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EMPIRICAL ANALYSIS OF THE DRIVERS OF INNOVATION IN SUB-SAHARAN AFRICA

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DECLARATION

This is to certify that this thesis is the result of research undertaken by Alex Asante Bamfo towards the award of Master of Philosophy Economics in the Department of Economics, University of Ghana. I hereby declare that with the exception of references made to other people's works, which have been duly acknowledged, this thesis is entirely my own work under the guidance of my supervisors and neither part nor whole of it has been presented for another degree anywhere.

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DEDICATION

I dedicate this work to my wife Mrs. Dora Bamfo Asante for her love and financial support in the course of the programme.

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I wish to express my profound gratitude to the Almighty God for His abundant grace and mercies for granting me the knowledge, strength and protection for the successful completion of this thesis.

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LIST OF ABBREVIATIONS/ACRONMYS

AU	-	African Union
AMCOST	-	African Ministerial Council on Science and Technology
ARIPO	-	African Intellectual Property Organization
ASTII	-	African Science Technology and Innovation Initiative
CPA	-	Consolidated Plan of Action
FDI	-	Foreign Direct Investment
FE	-	Fixed Effects
GIPC	-	Ghana Investment Promotion Centre
GDP	-	Gross Domestic Product
GMM	-	Generalized Method of Moments
GII	-	Global Innovation Index
IMF	-	International Monetary Fund
I.T	-	Information Technology
IV	-	Instrumental Variable
ICT	-	Information Communication Technologies
MDGs	-	Millennium Development Goals
NEPAD	-	New Partnership for African Development
OECD	-	Organization for Economic Co-operation and Development
OLS	-	Ordinary Least Squares
PRSPs	-	Poverty Reduction Strategy Papers
PCT	-	Patent Cooperation Treaty
R&D	-	Research and Development
RE	-	Random Effects
SSA	-	Sub-Saharan Africa
SMEs	-	Small and Medium Scale Enterprises
UNECA	-	United Nations Economic Commission for Africa
UNDP	-	United Nations Development Plan

UNESCO	-	United Nations Education Scientific and Cultural Organization
UNCTAD	-	United Nations Conference on Trade and Development
UNIDO	-	United Nations Industrial Development Organization
USA	-	United States of America
WIPO	-	World Intellectual Property Organization
2SLS	-	Two Stage-Least Squares

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ABSTRACT

Technological innovation is the main driver stimulating labour productivity growth and development in the OECD countries and the industrialized world. However, advancement in technological innovation is lower in SSA than any other continent in the world perhaps resulting from the poor industrial development, poor human capital accumulation, unfriendly business environment and a host of other militating factors. The principal motive of this paper therefore set to examine the drivers of innovation specifically to sub-Saharan Africa. Panel dataset covering 30 selected SSA countries from 2011 to 2014 was used together with the modern and robust econometric estimating techniques, the Pooled OLS and the System GMM in estimating the empirical model. Results from the empirical estimation indicates that, institutional quality, human capital accumulation, expenditure allocated to R&D (percentage of GDP), domestic credits allocated to private sector (percentage of GDP), intensity of domestic trade and competition have a positive and significant effect on innovation advancement in SSA. However, the physical infrastructure deficit, collaboration between universities and industrial sector in terms of joint research, ease of starting new businesses have a negative and insignificant effect on innovation promotion in the region. FDI inflows to SSA have positive effect on innovation, however statistically insignificant. Based on the empirical results above, the study recommends that institutions of state such good governance, rule of law, contract enforcement, protection of intellectual property rights must be promoted to stimulate risky innovative investment. Additionally, there must be more focus on technical and vocational training to develop the creativity and ingenuity of the labour force, increase expenditure on R&D and physical infrastructure to reduce the operational and logistical constraints on firms. Also, adopting a well-functioning National Innovation Policy and finally, implementation of public procurement laws to boost competitive bidding to ensure competition among firms in the region.

CHAPTER ONE

INTRODUCTION

1.0 Background to the study

Advancement in technological innovation for achieving long-run productivity growth and competitiveness is an issue which has received considerable attention in the global policy debate and in the world economic discourse. The focus on innovation as growth process gained the attention of development economists when Solow, (1957) estimated from an empirical data and observed that more than 70 percent of United States economic growth between 1909 and 1949 was residual and not accounted for by the conventional increases in capital assets and labour force. Today, the demand for sophisticated products with high technological contents on the global market has made technological innovation the key factor in international competition and cross-border interactions (see Global innovation index, 2014).

