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**ICT Development and Economic Growth: Are Southeast African Countries
Doing Enough to Leverage on ICT?**

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Abstract

ICT is fast growing across continents and has brought about aspects of economic growth within countries, particularly developed countries. Over the years, productivity has noticeably increased with businesses and governments having easy access to global markets, hence improved trade openness. In this study, we analyze the state of ICT in Southeast African countries to understand whether ICT has been underutilized or to whether they are leveraging the use of it. From literature, Solow (1956) and Swan (1956) have argued that absence of technology innovation leads to economic stagnation that leads to high unemployment. In this study, we analyze ICT and its impact on unemployment as well as human capital in Southeast Africa. Also, the study analyzes consumption expenditure, trade and inflation and their relationship with ICT while alluding that they could be potential growth enhancing factors of ICT. The study proposes to use a two-step system generalized method of moments (GMM) estimation technique while drawing its theoretical underpinnings from the neo-classical growth model.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

The development of Information and Communication Technology (ICT) infrastructures and whether it has an impact on economic growth has been of interest to many economic researchers. Empirical research has shown that ICT development is positively correlated with economic growth, especially in developed economies (Said, Hassen, & Hammami, 2015). Evidently, one could arrive at the conclusion that without ICT, there would be no growth through observing: the health sector where databases in hospitals are used to further research in the medical field (Fisher, Lindenauer, & Feudtner, 2012), the education sector where schools can carry out remote learning through online sources (Shaw, 2010), the transport sector where people can easily access taxis and buses through ride hailing mobile applications (Kong & Moody, 2020), and improved financial systems where people can transfer money efficiently through digital payment systems (Amca & Kansoy, 2007). ICT refers to communication devices that constitute mobile phones, computers, networks, and satellite systems (Adeleye, 2019).

Regarding the potential benefits of ICT development, the extent to which countries have developed various sectors within their economy is variant across the globe. The interest shown by researchers has resulted to questions that seek to understand the existence of this variation. Glimpsing at leading economies such as the US, the level of output in the manufacturing sector has been increasing with time (Hicks & Devraj, 2015). Arguably, the continuously increasing demand for both durable and non-durable goods from both local and global consumers has led to an increase in output, ergo, to meet this increasing demand, this necessitates the existence of proper distribution channels. Hicks & Devraj (2015) found that through improved ICT infrastructures which are disguised as distribution channels, such manufacturing firms in leading economies have been able to meet increasing demand.

Also, the increasing use of ICT has led to the rise of a new economy, the “sharing economy”. A sharing economy is a system in which consumption is through community-based online services, that allow peer to peer sharing of goods and services mostly in the form of renting (Hamari, Sjöklint, & Antti, 2016). The growth of this economy has led to innovations that allow market interactions to be cheap and efficient by making them accessible online. This has promoted the use of underutilized assets

by easing their access in the marketplace and has reduced their need of ownership (Sundararajan, 2016). Through forces of demand and supply, the availability of jobs in the market is expected to increase and ultimately reduce the levels of unemployment.

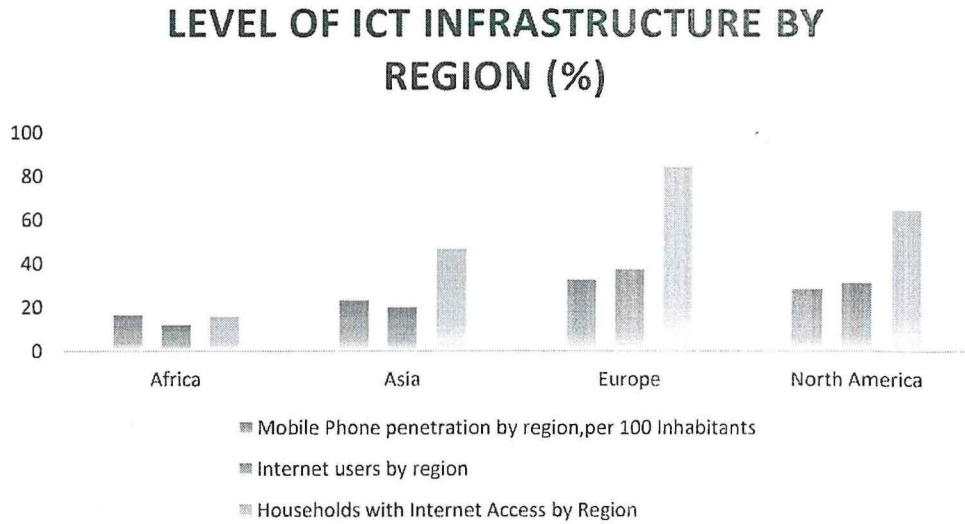
However, such innovations through ICT are advanced through continuous research and development. Countries that have shown tremendous growth because of ICT have prior invested a lot of money in research and development (R&D). Generally, ICT infrastructures have been key tools in ensuring proper systems of collecting data, storing, analyzing, and interpreting the data are in place during the R&D process (Prado & Marzal, 2013). Consequently, innovations through R&D have led to increased productivity of workers by merging ICT infrastructures and electronics to automate production (Schwab, 2016). Despite R&D's positive impact, feasibility of investing in R&D has proven to be a challenge for developing economies due to high investment requirements that are beyond the range of affordability (Meng & Mingzhi, 2002). Instead, most developing economies resort to imitate business models from other leading economies (Benhabib & Spiegel, 2003).

In addition, leading-economies such as the US, allow for the diffusion of ICT infrastructures to following-economies (developing economies). However, this is dependent on the levels of education in the following economies. Benhabib & Spiegel (2003) assert that the higher the levels of education in a country the faster the diffusion of technology and this in turn affects the growth of the economy. Hence, human capital is a growth enhancing channel of ICT. Part of the motivation of this paper is to assess whether human capital and ICT are positively related and if this influences the growth of economies. Also, we seek to investigate whether the reverse holds as to whether high levels of ICT penetration imply high levels of human capital.

