixed Effect Regression with country and year dummies

	Dependent variable: Log(Labour productivity)
log(Broadband)	0.06 ***
	(0.01)
log(Population total)	0.12
	(0.23)
CPIA_Standardized	0.08 **
	(0.03)
log(Education)	0.32 ***
	(0.08)
FE Country	YES
FE Year	YES
R^2	0.50
Adj. R^2	0.43
Num. obs.	326

Note: *** p < 0.001; ** p < 0.01; * p < 0.05. The table is a result of a fixed effect regression model with individual effects and within transformation, performed with an unbalanced panel data of 34 countries, a time range of 1 -16 years, and with a total of 326 observations.

The estimated coefficient of log-transformed broadband is 0.06 in **Table 7**, indicating a strong positive statistical relationship between log-transformed broadband and log-transformed labour productivity at 0.001 level. The estimated coefficient of log-transformed population total is 0.12, suggesting a positive but non-statistically significant relationship between log-transformed population total and log-transformed labour productivity. In addition, the coefficient estimate for standardized CPIA is 0.08, indicating a statistically significant relationship between standardized CPIA and log-transformed labour productivity at 0.01 level. Whereas the estimated coefficient of log-transformed education is 0.32, showing a 0.001 level of statistical significance between log-transformed education and log-transformed labour productivity. The R-squared value of our model is 0.50 which indicates that the independent variables explain approximately 50% of the variation in the dependent variable. The adjusted R-squared value of our model is 0.43 which considers the number of variables and provides a more conservative measure of the fitness of our model to explain the variation in our analysis.

The report in **Table 7** show that country dummies and year dummies are included to control unobserved heterogeneity and time-specific effects respectively. By including the country dummies, it allows us to capture the fixed effects specific to each country in our panel data. Including separate dummy variables for each country controls for country-specific factors such as Institutional differences, policy endogeneity, cultural factors, and resource endowment that are constant over time but may affect the dependent variable. These dummies account for unobserved heterogeneity across countries that may bias the estimated coefficients if not appropriately controlled for.

Similarly, we include the year dummies to capture time-specific effects, common to all countries. The year dummy variables control for factors that vary across different years but affect all countries equally. By including separate dummy variables for each year, we carefully control for time-specific shocks, events or trends like global events, economic cycles, level of technological advancement, that may impact the dependent variable and ensure that the estimated coefficients reflect the true relationship between the independent variables and the dependent variable.

Including both country dummies and year dummies in our regression model accounts for both country-specific heterogeneity and time-specific effects, providing more reliable and accurate estimates of the causal relationships between our explanatory variables and the dependent variable.

Table 8: Comparison of the different models

Comparison of Panel Regression Results

	Labour Productivity					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
(Intercept)	6.324 ***					
	(0.21)					
log(Broadband)	0.118 ***	0.108 ***	0.072***	0.066 ***	0.06 ***	0.06 ***
	(0.02)	(0.008)	(0.01)	(0.01)	(0.01)	(0.01)
log(Population total)			0.719 ***	0.84 ***	0.12	0.12
			(0.15)	(0.15)	(0.23)	(0.23)
CPIA_Standardized				0.09 ***	0.08 **	0.08 **
				(0.03)	(0.03)	(0.03)
log(Education)					0.32 ***	0.32 ***
					(0.08)	(0.08)
FE Country	NO	YES	YES	YES	YES	YES
FE Year	NO	NO	NO	NO	YES	YES
R^2	0.08	0.40	0.45	0.47	0.50	0.50
Adj. R^2	0.07	0.33	0.38	0.40	0.43	0.43
Num. obs.	326	326	326	326	326	326
Residual Std. Error	0.851 (df = 324)					

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

6.2. RESULT DIAGNOSTICS

6.2.1. Breusch-Pagan LM test for cross-sectional dependence

The test statistics of Breusch-Pagan LM test for cross-sectional dependence in our panel data shows a p-value of 2.2e-16 which is extremely small. The cross-sectional dependence test refers to the presence of interdependence or correlation among observation in a cross-section or group of entities in a dataset. This test is to examine that the observations for different entities or countries are not interdependent and can exhibit some form of similarity or correlation. Based on this result (**Appendix 6**), we will reject the null hypothesis of no cross-sectional dependence and accept the alternative hypothesis which suggests that there is evidence of cross-sectional dependence in the panel data.

6.2.2. Breusch-Godfrey/Wooldridge test for serial correlation

The Breusch-Godfrey/Wooldridge test for serial correlation was implemented in our panel regression model. The test statistics produced a chi-squared result of 60.57 degrees of freedom, with an associated p-value of 7.093e-15 which is very small (**Appendix 7**). Based on this, we reject the null hypothesis of no serial correlation in the idiosyncratic errors and accept the alternative hypothesis that there is evidence of serial correlation in the panel model's errors. This implies that there is a systematic pattern of correlation among the error terms cross time within each country in the panel data. The violation of the assumption of no serial correlation implies that there may be omitted time-varying factors or autocorrelation present in our model that needs to be addressed for accurate inferences.