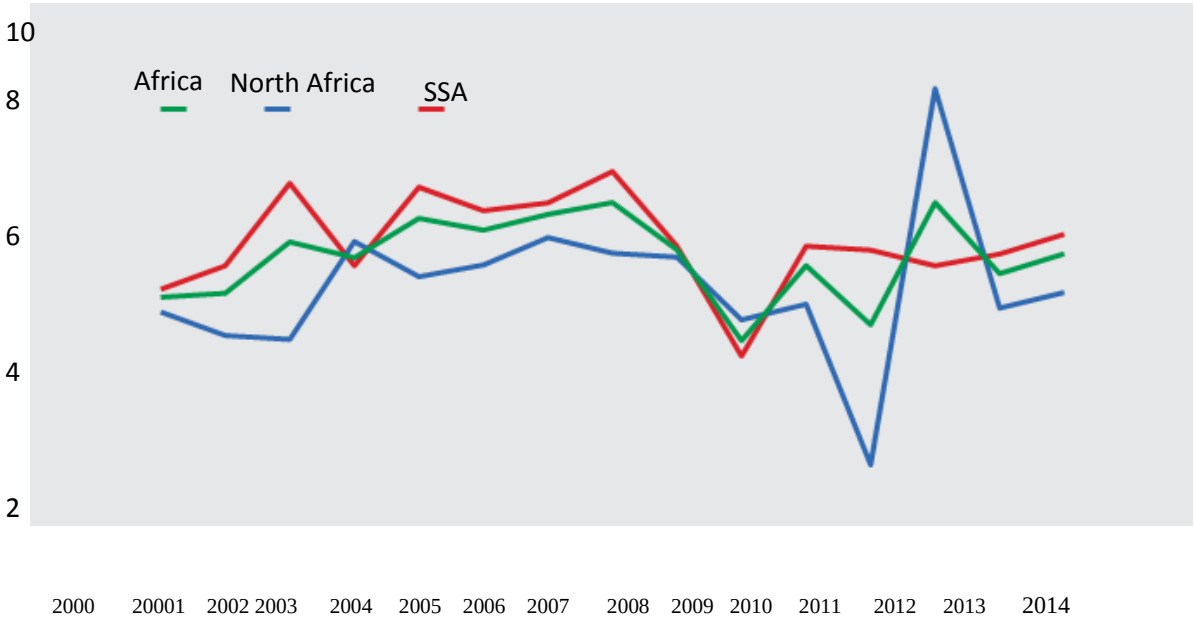
Generally, "Innovation" referred to in the economic literature as technical change or technological change is the mechanism through which countries' or organizations constantly generate new ideas or new knowledge to produce new products, processes, and systems required for adapting to the changing markets, technologies and modes of competition"(see D'Aveni, 1994). The OECD (1997), also, defined innovation as all the scientific, technological, organizational and financial including the commercial activities necessary to create, implement, and market new or improved products and services.

Romer,(1986) indicated that the most important factor driving the competitiveness, productivity growth, job creation and the engine fuelling growth of the industrial economies is technological innovation. Grossman and Helpman (1991) and Hall and

Jones (1999) in their own words posit that the main factor responsible for the vast cross-country differences in growth performance, the high variations in per-capita income and total factor productivity is the result of the differences in technological innovative capacities. Crespi *et al*., (2010) conclude that applying technological innovation leads to a more efficient use of the productive resources and enhance the transformation of new ideas into economic solutions. Investment in knowledge for productivity growth and competitiveness has grown more rapidly than investment in machinery and equipment since the mid-1990s in most industrialized and OECD countries as it ensures labour efficiency and sustained productivity growth than capital assets which is subject to diminishing returns in the long-run (see OECD, 2005c).

Growth rate of Africa for the past decade has been robust and resilient compared to the rest of the developing world which shares same characteristics with the continent.

Fig :(1.1): Africa's economic Growth trajectory (2000-2014)



Source: African Development Bank, 2014

Between the year 2000 and 2014, growth rate in annual GDP averaged more than 5 percent, with sub-Saharan Africa (SSA) achieving an average rate of 5.6 percent higher than growth rates achieved by North Africa 4.5 percent, Latin America and Caribbean 3.4 percent, Europe and Central Asia 0.2 percent (see figure 1.1 above). Despite this remarkable growth performance witnessed, SSA continues to lag behind in terms of development and global competitiveness compared to rest of the developing world. In 2013, out of 20 countries ranked lowest in the global competitive index report, 14 were SSA countries (see Global Competitive report, 2013). Additionally, as North America scored 58.11 percent and ranked first in global innovation advancement, sub-Saharan Africa obtained 27.45 percent and ranked least (see Global Innovation index report, 2014).

Countries in SSA are relatively endowed with natural resources such as gold ,diamond nickel, uranium, manganese, Timber, crude oil, just to mention a few compared to other continents in the world, however, Tidd *et al*.,(2001), posit that in the current wave of globalization, competition and technology driven-world, growth and development of countries and their resident firms does not necessarily depends on the quantum of capital assets, level of labour force and the natural resources the country is endowed, it rather depends on the ability of the country to efficiently exploit these resources to innovate to enhance productivity and growth.

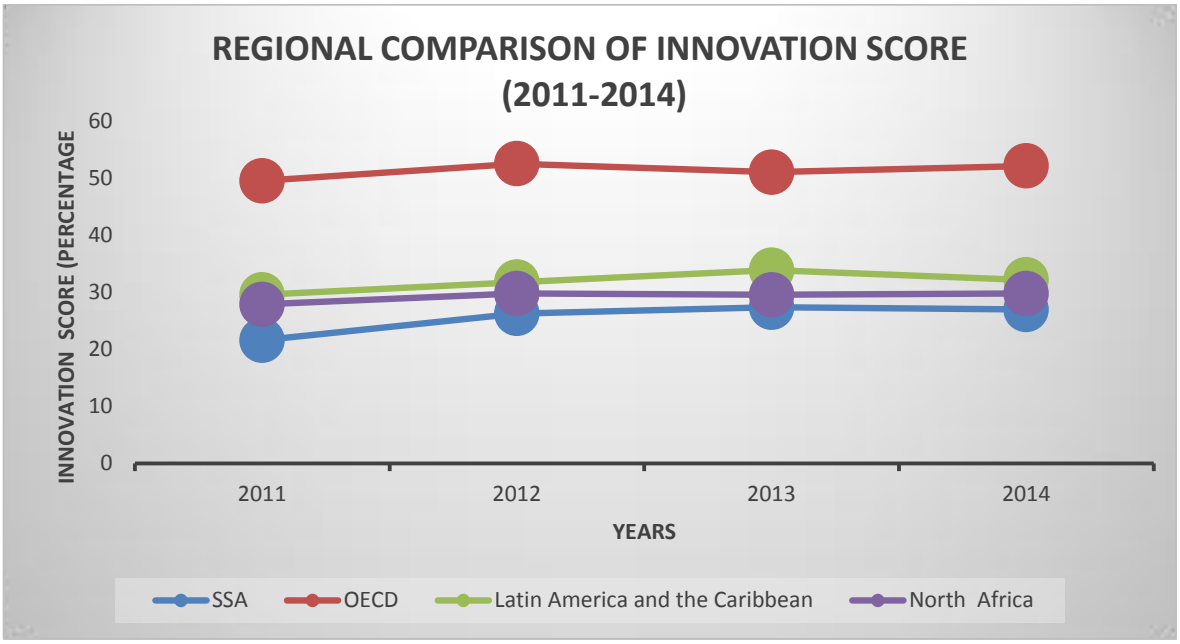
Drawing lessons from the "Asian Tigers" i.e. Singapore, Taiwan, Korea, Malaysia and currently countries such as China and India who are making significant progress in productivity growth, development and global competitiveness achieved through investment in technological innovation, SSA which has the least global competitive