Despite the trickle down of innovations from developed to developing economies through ICT, the accessibility of ICT infrastructures in developing countries is still a challenge. The existing digital divide in developing economies has lagged the economic impact of ICT (Ming-te, 2001). First, poverty could explain this phenomenon in that most of the population in sub-Saharan Africa cannot afford to have ICT services at their disposal. Second, the political landscape has deterred from investing in ICT because ICT infrastructures can be used as channels to enhance

transparency within the system. Notwithstanding the minimal investment in the sector, national allocations in Africa increased by 85% in 2018 to \$1.1bn. Reports from the Infrastructure Consortium of Africa (ICA) show that West Africa had the highest allocation of \$109m.

Figure 1: ICT Infrastructure Penetration by Region.



Various African countries have shown the importance of innovations through ICT. For instance, Kenya is one of the leading countries in the world when it comes to mobile money with its mobile money transfer service (M-pesa) promoting growth of the financial sector in Kenya.

Existing literature has been centered on addressing whether ICT development has a positive impact on the growth of economies. This study seeks to investigate the nexus from a different standpoint. There seems to be a consensus in the literature world that in developed economies, the relationship between ICT and economic growth is positive (Koutroumpis, 2009; Sepehrdoust, 2018). In Sub-Saharan Africa, empirical results have failed to arrive at the same conclusion (Ranis, 2004). Higher penetration levels have indicated potential slowdown in economic growth. However, the focus on this study is to investigate whether African countries are doing enough to leverage on the rising ICT penetration levels. In this study, we focus on four ICT variables: internet users, broadband users, mobile phone users and telephone users.

1.2 Problem Statement

ICT is a fast-growing in Sub-Saharan Africa and subsequently governments within the Southeast African region, our focus panel on this study, have proposed to include use of ICT in their budgeted projects. Rwanda, for example, has efficiently leveraged on ICT in the health sector with levels almost reaching the MDG for maternal healthcare (Ben-Ari, 2014). The Kenyan government, comparably, has incorporated the use of ICT in their big 4 projects having allocated \$160m in the ICT sector, which is the largest allocation within Africa to ICT (The Infrastructure Consortium for Africa, 2020). This has been the trend in most Southeast African countries. With continuous investments in ICT, it is expected that through direct interaction with various sectors in the economy, issues such as lack of education and unemployment could indirectly be addressed and potentially be eradicated.

However, African economies at large still trail behind as compared to other regions in the world. According to World Bank reports, internet penetration in Africa is at 24%. Though, this is not an indicator as to whether African economies are converging at global levels. Research from Deco et al. (2019) has shown that sub-Saharan countries portray convergence to the world technology frontier.

Various studies have been conducted to analyze the relationship between ICT development and economic growth. Existing literature, however, has shown contradicting results on the relationship specifically in developing economies. This contrasts the theory that ICT development plays a significant role in economies achieving sustainable economic growth as concluded by (Ejemeyovwi, Osabuohien, Johnson, & Bowale, 2019). This shows that the study is still open for discussion and that there is more to be researched in the area within African economies. Furthermore, developed economies that have shown tremendous economic growth due ICT infrastructures also show that complementary factors such as the trade environment and consumption expenditure have a positive relationship with the growth of these economies (Sulong & Albiman, 2016). Could this imply that the success in the penetration levels of ICT is interlinked with these complementary factors?

In sub-Saharan Africa, studies conducted have mainly focused on economic growth with its relation to ICT infrastructures with a few having barely scratched the surface on analyzing whether Southeast African countries are leveraging on ICT technology.

This study proposes to fill the gap by analyzing the interactions of ICT with unemployment, trade, consumption expenditure, inflation, and human capital. This study also proposes the use of panel estimation by using a Generalized Method of Moments (GMM) estimator as opposed to time series econometric analysis.

1.3 Research Objectives and Questions

1.3.1 General Objective

The objective of the study is to examine the relationship between ICT development and economic growth.

1.3.2 Specific Objective

1. To examine the impact of ICT infrastructures on the growth of economies in Southeast Africa.
2. To investigate the complementary factors for ICT development in Southeast Africa. This involves the assessment of human capital and consumption expenditure, with regards to promoting economic growth by forming an interaction term with ICT.

1.4 Significance of Research

(Sulong & Albiman, 2016) argues that from a policy perspective, developing economies particularly those within the Sub-Sahara region, should implement policies that promote investment of ICT infrastructures to ensure sustainable development and economic growth. Existing literature has swayed from investigating the benefits of investing in ICT and has rather focused in its impact to economic growth. This research would benefit the policy makers in Southeast African member countries by offering insights to whether ICT innovation is currently being under-utilized and on how the respective governments can leverage on the use of ICT. In addition, it would also contribute to the academic society by extending the literature on the topic of how economic growth is related to ICT investment and contribute to the overall discussion on ICTs growth enhancing channels.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

In this chapter, we review the theories that best explain the underpinning relationship between ICT and economic growth. The neo-classical growth theory, the neo-Schumpeterian theory, and the theory of endogenous growth are discussed below and were chosen from literature that from a consensus, agree these are the relevant theories to the topic of study (Sulong & Albiman, 2016; Khuong, 2011; Said, Hassen, & Hammami, 2015).

2.1 Theoretical Review

2.1.1 Neo-Classical growth theory

An essential to increasing productivity is through the acceleration of production inputs such as human capital (Khuong, 2011). Solow (1956) and Swan (1956) theoretical works have focused on the input factors necessary for productivity to increase. From their studies, forces that ultimately lead to economic growth are labor (L), physical capital and human capital (K), and technology change (A). The aggregate production function in equation 2.1 represents economic growth (Y), which is the GDP per capita, as a function of capital and labor.

$$Y = Af(K, L) \quad (2.1)$$

Ideally, while increasing capital goods per worker (capital deepening), output per worker is expected to increase as presented by Aghaei & Rezagholizadeh (2017), till the law of diminishing marginal returns sets in. Any further increase in capital goods per worker is expected to cause economic stagnation, where such periods tend to be accompanied by high unemployment rates.