6.3. DISCUSSION

The Internet has impacted our everyday lives in various ways, and the numerous advantages that come with the Internet to businesses, the economy, and the broadband Internet itself are widely acknowledged. This study finds a significant and positive impact of broadband Internet on labour productivity, which is robust after controlling important economic variables - population, education, and institutions (CPIA). It is consistent with the findings of earlier research by Czernich et al., (2011) and contributes to a wide range of other literature based on our empirical findings. There have been varied results from similar research in the past, some having a very strong positive impact and others reporting otherwise. A study by Maurseth, (2018), looked at the impact of the Internet on economic growth, and produced interesting results, which were built on the works of Choi & Hoon Yi, (2009), while using the same data, approach and stretching the timeline. They reported significant and positive results in earlier periods which were identical to Choi & Hoon Yi, (2009), and reported negative and significant results for later years. Based on his study, the advantages of the internet are more prominent in its earlier periods and not in later periods.

Our study's findings report about 0.11 percent increase in labour productivity for each percent increase in broadband, and about 0.6 percent increase after controlling for other variables, of which both results are statistically significant. This shows that broadband have a positive impact on labour productivity in African countries. To elaborate on the usage of broadband in Africa, an overview of the total usage of broadband in Africa is presented in **Figure 2**.

Although in this study, the aim was to examine the effect on broadband internet in 50 countries of the African region. However, only 34 countries were observed in varying number of years due to missing observations in the panel data set, hence we were left with unbalanced panel data set. The countries were made up of majorly 14 Eastern African countries, 13 Western African countries, 5 middle African countries, 1 Southern African country and 1 Northern African country[4]. South Africa is remarkably a country with high broadband Internet usage and supply, and generally

[4] The 34 regional African countries used for this study include Comoros, Chad, Benin, Guinea, Mali, Cote d'Ivoire, Mauritania, Niger, Senegal, Djibouti, Madagascar, Togo, Cameroon, Democratic Republic of Congo, Burundi, Nigeria, South Sudan, Lesotho, Kenya, Uganda, Ghana, Gambia, The, Malawi, Zimbabwe, Eritrea, Sudan, Rwanda, Tanzania, Angola, Mozambique, Cape Verde, Sao Tome & Principe, Ethiopia and Liberia.

considered as a location with the early arrival of fast Internet connection. Given that it does not have any variable in institutional policy proxied by CPIA that was used to control for other confounding variables that influence labour productivity, it was exempted from our dataset.

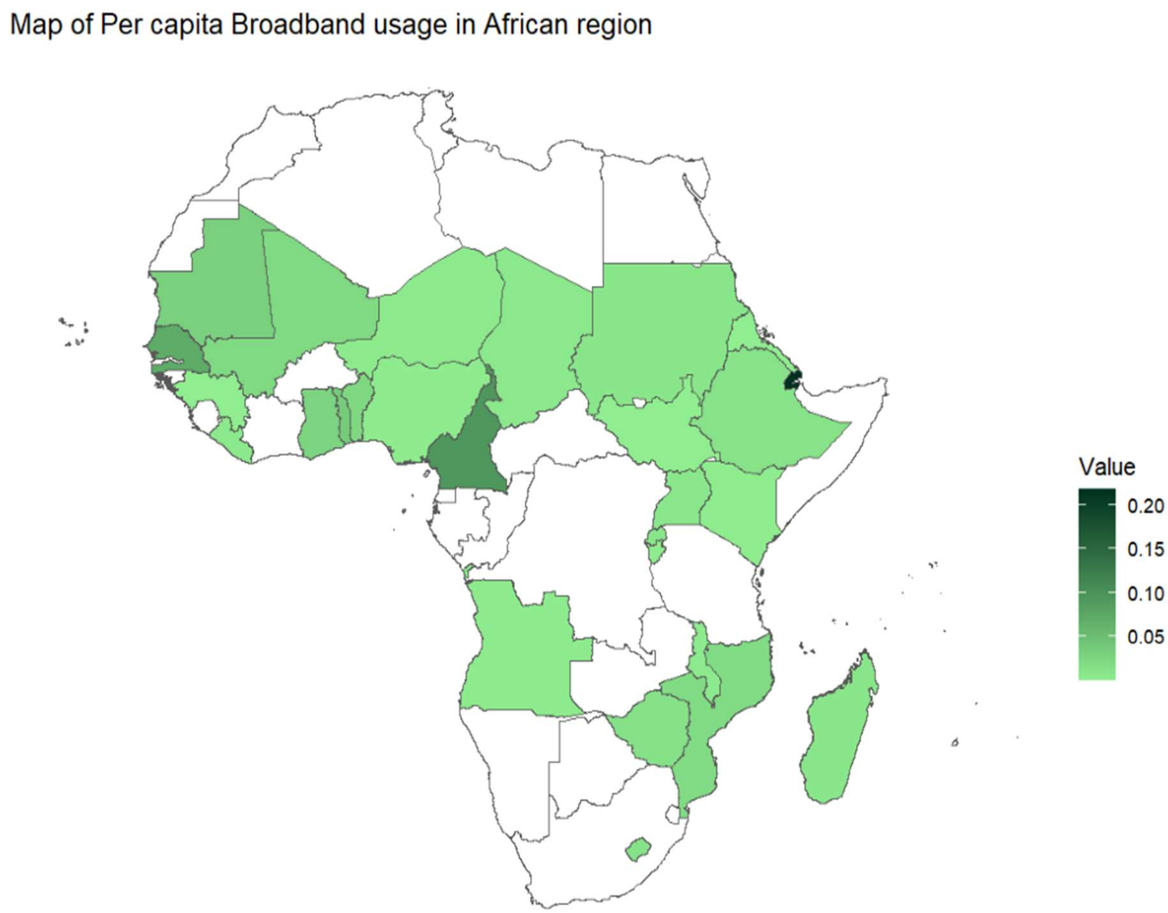

Figure 2:Map of Per capita broadband Internet usage in Africa.