outlook can no longer take myopic stance on identifying the drivers of innovation if it aspire in boosting productivity growth to ensure the region's competitiveness at the global market, achieve the Millennium and Post Millennium Development Goals (MDGs) and joined the international race of competition (see Keller and Samuels, 2003).

1.1 Statement of the Problem

The importance of technological innovation for economic growth (productivity increase) and social welfare (employment generation) has long been a fascinating topic for economic historians and growth economists since the advent of the industrial revolution in the mid eighteen century. Arocena and Sutz (2005), argue that, with the inception of the innovation-growth relationship which is directly linked to industrialization, developing countries are those lagging behind during the transition from the agriculture to industrial society. Schumpeter, (1911) was the first economist to realize the positive effect of technological innovation on economic growth, and since then, extensive empirical studies have explored the drivers of innovation with specific focus on the industrialized, OECD and some few developing countries (see Almeida *et al*.,2008; Rahomuni *et al.*, 2011).

Fig :(1.2): Trend of innovation in SSA (2011-2014)



Source: Author's computation, 2015 from the Global Innovation index (2011-2014)

Over the decade of resilient and robust growth in GDP achieved by SSA, the region continues to be less competitive in the global market relative to other developing continents in the world. Technological innovation driving long-run growth of developed countries is lower in SSA than any other continent in the world (see figure: 1.2 above showing the trend of innovation advancements in SSA vis-à-vis other regional blocks). With the observed importance of technological innovation to productivity growth, social welfare improvement and global competitiveness, very few studies have explored the specificity of drivers of innovation in the case of SSA (see Bogliacino *et al*., 2009).

For instance, Wolf (2007), with a sample 15 African countries argued that innovation is the main driver necessary to boost labour productivity growth in Africa; however, the capacity to innovate is lower both at the private and public sectors. Danquah and Quattara (2014), from a panel data of 19 SSA countries posit that human capital, empirically observed as an important determinant of innovation impacts positively on

efficiency change (innovation adoption) only in SSA but its effects on technical change (technological innovation) is insignificant. Furthermore, Sakala and Kolster (2014), using three (3) North African countries (Morocco, Egypt and Tunisia) indicates that innovation in these countries are far from R&D, an important variable which is assumed to be the main indicator of innovative performance of a country.

Governments in the sub-Saharan Africa are making significant effort to boost productivity growth and also enhance the region's competitiveness at the global level through the adoption of the various alternative policy mix. However, technological innovation which is observed as the major driver of productivity growth and competitiveness in the industrialized and OECD countries', very little attention is accorded to this growth process in the region. This problem could be attributed to the poor physical infrastructure development (Poor power generation capacity for industrial development and accessible road networks), low investment in research and development activities both at the private and public sectors, poor human capital accumulation and the unattractive business environment (high interest, inflation rates volatility etc.), institutional failures and other equally distracting economic challenges in the region. In view of this, policies to drive innovative activities in the region have been relatively weak. SSA needs to innovate to achieve economic transformation, compete favourably in the international market and also improve the living conditions of it's the citizens. These emerging issues therefore makes it indispensable to identify and bring to fore the drivers of innovation specific to SSA to contribute to the literature and the continuous policy discussions on innovation enhancement.

1.2 Research Questions

It has now become a general consensus among development economists and managers of economies of the world today that technological innovation is the main engine fuelling productivity growth and global competitiveness and cross-border interactions. Investment in knowledge has gained more currency than in machines, however, generating more ideas to innovate in SSA has been generally lower as shown in the trend of innovation advancement in figure (1.2). The crucial question which requires an appropriate answer then is what drives innovation in SSA? In view of these emerging issues, the study seeks to find solutions to the following questions.

- How does the institutional framework impact on innovative investment in SSA?
- How does the human capital accumulation impact on innovation advancement in SSA?
- To what extent does the expenditure allocated to R&D activities (percentage of GDP) drives innovation in Sub-Sahara Africa?
- How does the physical infrastructure base (power generation and road networks) affect innovative investment in SSA?
- To what extent does the collaboration between the universities and industrial sector in terms of joint research impact on innovation in SSA?
- How does the business environment impact on innovation advancement in SSA?

1.3 Objective of the study

The broad objective of this study is to empirically examine the drivers of innovation in the case of SSA. In doing this, the study seeks to achieve the following specific objectives.

The specific objectives of the study;

- Investigate the impact of institutional quality on innovation advancement in SSA.
- Find out the extent to which the human capital accumulation drives innovation in SSA.
- Explore the impact of expenditure allocated to R&D on innovation advancement in SSA.
- Assess the impact of physical infrastructure base (power generation and road networks) on innovation promotion in SSA.
- Find out whether the collaboration between the universities and industrial sector in terms of joint research affect innovation advancement in SSA.
- Explore the extent to which the business environment impact on innovation in SSA.

1.4 Testable Hypothesis

The study seeks to test and validate the following hypothesis.

1. H_0: Institutional framework does not have any significant effect on innovation advancement in SSA.
2. H_0: There is no significant relationship between human capital accumulation and innovation advancement in SSA.
3. H_0: Expenditure on R&D (percentage of GDP) has no significant effect on innovation advancement in SSA.
4. H_0: There is no significant relationship between the physical infrastructure base (power generation and road networks) and innovation advancement in SSA.