Marginal productivity of labor will also be expected to increase since the wage rate per worker is increasing. However, diminishing returns from an increasing capital-labor ratio will in the long run lead the economy into a steady state. Similarly, increase in real wages will also be followed by a fall of the return on capital to where capital deepening becomes less profitable, hence a steady state. To prevent the stagnation of both capital income and wages, Solow (1956) and Swan (1956) propose the use of technology innovation. Technological change, according to them, involved the use of advanced production processes and introducing new and improved goods and services such as internet and broadband technology.

We study the effect of ICT penetration on unemployment levels to inform the notion as to whether Southeast African countries are leveraging on ICT. The neo-classical growth theory seems to address unemployment by assuming technology stops economic stagnation and ultimately curb unemployment. Hence the model will be pivotal in this study.

2.1.2 Neo-Schumpeterian growth model

The underpinnings of the neo-schumpeterian model are focused on innovation through technology implying their centrality in being the key drivers of emerging industries through promoting entrepreneurship (Hanusch & Andreas, 2007). In addition, it assumes that economic growth is as a result of creative destruction in business that ultimately leads to innovation of new technologies (Aghion, Akcigit, & Howitt, 2014). Despite its importance, innovation has mainly been steered by leading economies due to availability of funds to invest in research and development (Prado & Marzal, 2013).

For many developing economies, diffusion of technology innovations and imitation is the available option. However, the possibility of cross-country convergence developing economies was documented by (Aghion, Akcigit, & Howitt, 2014; Benhabib & Spiegel, 2003). The diffusion of technology, by developing countries, was argued to reach the global technology frontier at a faster rate. Howitt (2000), argued that the possibility of this phenomenon was because developing countries take a large technology advance when catching up to the world technology frontier.

The neo-schumpeterian model is centered on new innovations as the driver for economic growth. In this study, however, we mainly focus on the evolution of respective ICT infrastructures and not on the innovation of new ones. In addition, the panel under study is from the sub-saharan region, which arguably is subject to diffusion of technology as opposed to new innovations.

2.1.3 Endogenous growth models

Continuous investments in ICT has over time proven to yield high returns (Pradhan, Malik, & Bagchi, 2018). First, the positive network externalities of ICT use by modern economy businesses, that is, the ripple effect of derived value by users has been quite profound the more people interact with ICT. Market transparency through digital systems has also opened access to international markets causing an increase in trade. Ideally, the continuous generation of ideas that lead to innovations in the marketplace

is expected to be the main driver of economic growth, hence the endogenous growth model.

The underpinnings of the model as developed by Romer (1989) and Barro (1996) are to treat technological change as an endogenous variable, implying that economic growth is dependent on capital accumulation. On the contrary, studies by Swan (1956) and Solow (1956) only consider technology to be exogenous to their models and assume diminishing marginal returns to human physical capital. Romer (1989) modelled how decisions by economic agents and conditions in the market determine how new technologies are created. He modified the neo-classical production function to allow for self-sustaining endogenous growth. In his model, both physical capital stock and knowledge capital stock are accounted for. The additional knowledge capital stock in his model suggests non diminishing marginal returns to knowledge capital.

Economies can generally get more output with the same inputs of capital and labor if they invest in R&D to generate new ideas that increase productivity. (Romer, 1989). With output (growing in tandem with investments) being greater than depreciation, the accumulation of capital is expected to further boost GDP per capita. In conclusion, if ideas continue improving, economies will continuously grow and avoid stagnation.

Despite the endogenous growth model being a more recent model compared to the neo-classical and neo-Schumpeterian models, its practicality in terms of measuring ideas seems quite far-fetched. In this study, we alternatively advance the Solow model in explaining our research objectives.

2.2 Empirical Literature

2.2.1 ICT and Investments

ICT infrastructures have been pivotal in promoting economic growth. In addition, investments poured into ICT have contributed to its development process. For instance, Koutroumpis (2018) sought to analyse whether income distribution within countries affects the investment choice in ICT as well as whether network speeds affect the growth of economies. The study involved a panel of OECD economies from 2002 to 2016. The study could have been approached in two different ways by either employing an experimental research design with required treatment or by incorporating the use of macro data in a growth accounting approach. Koutroumpis replicated Waverman et al. (2005) framework, the second approach, by analyzing both

the direct effect and reverse effect of ICT using a micro demand and supply model in combination with an aggregate production function. His results showed that income distribution contributed to the adoption and supply of ICT. In addition, countries that invested in higher speeds of ICT reported higher output per capita. ,

Lee et al. (2012) studied a panel of sub-Saharan countries to find out the effect of ICT development on economic growth from period 1975 to 2006. In this study, the ICT variables are also factored to be endogenous, implying a bidirectional relationship between economic growth and investments in the ICT infrastructures. By replicating the cross country growth framework as presented by Datta & Sumit (2004), they focus on a panel of 44 sub-Saharan countries that have been experiencing robust growth in ICT within the region. The increasing use ICT was documented to be as a result of lower costs of investing in it. They find that the increasing use of ICT within the region has promoted economic growth. Their study however did not capture recent ICT variables such as internet and broadband penetration that have gained the spotlight among researchers, hence their findings showing that investing in ICT was inexpensive. Internet and broadband technology however, have shown to be costly for most individuals to invest in.

2.2.2 ICT and Growth Enhancing Channels

With regards to economic growth, Pradhan et al. (2018) sought to find out the nature and direction of the relationship between ICT and macroeconomic factors such as Consumer price index, labor force and gross fixed capital in a panel of oil producing countries (OPEC). The year-on-year data ranging from 2001-2012 was used in conducting the cointegration and causality tests. They identified that both ICT infrastructure and financial development showed no significance in the long-term growth of western Asian economies. However, Sepehrdoust (2018) conducted a similar study to capture both ICT and financial development on OPEC countries from the year 2002-2015. He replicated the generalized solow growth model and the GMM estimator to analyze the relationship. The results were different showing that a 1% increase in ICT use leads to the growth of the economy by 0.05%. The contrasting results could be explained by OPEC countries being major oil producers implying that they are highly dependent on revenues from the trade of oil as their main source of revenue and economic growth.