This figure shows the geographical overview of the per capita broadband usage in countries of African region, from the period of 2005 to 2020. Data source: World Bank Indicator

On one hand, the broadband Internet usage per individual for countries like Djibouti, Cameroon and Senegal are seen in **Figure 2** with relatively very high broadband usage per individual. On the other hand, it can be observed that for country like Nigeria, the per capita consumption of broadband is seen to be below medium. For Djibouti, this could be because they are lightly populated with only about 1.1 million people, compared to countries like Nigeria densely populated with over 210 million people. The countries with unavailable (NA) values are shaded in white.

Drawing from the findings and arguments in various works of literature, it can be deduced that certain important factors were present for the advanced countries to see such tremendous effect and unleash the great benefit associated with the broadband Internet, which is not present in developing countries. Human capital plays an important role in making efficient use of the Internet. The internet complements highly skilled workers. Following the study by Akerman et al., (2015), an extensive study was done on the skill complementarity of broadband Internet using Norwegian data, their results showed high productivity (increased output elasticity) with highly skilled workers. Productivity and worker output are increased with the availability of broadband Internet adoption in firms and this change in productivity is skill biased. Since the Internet complements highly skilled workers or employees, holding the Internet constant (either availability or adoption of the Internet) and increase in high-skill workers will lead to an increase in labour productivity. Basic literacy skill is necessary for the effective use of the internet and one-third of adults in low-income countries lack this skill, this shows how human capital is important in the production process and could explain one of the reasons developing countries are not performing so well and not catching up with developed countries (Kenny, 2003).

There needs to be government intervention in policy making and investment towards the provision (availability) and the adoption (usage) of the Internet. The internet has been a thing only assessed by the rich or those who can afford it, and by people living in the cities (Jensen, 2000) especially in the developing countries. Rural engagement and training strategies for the youth should be set in place, especially in ICT to effectively equip and tap into these resources.

An overview for the total level of the log of labour productivity in African countries is represented in **Error! Reference source not found.**. It represents an entity's (country) total log-transformed labour productivity over varying periods. The number of years among countries are not evenly distributed, due to omitted observations in variables of interest.

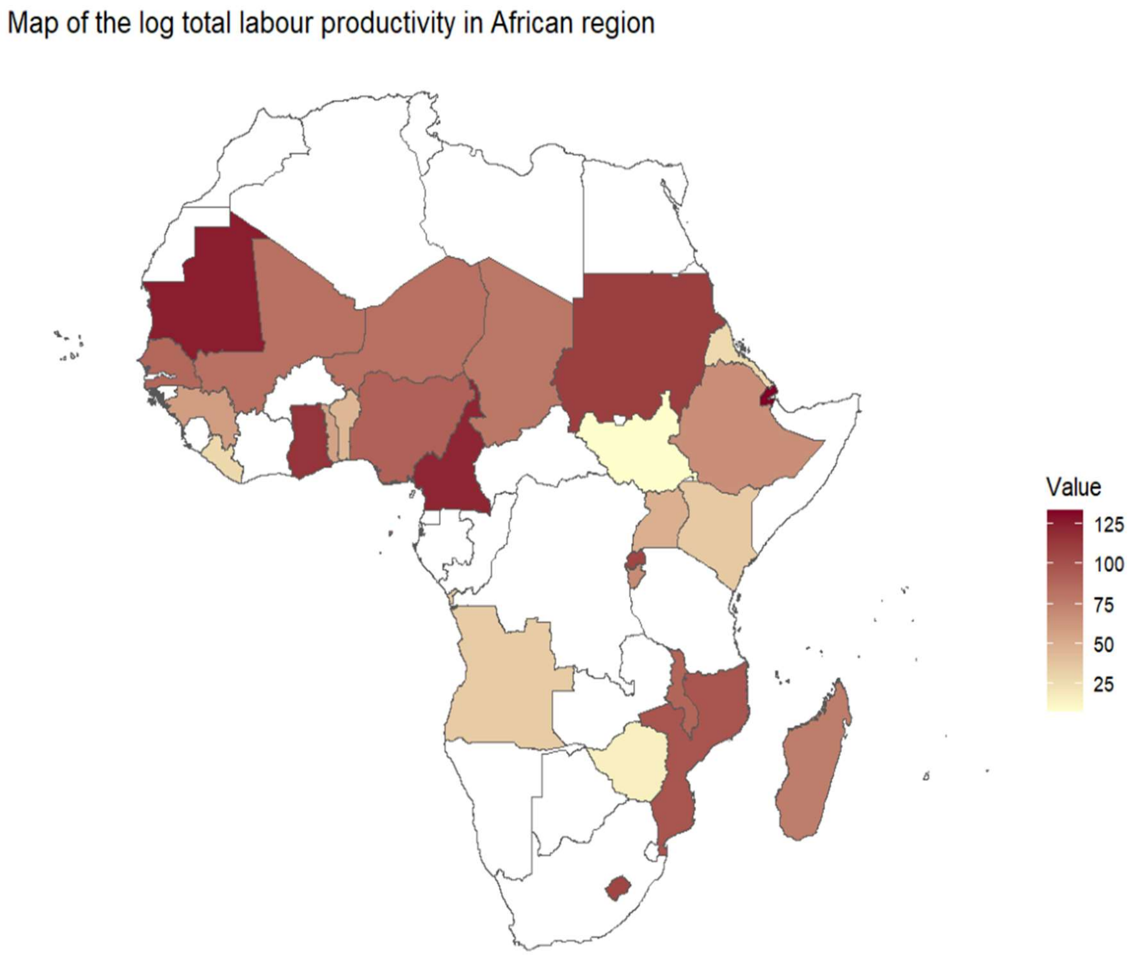

Figure 3: Map for the log of total labour productivity in African regions

This figure shows the geographical overview of labour productivity in countries of African region, from the period of 2005 to 2020. Data source: World Bank Indicator