5. H_0: Collaboration between the universities and the industrial sector in terms of joint research has no significant effect on innovation advancement in SSA.
6. H_0: There is no significant relationship between the business environment and innovation promotion in SSA.

1.5 Methodology and scope of the study

The study examines the drivers of innovation in the case of SSA using dataset drawn from the Global Innovation Index reports from 2011 to 2014 to provide quantitative estimates of the explanatory variables. The quantitative procedure involves the specification of a dynamic panel model that links innovation (the dependent variable) to the explanatory variables adopted for the study. The study involves a sample of 30 sub-Saharan African countries selected strictly based on data availability. The sampled countries used in this study are represented in appendix 2. The alternative estimation techniques adopted to ensure consistency and robustness of the estimates is the Pooled OLS and the Systematic GMM estimators. Additionally, sensitivity test such as the unit roots, autocorrelation, heteroscedasticity, over-identifying restrictions and the fixed effects is also conducted to ensure that the estimate of the explanatory variables are reliable.

1.6 Significance of the study

For countries at the bottom of the development pyramid such as SSA, technological innovation is decisive for industrialization and catch-up. However, the capacity to innovate is lower in the SSA compared to other regions in the world (see African innovation outlook, 2010). The extant literature shows that majority of innovation studies is concentrated in the OECD and developed countries with a handful of these studies in the case of SSA (see Wolf, 2007; Danquah and Quattara, 2014). However,

realizing that Africa can benefit from innovative activities, in 2005, the African Ministerial Council on Science and Technology (AMCOST) adopted African Science and Technology Consolidated Plan of Action (CPA) which articulates the African Union agenda for harnessing innovation to boost economic growth and improves lives of the African people.

The major challenge to this plan of action is how to build the capacity and competencies to innovate and also link technology and innovation to poverty reduction, job creation, sustainable livelihoods and improved well-being of the citizens in Africa (see African innovation outlook, 2010). With the spate of globalization and competition which is driven primarily by technology and innovation, it is only the countries making significant investment in innovation which can compete favourably in the global market. Sub-Saharan African countries need to achieve sustained growth rates, produce goods, services and systems which can compete favourably in the global market. However, technological innovation which can help the region achieve this objective, very little is known about the factors driving it. The paucity of the innovation studies have impacted negatively on the evidence-based decision at the policy level to boost the innovative capacity in the region. To enable SSA to harness and apply science, technology and innovation to eradicate poverty and achieve sustainable development, and also contribute to the global pool of scientific knowledge, identifying the drivers of innovation is critical.

This study therefore uses current data on innovation and modern econometric approach to determine empirically the main factors driving innovation in the case of SSA to contribute to the literature and the continuous debate on the drivers of innovation. More

importantly, for SSA also not to be left behind in the current knowledge driven world, examining the drivers of innovation to promote productivity growth and competitiveness is paramount.

1.7 Organization of the study

The study is organized into six (6) main chapters as follows: Chapter One focuses on the introduction which includes the background of the study, problem statement, research questions and objectives, hypothesis, significance and scope of the study. Chapter Two, delves into the theoretical and empirical studies backing the study while the third Chapter present an overview of innovation specifically to SSA. The Fourth Chapter, captures the methodology adopted for the study focusing on model specification, data sources, variable description, framework for calculating the innovation score for each country and the main estimation techniques employed in the study. The remaining Chapters, Five and Six consists of discussion on the results from the empirical estimation, brief summaries, conclusions, limitations of the study and finally policy recommendations based on the findings.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the theoretical and empirical studies on innovation. The section consists of three main thematic areas. Section one focuses on the definition of innovation as a concept. The second section is devoted to reviewing the various theoretical foundations of innovation. The last section explores some of the empirical studies conducted on the drivers of innovation.

2.1 The definition of Innovation

Innovation is a concept used very often by different disciplines in different contexts. In the different contexts, the meaning is sometimes changed or interpreted differently. Fagerberg *et al*., (2005) indicate that innovation is a multifaceted phenomenon which cannot be easily squeezed into a particular branch of the social sciences or humanities, and sees innovation as "a multitude of perspectives based on – or cutting across existing disciplines and specializations". Schumpeter (1911), the originator of the concept, defined innovation in five different ways.

"First, the introduction of a new good or product – (that is a commodity with which consumers are not yet familiar – or of a new quality). Second, the introduction of a new method of production – (that is one not yet tested by experience in the branch of manufacture). Third, the opening of a new market-(that is, a market into which the particular branch of manufacturer of the country in question has not previously entered, whether or not this market has existed before). Fourth, the conquest of a new source of supply of raw materials or half-manufactured goods – (again irrespective of whether this

source exists or whether it has to be created). Fifth, the carrying out of new organization of any industry" (see Schumpeter, 1911).

The OECD Oslo Manual & Eurostat's criticizes the Schumpeter's, (1911) definition to exist as actions carried by business people on their daily basis and as such does not constitute innovation. For example, the manual argues that, opening of a new market can be carried out by the marketer in his daily activities by using his old and practiced methods which does not necessarily implies new untested creative idea. On this basis, the OECD Oslo manual defined innovation as " applying new knowledge or new ideas gained to create new and significantly improved product (goods or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations'' (see Oslo Manual and Eurostat's, 2005). The manual thus identifies four main foci of innovation as product, process, marketing and organizational innovations.

- A product innovation is the creation of a good or service that is significantly-improved with respect to its characteristics or intended uses and it includes significant improvements in technical specifications, components and materials, incorporated software and user friendliness or other functional characteristics (see Oslo Manual, 2005). The manual indicates that design changes which do not involve a significant change in the product's functional characteristics or intended use, such as a new favour or colour option, are not product innovations.