Sassi & Goaid, (2013) similarly investigated the finance-growth puzzle that is based on the schumpeterian model as well as the ICT-growth puzzle on 17 countries from the Middle East and North African (MENA) region from 1960-2009. From schumpeterian theory, both ICT and financial development are expected to promote economic growth. However, their findings on financial development were consistent with empirical literature which contrasts theory, finding a significantly negative effect of financial development on economic growth. The banking sector which is the hub of financial development, was observed to operate as if in a monopolistic market due to high barriers of entry that significantly lessen the competition.

Further, while using a method of moments estimation method, they observed that the interaction between ICT infrastructures and financial development positively impacted growth. However, this was constrained to a threshold level of ICT development. Despite the required threshold, ICT infrastructures independently proved to promote economic growth. In relation to trade openness, reduced trade barriers signaled triggering economic growth. Inflation and government consumption also had a significant impact on growth with high rates of inflation and high government consumption indicating macroeconomic instability that dampens economic growth.

2.2.3 ICT and Economic Growth

Toader et al. (2018) investigated whether productivity can be enhanced by ICT use and what effect does this have on economic growth using a panel of European countries under an 18 year period ranging from 2000-2017. In their study, both a linear regression analysis and a General Method of Moments estimator were factored. They found that digitization does enhance productivity and that a 10% increase in digitization would lead to a 0.75% increase in a country's GDP. His results hail from the fact that increased trade openness increases competition within local firms and imports as well as increases global demand for exports. As a result, pressures to: (1) innovate new methods that will reduce production costs, as well as (2) adopt technologies that will ultimately increase productivity, lead to economic growth.

Sulong & Albiman (2016) similarly examined the long run relationship between ICT on economic growth within the sub-Saharan region. They analysed data of 45 countries for a period of 27 years, from 1990-2014, focusing on what the main growth

enhancing channels of ICT are. They widened the scope of ICT variables including internet and mobile penetration to their study. Using a panel method technique of GMM estimation, they focused on the non-linear effect of ICT infrastructures on economic growth and their threshold values. They reported a direct impact of ICT infrastructures on the growth of Sub-Saharan economies. In addition, human capital and domestic investment were identified to be the main growth enhancing factors of ICT in the economy. However, their results showed that mass penetration of ICT infrastructures leads to slow economic growth going against the expectation of a direct relationship existing. This implies that sub-Saharan countries are still faced with the challenge of absorbing the full potential of ICT due to factors such as poverty and political instability. This study was consistent with that conducted in the MENA region, where a threshold level is required to be of value to promoting economic growth.

Khuong (2011), using a panel of 85 countries for a 10 year period from 1996 to 2005, argued that ICT penetration can positively affect growth of economies by encouraging technology diffusion and innovation. This enhances the quality of decision making by firms and households ultimately increasing demand and reducing production costs which in both cases, increases output levels. He analyzed whether the world economic performance improved within the period of study as compared to the previous decades. In addition, the study was concerned at whether there were significant structural changes on the growth patterns of these countries. While controlling for other potential growth drivers and country fixed effects, he employed a GMM estimator to analyze causal link between ICT and growth. Using the chow test for structural stability, the study indicated substantial economic growth and significant structural change as opposed to subsequent previous 10 year periods (1976-1985 and 1986-1995), as well as a causal relationship between ICT infrastructures and economic growth.

Deco et al. (2019) investigate whether internet, mobile and telephone use promotes economic growth. To capture the effect, they use a dynamic panel GMM estimator on a panel of Southeast African countries from 2000 – 2015. Their analysis compared countries that had privatized ICT infrastructures to those that had not. They found that conditional convergence was present showing that countries which grow at a slow rate had the highest levels of output. Also, they found that ICT infrastructures have a positive impact on the growth economies by 0.03 and 0.01 for countries that privatized

and those that did not privatize ICT respectively. In general, they reported a strong impact of ICT on economic growth.

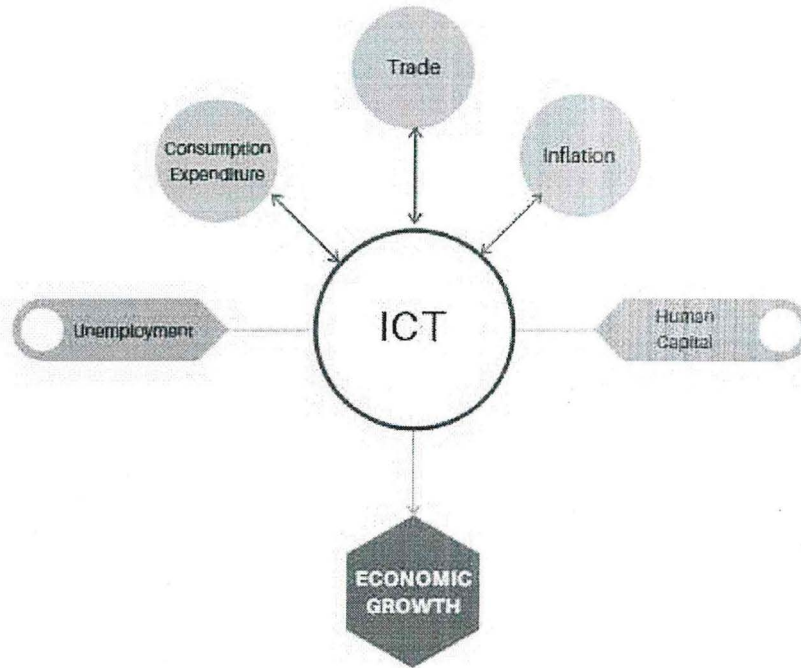
2.3 Research Gap

This study differs from previous studies as it proposes to investigate the causality between ICT and its expected growth enhancing factors; consumption expenditure and human capital. This study also extends the literature by looking at the variables unemployment and consumption expenditure, which have not been captured in existing literature. By including unemployment and consumption expenditure, the study questions whether ICT development has an impact on the unemployment levels plus whether consumption expenditure is a growth enhancing channel for ICT development.