In **Figure 3**, we observe high levels of labour productivity in Eastern African countries like Djibouti, Mozambique, Rwanda, followed by West Africa to include Ghana and Mauritania. Cameroon, Sudan, Sao Tome and Principe and Lesotho also show high levels of labour productivity. Although labour productivity growth has other influencing factors, our findings show that broadband Internet has a reasonable share in the percentage growth of labour productivity. Similarly, as in **Figure 2** the areas or countries shaded in white represent no values to show their levels of productivity.

Broadband Internet requires huge investments in infrastructure that individuals cannot afford even if it is available. It can be a hindrance to growth if broadband-related infrastructures and its complementary resources are inaccessible like human capital, personal computers, software, and other gadgets (Czernich et al., 2011). The Government needs to provide the necessary infrastructure and have educational programs that equip its human capital with the skills in ICT since it complements the Internet. There should be policies that favor the adoption of the Internet by individual and firm business processes, especially in rural areas. These policies could be in the form of a reduction in data cost and having plans that make personal computers and other accessories that promote the Internet usage affordability and accessibility in schools and rural areas. Partnership with other service providers to make accessible accessories and services much easier and less costly should be encouraged. There has been much growth associated with the Internet both in labour productivity and economically, because of the low cost of the Internet and its complementary inputs. Similarly, there has been massive funding support from the US government in 2009 and some other OECD countries to roll out broadband infrastructure (Akerman et al., 2015). Hence, African countries and economic policy maker can adopt the strategies implemented by developed countries in their full involvement towards broadband Internet infrastructural development by governments, to implement in developing countries.

According to Acemoglu et al., (2005), the fundamental cause of growth is an institution and the difference in development in countries is a result of differences in institutions. Economic and political institutions are major determining factors. Institutions could be referred to as rule of law, regulations, and government policies. Economic institutions are the social decisions that form and shape the economic outcome of a country. There are weak institutions in low-income countries as compared to a cross-country level. In the referred countries, there are unenforceable contracts, property and copyright issues and markets not functioning efficiently. These factors stifle growth and would impede any foreign investment in a country, especially where the fundamentals are not adhered to. The Internet can be available but poor institutions would prevent foreign investments from unearthing the advantages of its usage. It becomes difficult to establish any meaningful venture when there are no clearly defined rules and regulations and there are no proper procedures for redress when there is breach of contract. These inefficiencies breed bribery and corruption and lead to inefficient allocation of resources in a country.

Another concern is the political institutional instability, which is a political power look-alike, but fails to conduct checks and balances on political leaders. Political instability is quite common in most African countries. Most leaders become power drunk and do not allow the rule of law to function as it should. They may make policies favoring their ambitions and engage in devious activities that could trigger political unrest. Political stability, and enforceable contracts, property rights, procedural redress are important for growth. In the absence of these factors, investments will not be possible since the cost involved in investing in human capital, technology and others will outweigh the benefit (Jones, 2019).

High-speed internet prompted a political and economic revolution in Africa through the emancipation, participation, and promotion of mobile money (D'Andrea & Limodio, 2023), and stimulation of job opportunities (Hjort & Poulsen, 2019). At the same time, local financial markets experienced immense changes caused by the effect of this technological upsurge (D'Andrea & Limodio, 2023). Some scholars claim that government institutions and policies are instrumental in fostering activities that contribute to productivity growth and development (Minniti, 2008). Diewert, (2004) in his study, 'Theories of Productivity Growth and the role of Government in facilitating Productivity Growth" argues that one of the other factors influencing growth is the access to international exposure, where knowledge and technology can be transferred. To be able to benefit from this knowledge transfer, there is need for local investment in human capital and specialized skill programs. Based on this view, we categorized the African countries according to the colonies to examine if there is commonalities and relationship on a cross-country level.