- A process innovation is the creation and application of new significantly-improved production or delivery method, including significant changes in

techniques, equipment and/or software (see Oslo Manual, 2005). For example, introducing of a new automation method on production line, or in the context of ICT, developing electronic system linkages to streamline and delivery processes.

- A marketing innovation is the implementation of significantly-improved marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. The marketing method must not have been previously used by the firm.

- An organizational or managerial innovation is the implementation of a new or significantly- improved method of the firm's business practices, workplace organization or external relations. It requires more than mere organizational change or restructure. In fact, the organizational method must not have been previously used by the business and must be the result of strategic decisions taken by management (see Oslo Manual, 2005). Examples include implementation of a new method of distributing responsibilities and decision-making among employees, decentralizing group activities, developing formal and informal work teams, new types of external collaboration with research organizations or the use of outsourcing or sub-sourcing for the first time.

2.2 Theoretical Review

Before the framework for this study is actually examined, it is necessary to elaborate on the theoretical perspectives on the concept of innovation. The theoretical foundation of innovation as a growth and development process is credited to Schumpeter (1911). He identified the three main processes of innovation as Invention- the first generation of the idea, Innovation- the first commercial application of

the idea in the market, and Diffusion- the spreading of the technology or the process in the market. In his earlier view in (1911), he stressed that innovation is driven primarily by entrepreneurs whose fundamental motive is incremental profit (see Xu, 2007). However, in his later seminal paper, Schumpeter, (1939) argued that, firm's decision to commit resources to research and development to innovate is mostly influenced by the size of the firm and the features of the industry. He posit that larger firms outperformed the smaller firms in terms of profits, level of output and market leadership and as such will be more willing to allocate financial resources to conduct R&D to enhance innovation activities than smaller firms (see Freeman, 1982; Thurik and Wennekers, 2004).

In furtherance to the above proposition, Schumpeter (1961) observed that strong market incentives and competition are very essential factors which will propel larger firms to conduct more R&D. Though Schumpeter believed in positive effect of market competition on driving innovation, he recount that perfect competitive market could not be the driver due to the high probability of imitation from rival competitors, as such he concludes that there is higher incentive for monopolist or larger firms to innovate to maintain the high profits and market leadership than smaller firms.

In a sharp contrast to this argument by Schumpeter, (1961), Arrow, (1962) assert that, the strict barrier of entry into monopolist firms, control of essential resources, higher profits gains as result of minimum competition, would serve as a major disincentive for the monopolist to innovate, rather, however, in an attempt the perfect competitor to control some market share in the contestable market serves as higher incentive innovation (see Arrow, 1962). Amid the above arguments, Aghion *et al.* (1997) extended the Schumpeterian framework and developed new models of competition on technical

change by introducing that more competition could be conducive for innovation and productivity growth through the "escape-competition" effects. More precisely, competition may increase the incremental profits from innovations and thereby encourage more R&D development by firms with the aim of escaping the competition, particularly in sectors where incumbent firms are operating similar technological levels. Thus, "neck-and-neck" sectors, since intensive competition between firms will increase each firm's incentive to acquire its technological lead over its rivals (see Aghion *et. al*. 1997).

The macroeconomic foundation to understanding the effects of technological innovation to productivity growth and competitiveness of countries gained more attention from Solow's, (1957) Residual. A major critique of Solow's, (1957) growth theory by the new growth theorists was the fact that Solow, (1957) assumed technological change (innovation) as exogenous without bringing to fore the factors driving this important component of productivity growth. Jones, (2002) indicates that Solow, (1957) assumed technological change as "manna" from heaven without telling how it evolves over time and the payment it receives. However, this Solow's (1957) residual term in his empirical study brought renewed interest among new development economists to provide more theoretical contributions to drivers of innovation.

The earlier work of Nelson and Phelps, (1966) argues that a more educated labour force adopt new technologies faster thereby closing the technological gap. This idea of Nelson and Phelps (1966) has been given the same theoretical support by the endogenous growth theories pioneered by Romer, (1990a) and Aghion and Howitt, (1992) who described the stock of human capital as the engine of growth through innovation. Romer , (1990a)

demonstrate that the most crucial factor driving technological change (innovation) is the production of more ideas or knowledge resulting from accumulation of more human capital employed in the research sector.(see Romer,1990a).

The effect of human capital on technological change and enhancement of productivity growth can be analyzed in three main models: Human capital model, ‘‘Catch-up" model by Nelson and Phelps, (1966) and "Learning by doing" model by Arrow, (1962). The human capital is considered as an input in the production function which determines productivity growth and hence output growth. The "catch-up or "convergence" model of human capital argues that international competitive pressures promote the diffusion of technological knowledge worldwide and that the technological knowledge often spreads from the developed countries to the developing countries and the ability of the developing countries to benefit from the foreign technologies to improve on their obsolete technologies for "catch-up" depends on the quality of human capital for absorption (see Nelson and Phelps, 1966).

The third model on the effect of human capital on innovation is termed as the "learning by doing’’, put forward by Arrow,(1962) which states that workers assimilate gradually the existing technologies or newly introduced technologies, therefore their efficiency increases overtime and further indicates that "learning" process occurs more rapidly with workers with higher level of education (see Arrow, 1962).

From the 1980s to date, an important theoretical contribution made to Schumpeter's theories to innovation are the concepts of National Innovation Systems and National Innovation Capacity by the OECD. National Innovation Systems (NIS) is a systematic

network of institutions which collaborate to enhance the generation of innovative ideas within the borders of the country". The interaction among these units may be technical, commercial, legal, social and financial with the prime motive of promoting science and technology (see Niosi *et al.*, 1993). Goedhuys (2005) also defined the National Innovation Systems as "network of firms and other economic agents who, together with the institutions and policies bring new products, new processes, and new forms of organizational performance into economic use" (see Goedhuys, 2005).