2.4 Conceptual Framework

The conceptual framework offers a snapshot of the research study based from the literature review and the identified research gap.

Figure 2: Conceptual Framework



CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter focuses on the method used for analyzing the relationship between the development of ICT infrastructures and economic growth. The study employs a standard growth model that underpins the theoretical relationship between the variables. Thereafter, the study specifies the model to be used and the econometric method to be used.

3.2 Model Specification

3.2.1 Theoretical Underpinning

We consider a production function such as one in the equation below:

$$Y_{it} = A_{it} f(L_{it}, K_{it}) \quad (1)$$

Where: The aggregate output (Y) contains capital (K) and labor(L) for the countries (i) at time (t). A_t represents the technology level employed. Employing a Cobb-Douglas function as expressed below:

$$Y_{it} = A_{it} L_{it}^{\alpha_1} K_{it}^{\alpha_2} \quad (2)$$

The log form of the equation (2) is written as:

$$\ln Y_{it} = \ln A_{it} + \alpha_1 \ln L_{it} + \alpha_2 \ln K_{it} + \omega_{it} \quad (3)$$

Where:

$$\omega_{it} = \theta_i + \varepsilon_{it}$$

ω_{it} -

θ_i - The country specific unobserved effect which is time invariant

ε_{it} - The non-stochastic error term where the $E[\varepsilon_{it}] = 0$

Equation (3) can be re-written as:

$$\ln Y_{it} = \ln A_{it} + \alpha_1 \ln L_{it} + \alpha_2 \ln K_{it} + \theta_i + \varepsilon_{it}$$

Following equation (4), we can assume $\alpha_1 = \beta$, $\alpha_2 = \alpha$, $y_{it} = \ln Y_{it}$, $a_{it} = \ln A_{it}$, $l_{it} = \ln L_{it}$ and $k_{it} = \ln K_{it}$.

Our final model would be represented by:

$$y_{it} = a_{it} + \beta l_{it} + \alpha k_{it} + \theta_i + \varepsilon_{it} \quad (5)$$

3.2.2 Model Specification

The standard growth model below is adopted to carry out the study and is similar to what other researches have used such as (Sulong & Albiman, 2016) and (Bahrini & Qaffas, 2019):

$$GDPC_{it} = \alpha_0 + \beta_1 GDPC_{it-1} + B_2 ICT_{it} + \beta_3 x_{it} + \omega_i + \varepsilon_{it} \quad (6)$$

Where:

it – Represents the country specific data (i) at a specific period in time (t)

$GDPC_{it}$ – Represents the dependent variable Gross Domestic Product (GDP) per capita.

$GDPC_{it-1}$ – The lagged Gross Domestic Product (GDP) per capita used to capture the convergence effect of the countries .

ICT_{it} - Represents the proxies used to measure ICT penetration in the panel economies

x_{it} - Represents the control variables which are introduced to control for any contribution that they may have on the dependent variable (economic growth) of the panel countries.

ω_i – Represents the unobserved terms specific to each Country in this study and is time invariant.

ε_{it} – Represents the error terms

The $GDPC_{it}$ variable is used a proxy to measure economic growth and this is consistent with previous studies which have proven GDP to be a good measure for economic growth . Also, $GDPC_{it-1}$ variable is included to capture the convergence effect because we assume a dynamic process in which the lagged values may affect present values. In this case β_1 value for $GDPC_{it-1}$ is expected to be significant verifying that it may affect present GDP per capita (Barro, 1996). α_0 is a constant term

The ICT term is proxied by:

INT_{it} - Represents individuals using internet (% population)

MOB_{it} – Represents mobile cellular subscriptions (per 100 people)

BBD_{it} - Represents fixed broadband subscriptions (per 100 people)

The control variables term x_{it} is used to capture macroeconomic development within the economies and is proxied by:

UNP_{it} - Unemployment (as % of total labor force)

HUM_{it} - Human Capital

INF_{it} - The inflation, consumer prices in percentage

$CONS_{it}$ - The final consumption expenditure

Z_{it} - Growth Enhancing Factors of ICT

We include an interaction term in our model of ICT proxies and its expected growth enhancing factors to test on ICTs dependence on human capital, final consumption expenditure, trade and inflation in promoting economic growth. The equation is expressed below:

$$GDPC_{it} = \alpha_0 + \beta_1 GDPC_{it-1} + B_2 ICT_{it} + B_3 ICT_{it} Z_{it} + \beta_5 x_{it} + \varepsilon_{it}$$

3.2.3 The Generalized Methods of Moments Estimation Technique

To capture the long run relationship between the variables, the study uses a panel Generalized Method of Moments estimator following the extended neo-classical model version of the growth framework used to conduct panel analysis presented by (Roe, 2003; Barro, 1996). Given the nature of the data being year-year data, it is not possible to carry out our analysis on a time series setting.

(Arellano & Bond, 1991) argue that the use of GMM estimator helps us to avoid problems such as those of unobserved panel heterogeneity, serial correlation and endogeneity of lagged dependent variable. According to Bahrini & Qaffas (2019), traditional methods of panel analysis do lead to the problem of country specific effects especially when using a large sample size of the countries. Moreover, using traditional methods will lead to biased and inefficient parameters. To capture and deal with the endogeneity problem between the lagged $GDPC_{it-1}$ and $GDPC_{it}$, we use instrumental variables.