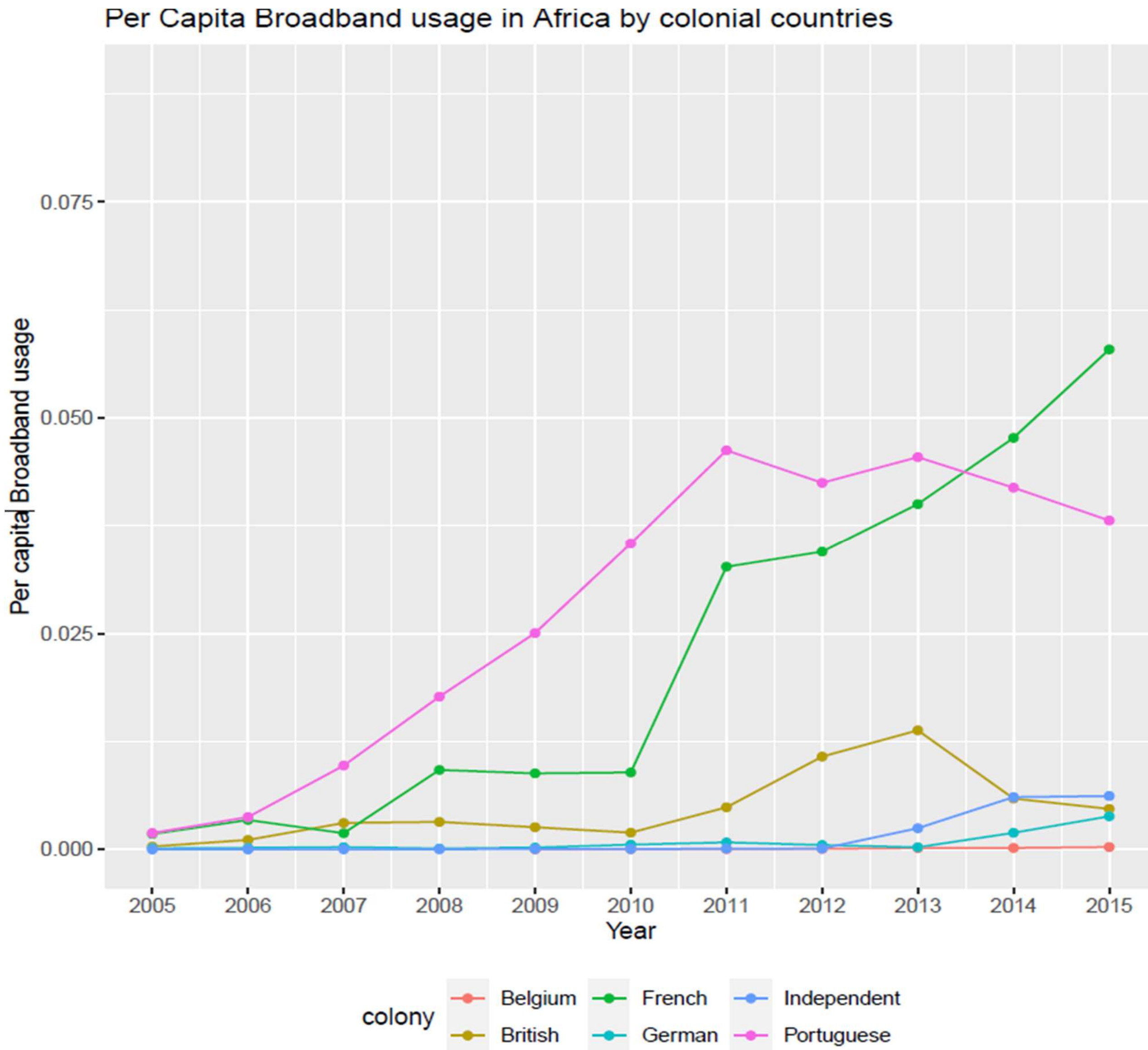

Figure 4: Graph of the Per capita broadband Internet usage from 2005 to 2015. Data source: World Bank Indicator

Comoros, Chad, Benin, Guinea, Mali, Cote d'Ivoire, Mauritania, Niger, Senegal, Djibouti, Madagascar, and Togo make up the countries colonized by the French. Cameroon was colonized by both the French and the British, but in this study, we categorized it as a country in the French colony. Nigeria, South Sudan, Lesotho, Kenya, Uganda, Ghana, Gambia The, Malawi, Zimbabwe and Sudan are the countries categorized as the British colonies in this study. Although there is ambiguity about the colonization of Eritrea, given the later British rule in the years 1941 to 1952 after the Italians, we classified the country as a British colony. Angola, Mozambique, Cape Verde, and Sao Tome and Principe are in the Portuguese colonial category, Democratic Republic of Congo and Burundi are in with Belgium, while Rwanda and Tanzania are with the Germans. However, Ethiopia and Liberia were not colonized and were referred to as independent countries in this study.

Evidently in the years 2006 to early 2014, and 2010, per capita broadband usage was at its peak in Angola, Mozambique, Cape Verde and Sao Tome and Principe. The African countries colonized by the French took over in the later years from late 2010. However, in **Figure 5**, the countries colonized by the French displays strong level of labour productivity, accompanied by the British colonies.