Central to the NIS is the fact that policies and institutions matter significantly in dealing with market failures and the promotion innovation, therefore given risks and uncertainties associated with innovative activities, a functioning social and economic institutions that protect the interest of economic agents will promote the risky investments and interaction with economic agents'. A well-functioning NIS consist of institutions such as universities, R&D institutions, business associations, strong and viable financial institutions which is linked to business sector and provides the financial intermediation for funding risky business R&D activities, trustworthy legal system which ensures contract enforcement with commitment to promotion of economic innovation. (Freeman, 1995).The evidence of importance of effective National Innovation System to growth and economic development was first witnessed in the extraordinary success of the Japanese and South Korea's technological and economic "catch-up" and the collapse of the socialist economies of the Eastern Europe, (see Freeman, 1995). Since then, the major framework adopted by countries who aspire to increase their international competitiveness has focused on building more robust NIS that drive technical change.

Related to the National Innovation System is the National Innovative Capacity (NIC). The NIC refers to a country's potential "as both political and economic entity to produce a stream of commercially relevant innovations .The National innovation capacity

framework draws on three distinct areas of prior research. The ideas-driven endogenous growth theory by Romer, (1990a), the Cluster-based theory by Porter, (1990) and the Research on National innovation Systems by Nelson (1993). The idea-base framework postulated by Romer (1990a) states that the innovation capacity of a country is determined by amount of expenditure committed to research and development cum the skilled pooled in the research sector, The other two theories by Porter, (1990) and Nelson, (1993) posits that the innovative capacity countries depends on the demand and supply conditions of the domestic economy, intensity of domestic market incentives, international trade openness, quality linkages with the education and research institutions (see Romer 1990a, Porter, 1990 and Nelson, 1993).

2.3 Empirical Literature Review

A number of studies have explored the determinants of innovation. Mankiw *et al.,* (1992) in the test of the Solow, (1957) growth model conclude that the model "fit" well in explaining productivity growth with the inclusion of human capital into the model. The study observed that economies possess labour with different education, and countries with high human capital are able to accumulate more technology to innovate than countries with lower human capital. Benhabib and Spiegel, (1994), showed from a panel data of 78 that the stock of human capital affects growth through two main mechanism. First, influencing the nature of domestically produced technological innovation (as in Romer, 1990a), and second affecting the speed of adoption of technology abroad (as in Nelson and Phelps, 1966).

Replicating the study conducted by Benhabib and Spiegel (1994), Krueger and Lindhal (2001) used data from 78 countries over the period 1965 to 1985 and argued that education is statistically significant and positively associated with growth and innovation

for countries with low level of human capital. Additionally, contributing to the debate on drivers of innovation, Vandenbussche *et al.*, (2006) analyzed 19 OECD countries using data from 1960 to 2000 conclude that innovation enhancement of a country requires relatively more skill intensive activities than imitation. In a current study by Islam (2010) also using a sample of 87 countries, the paper concludes that unskilled human capital contribute more to technical progress as they move closer to the technology frontier.

Wolf, (2007) analyzed a sample of 15 African countries and indicate that secondary school enrolment affect positively the productivity of the industrial sector and the overall labour productivity in those countries, however, tertiary school enrolment have no significant effect on both. Finally, Danquah and Quattara (2014), in a study of 19 SSA countries indicate that the stock of human capital in SSA have positive effect on imitation (technological adoption only) but has an insignificant effect on technical progress (innovation).

In the extant literature, an important variable used in comparing the intensity of technological innovation capacity of countries is R&D. (see Romer 1986, 1990a; Lucas 1988; and Aghion and Howitt 1992). Griffth *et al*., (2001) in a panel data analysis of 12 OECD countries posits that R&D have two main faces as in human capital in the innovation process. First it facilitate the "catch-up" process (innovation adoption) and secondly stimulate economies technical progress (creating domestic ideas to innovate). Rodriquez-Pose *et al.*, (2004) concentrated on the study of European countries and demonstrate that investment in R&D have a significant and positive effect on productivity growth and affect technical progress positively. Becheikh *et al. (*2006) reviewed 108 studies on innovation and observed that more than half of those studies

found research and development to have a positive and robust effect on economies rate of innovation.

Assessing the impact of R&D on labour productivity and economic growth in Nigeria, Akinwale, (2012) argues that gross expenditure on R&D plays a significant role in innovation enhancement in the Nigerian economy. In the same light, Vogel (2012), indicate from a study of 159 European regions that R&D and human capital have a positive and direct effect on the total productivity growth for that EU countries.

Recently, an input of production which has received massive attention in the growth process is accessibility of quality physical infrastructure. Infrastructure refers to the complex non-natural resources which are collectively used by industries in the production and distribution of products including energy supply systems, water supply, transport systems roads, airports and harbours, telecommunications systems and others. World Bank (1994) indicate that infrastructure creates production facilities and stimulate economic activities, reduce transactions and trade costs and also improves domestic competitiveness. Calderon *et al*., (2003a) indicates that infrastructure gap is an important growth bottleneck which has a negative impacts on industrial activities, innovation and the overall competitiveness of a country.

The first attempt perhaps to measure the effect of physical infrastructure on productivity growth was the study undertaken by Roeller and Waverman (2001). Their study focused on telecommunication infrastructure in a sample of OECD countries from 1970 to 1990 and observed that about one-third of the growth achieved by those economies was attributable to extension of communication infrastructure. Wendy *et al.,* (2002) in a study of 26 European countries indicated that market infrastructure base of the economy such

as transportation networks, communication infrastructure, power supply, framework of laws and financial set-ups had a positive effect on the technical progress of those economies. Similarly, replicating the study by Roeller and Waverman (2001), Esfahani and Ramirez (2003) showed from an analysis of 78 developing and OECD countries, that telecom and power generation have a significant and positive effects on firms innovative activities in those countries.