Table 1: List of Sample Countries

Select Countries within Southeastern Africa	
Botswana	Mauritius
Burundi	Mozambique
Comoros	Rwanda
Djibouti	Sudan
Ethiopia	South Sudan
Kenya	Tanzania
Madagascar	Uganda
Malawi	Zambia
	Zimbabwe

3.3 Data

This study focuses on (17) Countries within the Southeastern Africa region to investigate the impact of the development of ICT infrastructures on economic growth from the period 2007 to 2017 (Wieschhoff, 2013; Sowell, 2004). Table 1 shows the name of the countries sampled for the analysis. The 17 countries within the region were chosen because of data availability. The study uses secondary data that was obtained from the World Bank Open Data databank and the East African Community data portal.

3.4 Data Analysis

3.4.1 Unit Root Test

In this study, we use the Levin-Lin-Chu test and Fisher-Type test to test for presence of a unit root in our panel data. This is to test for the stationarity of our variables.

Where:

H_0 : The presence of a unit root in our panel

H_a : No presence of a unit root in our panel

3.4.2 Hausman Test

The Hausman test is used to test for whether our panel data has endogenous regressors. This will inform the decision to whether use the fixed effects or the random effects model.

H_0 : *Fit a re model (random effects model)*

H_a : *Fit a fe model (fixed effects model)*

3.4.3 Test for serial correlation

When modelling, serial correlation will result to smaller standard errors and a higher R-squared.

H_0 : *There is absence of serial correlation*

H_a : *There is presence of serial correlation*

3.4.4 Arellano-Bond Serial-Correlation Test

In this study, we use the Arellano-Bond test to check for serial correlation in our data. We test for first order and second order serial correlation on our first differenced errors where:

H_0 : *Errors in the first difference show no serial correlation of order 2 AR(2)*

H_a : *Errors in the first difference show serial correlation of order 2 AR(2)*

If we fail to reject the null hypothesis that there is no second order serial correlation would imply that our original error term is not serially correlated, and that our moment conditions are specified correctly. If we reject the null at higher orders, this will imply that the moment conditions are invalid.

In order for no serial correlation to exist in the errors, our AR(1) should be significant at the 5% level however our AR(2) is expected to not be significant at the 5% level. Hence, we reject the null hypothesis when:

$$pr > 5\%$$

3.4.5 Hansen Test

We use the Hansen test to check for overidentification in our model. Overidentification means that the model has more instruments than the number of groups.

H_0 : *Overidentification restrictions are valid*

H_a : *T* Overidentification restrictions are not valid

We fail to reject the null hypothesis if the probability obtained is greater than 0.05 from:

$$\text{Prob}>\chi^2 \geq 0.05(5\%)$$

However, if the probability < 0.05 , we reject the null hypothesis implying that we must impose restrictions on our instrument variables.

CHAPTER 4: ANALYSIS INTERPRETATION AND DISCUSSIONS

4.0 Introduction

This chapter represents the findings from the study. First, we present the descriptive statistics, then the diagnostics tests carried out, then the empirical findings from the study regression.

4.1 Descriptive Statistics

The descriptive statistics were used to show the information contained in our sample countries.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP per capita	183	336771.5	499047.5	586.9398	2029075
Internet penetration	200	10.57471	11.38663	0.37	55.68141
Broadband Penetration	198	0.882723	2.788399	0.000021	19.45435
Mobile Penetration	206	48.17021	35.67304	1.497995	163.8752
Consumption Expenditure	176	87.63174	14.94681	51.30996	145.517
Inflation	178	12.48104	32.20245	-27.7874	379.848
Human Capital	203	9010617	1.01E+07	156573	4.98E+07
Unemployment	209	6.580038	4.965643	0.599	17.921

Table 2 shows that the sample data had some missing values, implying that our panel is an unbalanced panel. The highest number of observations were in unemployment because all countries had their unemployment statistics reported. In sub-Saharan economies, availability of data is still an area of concern which has deterred researchers from research within the region. According to Sulong & Albiman (2016), data unavailability is an issue that has previously led to various methodology limitations on studies done within Sub-Sahara. In addition, ICT technology is still in its youth stage in Sub-Saharan countries and results to gaps in the data collected (Lee, John, & Gutierrez, 2012). The lowest number of observations were from the expenditure variable.

From table 2, we see that internet penetration and mobile penetration recorded greater standard deviation values compared to broadband penetration. This is an indication that they both had more rapid increase during the period of study compared to broadband use. This is because internet and mobile are easier to publicly access as compared to broadband. In addition, the mean values are higher than the standard deviation values despite the mean of GDP and both internet and broadband penetration

being higher. Following Sulong et al. (2016), this is because policies within the sub-Saharan region during the sample period tended to quickly change. However, mobile penetration, human capital, unemployment, and consumption expenditure variables reported higher mean values compared to the standard deviations implying that they do not largely vary. This was not the case for inflation because during the period, economic policies tend to have an effect on inflation, given that policies within the period rapidly change within short periods of time.

4.2 Diagnostic Tests

In the analysis, our consumption expenditure, unemployment, inflation, and mobile penetration variables were all stationary showing no presence of a unit root. This was informed by the p-value of the inverse normal Z score being less than the significance level of 5%, implying that the null hypothesis to be rejected, ascertaining stationarity at the 95% confidence interval.

Before carrying out any regression analysis, we performed a Hausman test to identify whether there are any endogenous regressors in our models. The Hausman specification test was necessary to determine which estimation technique would best suite between a fixed or a random effects model as put forward by (Hausman, 1978). The results for all the models reported p-values that were greater than 0.05, implying that we should fail to reject the null hypothesis and use a random effect model.

Table 3: The Hausman Test

Model	P-Value
<i>Using Internet</i>	0.6615
<i>Using Broadband</i>	0.0524
<i>Using Mobile</i>	0.1958

After performing the Hausman test, we tested for both serial correlation and heteroskedasticity in our model. The relevance of these tests is to ensure we produce consistent and efficient estimates. The p-value generated from the serial correlation test was less than 0.05, implying that there is serial correlation in the error term. In addition, the test for heteroskedasticity yielded results that were statistically significant, showing that we should reject the null hypothesis that our estimation is appropriate. These results further justify the use of a GMM estimation method that we employ in the analysis of our data. As Piper (2014) pointed out, the GMM method is

designed to allow for heteroskedasticity. In addition, we employ the use of a system GMM because they are designed to handle panel data with larger cross sections but with smaller time periods (Roodman, 2009).