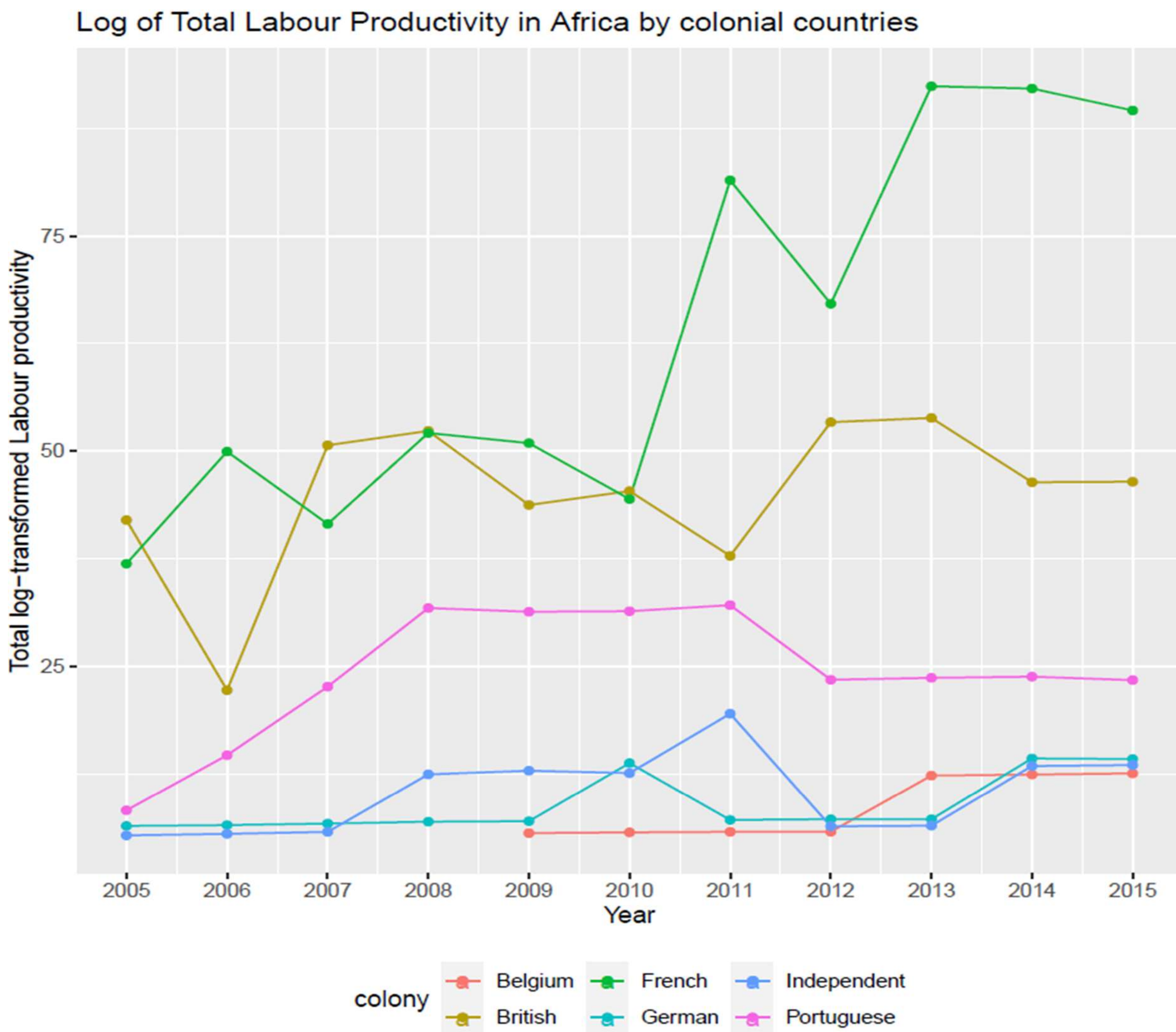

Figure 5: Graph of The log of Total labour Productivity in Africa by colonial countries from the period 2005 to 2015.
Data source: World bank Indicator

Although one cannot say that the high share of the level of labour productivity by the French colonies is caused by broadband internet, there is a consensus that the effect of the broadband Internet has a positive causal effect on the other factors that influence productivity growth like employment, business process, and human capital.

The role of government in the development of broadband Internet infrastructure and its availability cannot be downplayed. They establish policies and regulations that govern the telecommunications industry and broadband internet services. These policies involve the issuing of licenses, quality standards control, and pricing regulations that promote digital technology and create the environment and framework that encourage competition, investment, and innovation while ensuring consumer protection and fair market practices. Reports in a publication by the World Bank Group show that some areas of the Sub-Saharan African region are faced with extreme poverty due to a slow growth rate, income inequality, conflicts, and weak institutions that prevent them from harnessing the full potential of development, opportunities, and growth that digital technology offers. Accelerating broadband Internet connectivity will enable individuals, businesses, and governments in Africa to open new opportunities that foster social and economic development. According to the International Telecommunication Union-ITU, (2019), expanding mobile broadband penetration by 10 percent in Africa will scale up GDP per capita by 2.5 percent, and a 10 percent reduction in mobile costs will boost adoption of mobile broadband technology by over 3.1 percent (Nanfuka, 2022). The intensive use of ICT will foster several Sustainable Development Goals (SDGs), such as job creation, efficiency in government services, and financial inclusion. Development in the broadband internet sector will promote effective tech-enabled public delivery services, data harnessing and revolution, public management in various concentrated sectors, and more. The absence of clearly defined regulation, government commitment, skilled human capital, sufficient competition in the communication industry and the Internet Service Providers, infrastructural development, and adequate power supply, among other challenges, will only prevent this region from fully harnessing the full potential that broadband Internet connectivity offers.

The disposition of mobile telecommunications allows Sub-Saharan Africa to conquer poor, inefficient, and non-existent fixed-line infrastructure and Internet access and embrace mobile telecommunications for the use of both voice and Internet services (Mothobi & Grzybowski, 2017). Mobile phones can improve living standards, increase product efficiency for firms, and provide access to internet services for individuals like mobile money, email, social media, and internet browsing that are not entirely dependent on the availability of some physical infrastructure. In a study by Mothobi & Grzybowski, (2017) conducted in Sub-Saharan Africa, it was found that the adoption of mobile phones is higher in places with quality physical infrastructural facilities, and mobile phone users residing in areas with poor infrastructure are more likely to rely on mobile phones to make financial transactions than individuals in areas of better-quality infrastructure. One of the key factors contributing to the lack of access to financial services is deficient infrastructure and financial illiteracy. Mobile banking, or mobile money, provides access to financial account statements and transactions using mobile networks, which do not require the nearness of some other physical infrastructure. The expansion of mobile banking raises the probability of being banked (Mbiti & Weil, 2013) and may have a significant impact on economic growth in developing countries. Countries like Ghana, and Botswana had high subscription rates in 2014, while Ethiopia, on the contrary, experienced a stagnated subscription rate (Mothobi & Grzybowski, 2017).