Estache (2005) took stock of basic infrastructure characteristics and its impact on productivity in SSA and indicate that the impact of infrastructure on productivity growth is different compared to other regions in the world and that if Africa had enjoyed Korea's quantity and quality of infrastructure, it would have raised its annual growth per capita by about 1 percentage point every year. Agenor et *al.* (2006) observe that improvement in the stock of infrastructure can reduce the adjustments costs of private capital by lowering the logistical cost to boost productive investment in the private sector. In contribution to the debate of the effect of infrastructure on productivity growth, Alvaro *et al*. (2009) used panel data from 1999 to 2005 and observed that the most significant factor lowering the growth rate of Africa is poor quality electricity generation and interruption of transport services.

Like quality infrastructure which reduces the transaction and logistical constraints on private investment, an important factor observed to drive risky investment is the quality state institutions. Quality institutions such as independent judicial system, political stability, protection of the intellectual property and contract enforcement safeguard the interest of economic agents promote risky investment. Oyelaran-Oyeyinka (2004) indicate that strong institutions are imperative for technological innovation because it

mitigate the uncertainties that surrounds innovative activities by providing strong regulations that governs economic agents and thereby enforcing contractual obligations. Cull *et al*., (2005) posits that poor institutions and corruptions reduces productive private investment and undermines the incentives for domestic firms to reinvest their earnings which in turn affect the technical progress and the overall productivity growth. Comparing countries with similar culture and norms, Waguespack *et al.,* (2005) in a study of Latin America and the Caribbean found stability of political institutions to be important factor explaining the propensity to patent.

Additionally and important as well , Florent and Alexander (2014) used a panel data from 2004 to 2008 of a sample of 142 developed and developing countries and observed that for countries with quality economic institutions, innovation tends to be high for industries in those countries and their export base is also high. Moreover, Oluwatobi *et al.*, (2014) examined the effect of institutional quality on innovation in 40 African countries and observed that controlling corruption and improvement of regulatory quality results in higher innovation in Africa Contributing to the debate on the drivers of technical progress, Acemoglu *et al.*, (2006) in a cross-country empirical analysis observed that high barrier to entry by potential entrepreneurs to a market is detrimental to productivity growth as the country approaches the technological frontier. Also, Aghion *et al., (*2009) posit that the threat of technologically advanced entry by other firms increases the propensity of existing firms to allocate more resources to R&D to innovate. Furthermore, assessing the effect of business and trade liberalization, Scopelliti (2009) focused on 20 OECD countries and observed that trade and business liberalization are important drivers of technological innovation in those countries.

In the "catch-up" theory by Nelson and Phelps (1966) an important mechanism through which developing countries can close the technological gap with developed countries is through international trade openness. Das (1987) and Wang and Blomstrom (1992) showed that, domestic firms can gained knowledge from the multinational cooperation (MNCs) in the domestic economy by imitating their production techniques to boost their innovative capacity. Aitken and Harrison (1999) however believes that more foreign presence in the country can decrease productivity of domestic firms casting doubt on the idea of horizontal spillover effects, and indicate that for least developing countries alone, incoming FDI flows do not have a significant effect on local innovation. Fosfuri *et al.*, (2001) rather posit that existence of multinational firms may act as catalyst to boost the innovative performance of local firms resulting from the competition from the MNCs. Schiff and Wang (2006a) on the same line of argument indicate that for developing countries with low R&D intensity, trade openness and exposure to foreign competition provide a powerful inducement to adopt more technology in both importing and exporting competing firms which are likely to produce technology spillovers and productivity gains.

Asiedu (2005) in another study using a panel data of 22 African countries argues that the presence natural resources and large domestic market tend to promote more FDI inflows into the region. Fortainer (2007) concludes from the study of 71 countries that received FDI for the period 1981 to 2002 that, the effect of FDI on productivity growth varies between countries depending on their characteristics, however, the effect of FDI on innovation depends on domestic technological absorptive capacity of the country. The same conclusion was made by Soubbotina (2006). Thiam (2007) examined data of 14

SSA countries and showed that FDI inflows in SSA does not lead to technical change, however some countries in the region benefit from efficiency change.

The world today is generally described as Global Village. A world where information accessibility and use is an important determinant of productivity growth and competitiveness. Gretton *et al.,* (2004) suggest that ICT is a general purpose technology which provides an indispensable platform upon which further productivity-enhancing changes such as product and process innovation can be based. Koellinger (2005) posit that ICT makes it possible to reduce transaction costs, improve business processes, facilitates co-ordination with suppliers, fragment processes along the value chain (both horizontally and vertically) and across different geographical locations and increases diversification. Brynjolfsson and Hitt (2000) in a case study of European and United Kingdom firms' revealed that the introduction of information technology is an important determinant of the firm's innovative activities. Gago and Rubalcaba (2007), find that businesses which aims at improving service quality and achieving customer satisfaction makes more investment in ICTs. Jafari and Arab (2011) using a sample some developing and developed countries over the period 2003 to 2008 observed that investment in ICT have a positive effect on labour productivity for all the countries studied.

2.4 Concluding remarks

With the various empirical studies surveyed, a number of studies have explored the factors driving technological innovation with specific focus on the industrialized countries and other few developing countries outside SSA. Only few studies have explored specifically the drivers of innovation in the case of SSA. For these papers surveyed, it was also realized that majority of the studies focused on specific variable to

determine its effect on technological change. However, the findings made on the drivers of innovation in the industrialized countries may not necessarily apply to the case of SSA. This gap therefore makes it paramount to model an equation incorporating most of various factors observed from the empirical literature as determinant of innovation to examine their impact on technological innovation using empirical innovation data for SSA.