Also, the co-efficient of the lagged dependent variable is persistent as well as close to a random walk given that its value is tending towards 1. If we were to use the difference GMM, this would yield biased results and inefficient estimates, given that our data has a short time period of 10 years (Blundell & Bond, 1998). According to Bond et al. (2001), if the differenced GMM estimated coefficient of the lagged dependent variable is below or close to the fixed effect coefficient, then a system GMM should be used because of weak instrumentation that could lead to downward bias. From table 4, we see that the regression coefficients of the one step and two step difference GMM are close to and below the fixed effects coefficients, hence we employ the use of system GMM. In our analysis, we use the two-step GMM estimation technique because it is more robust.

Table 4: Regression coefficient results

Estimators	Co-efficient (Internet)	Co-efficient (Broadband)	Co-efficient (Mobile)
<i>Pooled OLS</i>	0.9955479	0.9967896	0.9977608
<i>Fixed Effects</i>	0.7955317	0.7169011	0.7211461
<i>One-Step Difference</i>	0.7216383	0.3100801	0.3842785
<i>Two-Step Difference</i>	0.6672155	0.2490789	0.3834747

Table 5 below represents the results obtained from running a two-step GMM on the effects of ICT on economic growth in sample countries. The diagnostic tests of focus will be the Arellano-Bond AR (2) test and the Hansen test for overidentification. The Hansen test is chosen over the Sargan test because the Hansen test works when there exists heteroskedasticity, hence the preference (Piper, 2014). From this regression, the AR (2) value of 0.131 shows that we fail to reject the null hypothesis that errors in the first difference show no serial correlation of order 2

In addition, the Hansen test was also used to test for overidentification in our model. From table 3, the Hansen test results of 0.546 from internet penetration, 0.57 from broadband penetration and 0.563 from mobile penetration imply that we fail to reject

the null hypothesis that our overidentification restrictions are valid. This means that all instruments used in our analysis have been specified correctly.

Table 6 below represents regression results that included interaction terms between ICT and its expected growth enhancing factors. The regression results are from a two-step GMM regression. From the Arellano-Bond AR(2) result of 0.529, 0.331 and 0.804 which are from running three different regressions of internet penetration, broadband penetration and mobile penetration respectively, we fail to reject the null hypothesis that the errors in the first difference show no serial correlation of order 2. The Hansen test p-values reported in table 4 also show that all our instruments have been specified correctly.

Table 5: Impact of ICT Technology using Two-Step GMM.

	(1)	(2)	(3)
	<i>GDPCit</i>	<i>GDPCit</i>	<i>GDPCit</i>
<i>GDPC it-1</i>	0.996*** (478.99)	0.996*** (384.86)	0.996*** (324.87)
<i>INTit</i>	0.000900* (2.25)		
<i>BBDit</i>		0.00203* (2.28)	
<i>MOBit</i>			0.000113 (1.31)
<i>HUMit</i>	0.0275* (2.48)	0.00934 (1.69)	0.00569 (1.28)
<i>UNPit</i>	0.00483 (1.79)	0.0000393 (0.02)	-0.0000170 (-0.01)
<i>CONSit</i>	0.00134* (1.96)	-0.000108 (-0.31)	-0.0000837 (-0.20)
<i>INFit</i>	-0.00138* (-2.57)	-0.00103*** (-3.40)	-0.000963** (-3.14)
Constant	-0.599* (-2.22)	-0.0591 (-0.44)	-0.0200 (-0.14)
<i>Arellano-Bond test for:</i>			
<i>AR (1) P-value</i>	0.206	0.196	0.185
<i>AR (2) P-value</i>	0.125	0.144	0.131
<i>Hansen test p-value</i>	0.546	0.57	0.563
<i>Number of countries</i>	19	19	19

t statistics in parentheses:

*** indicates the levels of significance at 1%, ** indicates the level of significance at 5%, * indicates the level of significance at 10%. For Sargan test, the null hypothesis is that the instruments used are not correlated with the residuals. The AR (2) test for autocorrelation's null hypothesis is that the errors in the first-difference regression exhibit no second-order serial correlation.

Table 4 below represents regression results that included interaction terms between ICT and its expected growth enhancing factors. The regression results are from a two-step GMM regression. From the Arellano-Bond AR(2) result of 0.529, 0.331 and

0.804 which are from running three different regressions of internet penetration, broadband penetration and mobile penetration respectively, we fail to reject the null hypothesis that the errors in the first difference show no serial correlation of order 2. The Hansen test p-values reported in table 4 also show that all our instruments have been specified correctly.

Table 6: Impact of ICT with Interaction Terms Using Two-Step System GMM.

	(1)	(2)	(3)
	<i>GDPCit</i>	<i>GDPCit</i>	<i>GDPCit</i>
<i>GDPC it-1</i>	0.984*** (138.40)	0.963*** (73.90)	0.997*** (123.27)
<i>INTit</i>	0.336** (3.21)		
<i>INTit * CONSit</i>	-0.0601** (-3.16)		
<i>INTit * HUMit</i>	-0.00451** (-2.80)		
<i>BBDit</i>		5.319*** (3.89)	
<i>BBDit * CONSit</i>		-0.859** (-3.22)	
<i>BBDit * HUMit</i>		-0.109*** (-5.02)	
<i>MOBit</i>			-0.0344 (-1.70)
<i>MOBit * CONSit</i>			0.00448 (0.91)
<i>MOBit * HUMit</i>			0.00105 (1.14)
<i>HUMit</i>	0.104** (2.60)	0.0545*** (3.29)	0.0249 (0.35)
<i>UNPit</i>	-0.0106 (-1.81)	-0.0125* (-2.16)	0.0197 (1.70)
<i>CONSit</i>	0.0105** (2.96)	0.00275** (3.16)	0.000765 (0.25)
<i>INFit</i>	0.000356 (0.58)	-0.00320*** (-14.69)	-0.00278*** (-5.34)
Constant	-2.326** (-2.87)	-0.538 (-1.76)	-0.946 (-0.82)
<i>Arellano-Bond test for:</i>			
<i>AR (1) P-value</i>	0.143	0.154	0.441
<i>AR (2) P-value</i>	0.529	0.331	0.804
<i>Hansen test p-value</i>	0.626	0.724	0.566

t statistics in parentheses:

*** indicates the levels of significance at 1%, ** indicates the level of significance at 5%, * indicates the level of significance at 10%,. For Sargan test, the null hypothesis is that the instruments used are not correlated with the residuals. The AR (2) test for autocorrelation's null hypothesis is that the errors in the first-difference regression exhibit no second-order serial correlation.

From both table 3 and table 4, we see that the lagged values of GDP are consistently significant from all regressions implying that our equation is a dynamic system and that we are correctly using the GMM estimation method (Sulong & Albiman, 2016).

4.3 Empirical Findings

From table 3, we observe that a percentage increase in internet penetration is associated with a 0.0009% increase in the short-run economic growth of these economies at the 10% level of significance, *ceteris paribus*. These results are consistent but significantly lower than those reported by (Sassi & Goaid, 2013; Waverman, Meschi, & Fuss, 2005). The reason could be the difference in the panel sample. The results imply that internet penetration and economic growth have an inelastic relationship. Also, a percentage increase in broadband penetration is expected to grow the economy by 0.002%. The impact of broadband technology is observed to be higher when compared to internet penetration. This is expected given that broadband technology is mostly used by businesses as opposed to internet which is based in households.

From table 4, we observe that both internet penetration and broadband penetration are the significant ICT variables that have an impact on the growth of these economies by 0.336% and 5.319 at the 5% and 1% levels of significance respectively, *ceteris paribus*. However, broadband technology consistently yields a higher impact when compared to internet technology. This contradicts results from Sulong & Albiman, (2016) which show that the impact of ICT becomes negative as penetration increases. This could be linked to the high growth of tech businesses within the region that rely on broadband technology. The interaction terms of both internet and broadband penetration with consumption expenditure and human capital yield statistically significant results at the 5% and 1% level of significance. The results show that both internet penetration and broadband penetration negatively depend on consumption expenditure and human capital.

This is reasonable for consumption expenditure because the more households spend on consumption, the less and less there is to spend on investments. In this case, ICT technology is considered an investment. This implies that the more people spend on other things the less money they have to spend on internet and broadband technology which has a negative impact on the growth of the economy. In Southeast Africa,

broadband and internet technology tend to be relatively expensive for many people hence a lack of incentive to invest in such technologies. A lack of incentive generates a negative effect on the growth of these economies.

With regards to inflation, the results prove to be robust in all model specifications according to table 3. Inflation is observed to be negative and statistically significant at all confidence levels. The negative relationship is as a result of the constantly changing regulations that hamper productivity and economic growth (Ming-te, 2001). In table 3, the results of both human capital and consumption expenditure tend to not be robust given that they only show significance in one model specification at the 10% level of significance, *ceteris paribus* under the internet technology model specification. From table 4 we observe that the results of human capital and consumption expenditure are not robust in all the three model specifications and they only show significance at the 5% and 1% level of significance under the broadband technology and internet technology model specifications.

CHAPTER 5: CONCLUSION, RECOMMENDATION, AND POLICY IMPLICATION

5.0 Introduction

In this section, we discuss the summary of the findings from the study as well as the conclusion and recommendations. Section 5.1 discusses the summary; section 5.2 draws the conclusions from the discussion and section 5.3 draws policy recommendations

5.1 Summary and conclusion

The aim of this study is to examine the impact of ICT technology on the growth of economies. From our analysis, both internet penetration and broadband penetration have proven to be the main drivers of the economy in the short run given the robust results produced in both table 3 and 4. Our analysis however did not highlight mobile penetration to be robust in the short run in all our model specifications which is a contradiction of previous studies done by (Sulong & Albiman, 2016; Lee, John, & Gutierrez, 2012).

The complementary factors included in the analysis were consumption expenditure and human capital. They both produced robust results in our model specifications showing to be statistically significant. However, both internet and broadband penetration showed to both negatively depend on them. In addition, mobile penetrations interaction with both consumption expenditure and human capital showed no statistically significant results consistently proving that mobile penetration has no short run impact on economic growth.

Previous studies investigated the marginal effect of ICT penetration on economic growth and yielded results that mobile phone technology was the highly significant variable in their studies (Waverman, Meschi, & Fuss, 2005; Sassi & Goaid, 2013). However, in this study, mobile penetration did not yield any statistically significant results. This could be a result of being a different scope of study.

5.2 Policy implementation

With regards to policies, the results show that countries within southeastern Africa need to direct more investments to increase technology adoption, particularly the broadband technology and internet technology. In addition, broadband technology that is mostly used by businesses is the technology that proves to have a higher impact compared to internet and mobile. This implies that the government should create incentives and a better business environment for businesses to grow within the region.

This could be in the form of creating more business incubators that help foster entrepreneurship. Offering grants to businesses could also help small businesses invest in leveraging on technology, in this case broadband technology.

5.3 Recommendations

In this report, we have identified that broadband technology that is used by institutions and business has the highest impact. Further studies on the topic could try capture whether ICT penetration is dependent on entrepreneurship with regards to promote economic growth. In addition, other countries such as Eritrea and Somalia were omitted because they did not have sufficient data to carry out the research. Further research could incorporate data from this countries as well as also extend to capture other regions in Africa such as West Africa.

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