Economists and policymakers' acclaim that the worldwide adoption of broadband Internet is the route to achieving a knowledge-based economy. The use of digital technology to advance the identification of an individual's need for medical care while at the same time maintaining quality is very important. According to a study by Vicente et al., (2020) conducted in the health-care sector of Sweden, an application was developed for transmitting real-time video images to promote effective patient assessment and diagnostic support by facilitating information flow between ambulance nurses and physicians in the role of regional medical support (RMS) in the ambulance care procedure. Based on their analysis, physicians experienced a positive impact using video image transmission in addition to the currently used mobile phone. In the absence of efficient mobile Internet access, this live saving opportunity cannot be fully harnessed, especially in the Sub-Saharan African region, where mobile Internet access is still a vision.

Additionally, Internet-based learning and the use of Internet-based facilities for teaching (McKimm et al., 2003) can facilitate learning efficiency (Cook et al., 2010). Internet literacy is a multi-faceted construct that involves the abilities to access, analyse, evaluate, and create content online (Livingstone & Helsper, 2010). Knowing the skills to access online contents facilitates the analysis of content produced by others, and this knowledge aids further access to content tools and techniques on the Internet. Internet literacy offers a research approach and opens a way for researchers to tackle Internet-based challenges.

Although the Internet promises varied benefits and opportunities on the one hand, it also comes with certain risks and may bring few negations on the other. In the education sector, students who use the Internet for educational purposes only constitute 13 percent, while those who use the Internet for online gaming, videos, social media, and social networking purposes make up about 56 percent, according to a data (Lavrinenko et al., 2019). The downsides encompass a wide range of intended and unintended experiences, including Internet scams, pornography, self-harming, violence and racial contents, harassment, and Internet bullying or privacy invasions (Livingstone & Helsper, 2010).

Based on the role played by developing countries in the global economy, their growth potential earmarks them as an interesting target for multi-national Hi-tech companies to consider and explore as a hub for new markets in the future (Badran, 2007). An Internet Report by ITU (2006) claims that broadband Internet absorption in middle-income countries (part of which are African countries) is on average higher than in upper middle-income countries, which makes the markets more attractive for investors who are willing to accept the associated higher risk level (Badran, 2007). For example, in Spain and other countries, Wi-Max technology was used within a very short time to connect villages to high-speed Internet access without relying on fixed-line networks. Similarly, the growth in IT in the USA was measured on economic indicators like employment, wages, and industry mix, and it contributed to rapid growth in employment and overall businesses. The IT sector was estimated to account for about 50% of the GDP growth rate in the Republic of Korea during the year 2002 (Badran, 2007). The core value of this study is for developing countries to adopt e-strategies in government, health and in education to induce demand for high-speed internet access. Economists have attributed the robust growth in U.S. productivity to the unprecedented investment and development of information technology (Wei-Te Hsieh & Goel, 2019).

6.4. LIMITATIONS

In our study, our findings do not fully reflect the impact of broadband Internet on labour productivity in the African region. This is because we only used available data on fixed broadband subscription or usage, as our measure for broadband Internet. However, in countries like Tanzania, Nigeria, Ghana, there is a high share of the use of mobile Internet like Wide Area Network (WAN), Local Area Network (LAN), and other forms of mobile Internet networks not captured in our study.

Reverse causality and endogeneity bias can be listed as a limitation in our study. Given the potential endogeneity of other labour productivity growth determinants (capital investment, research, and development) which equally accounts for labour productivity can cause biased and inconsistent estimates of the true causal effect. To address such issues, applying different approach of statistical analysis, to obtain comparable inferences and conclusions is highly recommended. There is a possibility that low productivity may cause low ICT investment, while high ICT investment may cause high productivity, or that both ICT investment and productivity growth may be jointly determined by a third variable (Wamboye et al., 2016).

Omitted variables and missing observations are common issues in statistical analysis, that involve when important variables are not captured in a regression model, or when observations in a data are not sufficiently captured to model the true values of a variable, thereby causing measurement error and inconsistent estimates of the relationships between the variables in a regression model (Wamboye et al., 2016)

7. CONCLUSION

The impact of broadband Internet on labour productivity in the African region has been remarkable and evolutional. The widespread adoption and accessibility of broadband Internet has favorably impacted labour productivity growth on a cross-country level.

In this study, a panel data from the World Bank Indicator consisting of 34 African countries was analyzed using a fixed effect panel regression model, from the period of 2005 to 2020. The findings suggest a 0.11 percent increase in the logarithm of labour productivity for each percent increase in broadband Internet used in the selected countries.

Increased access to information and technology, facilitated by broadband Internet has allowed employers to keep up with the most recent developments in research, best practices, and industry trends. There is a recorded increase in various production sectors due to improved knowledge, abilities, skills and access to information.

In addition, broadband Internet has opened new opportunities for entrepreneurial investment and development. It has enhanced digital inventions, e-commerce platforms, while providing avenues for productivity growth and employment opportunities. Consequently, the entrepreneurial environment in Africa has flourished, leading to increased productivity and economic development especially in areas of mobile money and enhanced banking services.

Furthermore, communicability and teamwork in business and among individuals has improved due to broadband Internet. Through numerous digital avenues, employees may speedily engage colleagues, stakeholders, and people in the value chain notwithstanding their location. Remote operation, collaborative working platform, virtual meetings, data exchange are common practices in firms in the developed countries, and are complementary of the broadband Internet. In the areas of education, broadband Internet connectivity has improved access to online education and hands-on skill training, giving room for workers to acquire new skills and qualifications remotely. This has enhanced the overall quality of the workforce and bridged the skills gap ultimately, while contributing to labour productivity.

The study on the impact of broadband Internet on labour productivity requires continuous research to enable institutions, policy makers and investors to adopt strategies on how to improve broadband Internet accessibility and infrastructure development in the areas of Sub-Saharan Africa. These areas possess a viable market for investment in broadband and will benefit from improvement of their living standard when such technological development is made accessible.

However, many African countries are still posed with challenges to harness half of the benefits which broadband Internet offers. This constraint ranges from Internet cost, accessibility, and skills to utilize the Internet. To provide fair access to broadband connection, the digital divide between the high- and low-income regions must be addressed, and the differences across countries as well. To fully optimize the potential impact of broadband Internet on labour productivity in the African region, policies, and strategies to improve broadband infrastructures and reduce the Internet prices must be addressed.

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APPENDIX

Appendix 1: Lagrange Multiplier Test or Honda Test

```
        Lagrange Multiplier Test - (Honda)

data:  log(Labour_prod) ~ log(Broadband) + log(Pop_total) + CPIA_Standardized +  ...
normal = 36.216, p-value < 2.2e-16
alternative hypothesis: significant effects
```

Appendix 2: F- Test for Individual and Time effect

```
        F test for individual effects

data:  log(Labour_prod) ~ log(Broadband) + log(Pop_total) + CPIA_Standardized +  ...
F = 135.79, df1 = 33, df2 = 288,
p-value < 2.2e-16
alternative hypothesis: significant effects

        F test for time effects

data:  log(Labour_prod) ~ log(Broadband) + log(Pop_total) + CPIA_Standardized +  ...
F = 1.1359, df1 = 15, df2 = 306,
p-value = 0.323
alternative hypothesis: significant effects
```

Appendix 3: F- Test for Individual and Time effect

```
        F test for individual effects

data:  Labour_prod ~ Broadband
F = 44.105, df1 = 33, df2 = 291,
p-value < 2.2e-16
alternative hypothesis: significant effects

        F test for time effects

data:  Labour_prod ~ Broadband
F = 0.91468, df1 = 15, df2 = 309,
p-value = 0.548
alternative hypothesis: significant effects
```

Appendix 4: Three type Lagrange Multiplier

```
        Lagrange Multiplier Test - (Honda)

data:  model_formula
normal = 36.216, p-value < 2.2e-16
alternative hypothesis: significant effects


        Lagrange Multiplier Test - time
        effects (Honda)

data:  model_formula
normal = -0.99452, p-value = 0.84
alternative hypothesis: significant effects


        Lagrange Multiplier Test - two-ways
        effects (Honda)

data:  model_formula
normal = 24.905, p-value < 2.2e-16
alternative hypothesis: significant effects
```

Appendix 5: Categorization of African countries under their colonies

S/N	Country	Region	Sub-region	Colonial country
1	Angola	Africa	Middle Africa	Portuguese
2	Benin	Africa	West Africa	French
3	Burundi	Africa	East Africa	Belgium
4	Cameroon	Africa	Middle Africa	French[5]
5	Cape Verde	Africa	West Africa	Portuguese
6	Chad	Africa	Middle Africa	French
7	Comoros	Africa	East Africa	French
8	Congo Democratic Republic	Africa	Middle Africa	Belgium
9	Cote d'Ivoire	Africa	West Africa	French
10	Djibouti	Africa	East Africa	French
11	Eritrea	Africa	East Africa	British[6]
12	Ethiopia	Africa	East Africa	Independent
13	Gambia, The	Africa	West Africa	British
14	Ghana	Africa	West Africa	British
15	Guinea	Africa	West Africa	French
16	Kenya	Africa	East Africa	British
17	Lesotho	Africa	South Africa	British
18	Liberia	Africa	West Africa	Independent
19	Madagascar	Africa	East Africa	French
20	Malawi	Africa	East Africa	British
21	Mali	Africa	West Africa	French
22	Mauritania	Africa	West Africa	French
23	Mozambique	Africa	East Africa	Portuguese
24	Niger	Africa	West Africa	French
25	Nigeria	Africa	West Africa	British
26	Rwanda	Africa	East Africa	Germany
27	Senegal	Africa	West Africa	French
28	South Sudan	Africa	East Africa	British
29	Sudan	Africa	North Africa	British
30	Sao Tome & Principe	Africa	Middle Africa	Portuguese

[5] They were also colonized by the British
[6] Was also colonized by Italy

31	Tanzania	Africa	East Africa	Germany
32	Togo	Africa	West Africa	French
33	Uganda	Africa	East Africa	British
34	Zimbabwe	Africa	East Africa	British

Appendix 6: Breusch- Pagan LM Test for cross sectional dependence in panel

```
        Breusch-Pagan LM test for
        cross-sectional dependence in panels

data:  log(Labour_prod) ~ log(Broadband) + log(Pop_total) +
CPIA_Standardized +     log(Education)
chisq = 1010, df = 479, p-value <
2.2e-16
alternative hypothesis: cross-sectional dependence
```

Appendix 7: Breusch-Godfrey/Wooldridge Test for serial correlation in panel

```
        Breusch-Godfrey/Wooldridge test for
        serial correlation in panel models

data:  log(Labour_prod) ~ log(Broadband) + log(Pop_total) + CPIA_Standardized +  ...
chisq = 60.572, df = 1, p-value =
7.093e-15
alternative hypothesis: serial correlation in idiosyncratic errors
```