CHAPTER THREE

OVERVIEW OF INNOVATION IN SUB-SAHARAN AFRICA

3.0 Introduction

In other to analyze the drivers of innovation in SSA with reference to the empirical literature reviewed, it is imperative to review the activities and policies aimed at advancing innovation in the region. In doing so, the chapter focuses on the major development strategy adopted by most countries to boost economic growth. The level of industrial activity and foreign direct investment inflows received in the region. Also, the paper explores the nature of National Innovation Policy framework adopted by countries in the SSA, expenditure allocated to R&D (percentage of their GDP) and Sources of funding of R&D. Furthermore, the review looks at the collaborative activities between the university and industrial sector in the region, examine the policies on intellectual property right and lastly delves into the infrastructure base in the region.

3.1 Poverty Reduction Strategy Papers (PRSPs) in SSA

A major economic growth policy adopted by most sub-Saharan African countries is the designing and adoption of Poverty Reduction Strategy Papers (PRSPs) and other development frameworks. Generally the Poverty Reduction Strategy Papers describes the structural, social, and macroeconomic programmes to reduce poverty and promote economic growth. In SSA, PRSPs has been adopted by countries such as the Democratic Republic of Congo, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Rwanda, Tanzania, Zambia and Mauritius with other development frameworks such as Vision 2020 and Vision 2030 adopted by Ghana and Kenya respectively. The broad objectives identified in the various PRSPs is improving of the welfare of the citizens by investing more in education, healthcare systems, infrastructure, improving water quality

and its accessibility to the households and enhancing agricultural research to enhance food security.(see UNECA Economic report on Africa, 2008).

A review of the various PRSPs by Mugabe (2009) of 19 countries in the region identified that most countries in the region did not adequately integrate science, technology and innovations into their PRSPs and explicitly identify the innovation policy intervention necessary in achieving their poverty reduction goals. One of few exceptions is the Kenya's Vision 2030, which has devoted a considerable attention to science, technology and innovation. Kenya's PRSPs specifically emphasized measures to strengthen national scientific and technological capabilities for national and global competitiveness. The framework outlines priority for science and technology innovation programmes which involves strengthening science and technology institutions by improving their capacity through infrastructure and equipment, developing highly skilled human resources with emphasis on increasing the number of scientist and engineers and enhancing awareness of the role of science, technology and innovation in poverty reduction and economic growth (see Mugabe, 2009).

3.2 Industrial activity in SSA

Since the advent of the industrial revolution in the mid.18th century, industrialization is observed to be directly linked to innovation. Innovative ideas created in the country can be converted into usable product, process, marketing and organizational innovation through the activities of the manufacturing sector. Wolf, (2007) demonstrate that manufacturing output (percentage of GDP) is generally low both at the private and public sector in Africa. The share of manufacturing output to global manufacturing output of Africa is less than 10 percent of the region's total GDP. Majority of countries in the region contribute less than 1 percent in the global share of manufacturing output *(*see

UNIDO, 2005).This has contributed significantly to the region's poor competitiveness in the global market and impacted negatively on the prospects of innovation enhancement in the region. Additionally, volume of commodities exported by the region to the global market are either in its raw state or with very little value addition due to the low technology and innovation advancement in the region. (see UNCTAD, 2008).

3.3 Foreign Direct Investment Inflows in SSA

Foreign direct investment inflows represent an important channel through which new innovative ideas are transferred from the developed countries and multinational cooperation to the domestic economy as indicated in the catch-up theory of Nelson and Phelps,(1966). FDI could be soft (information) or hard (investment in machinery and equipment). In 2007, Africa attracted a record sum of US$53 billion in FDI, however, much of this investment targeted the extractive industries (minerals and oil exploration in some few countries in the region, such as the oil in Uganda and Nigeria, Gold and Diamonds in Ghana, nickel in Madagascar, Aluminum in Mozambique and copper Zambia with very small amount of the inflows going into industrial sector to enhance innovation. (see UNCTAD, 2008). In addition, UNCTAD (2010), revealed that SSA countries are not generating more of FDI in knowledge and technological transfer due to the weak absorptive capacity of human capital, infrastructure, low level of entrepreneurship, existence of companies and quality of policies.(see Africa Innovation Outlook ,2010).

3.4 National Innovation Policies in Sub-Saharan Africa

The National Innovation Policy is a systematic framework or national policy adopted to promote innovation in a country. Many countries in the region are now aware of the relevance of innovation to productivity growth and competitiveness, however, innovation

policies in SSA are more implicit often outlined in their trade and industry policies (see African Innovation Outlook, 2010). The review of innovation policies by Mugabe, (2009) of 19 sub-Saharan African countries revealed that only South Africa has an explicit national innovation policy. The review indicated that in 2007, South Africa Department of Science and Technology adopted a Ten-year innovation Plan with specific targets of building a strong skills base of scientists, technicians and engineers, increasing the country's share of global patents, tripling South Africa's share of research publications in the internationally peer-review journals and expanding its energy infrastructure with more than 50 percent.

For example, Mauritius innovation policy is integrated into legislation for trade, commerce and industrial development called the Industrial Expansion Act (Act 1993). Ghana has taken a similar approach and integrated its innovation policies into investment, industrial and trade policies framework, Ghana uses a wide range of policy instruments to promote technological innovation including Ghana Investment Promotion Centre (GIPC), Act 1994, Free Zones Act, 1995(Act 504), however, with no coherence policy focus on promoting technological innovation. Currently in Ghana, innovation has been added to the Ministry of Science and Technology, without defined targets for innovation advancement in the country. Countries such as Congo, Malawi, Lesotho, Madagascar, Mozambique, Rwanda, Uganda, Tanzania and Zambia rely on their industrial policy in promotion of their technological innovation without one specific national policy for innovation (see Mugabe, 2009).

3.5 Gross Expenditure on Research and Development (percentage of GDP) in SSA

Gross public expenditure (percentage of GDP) is the most common indicator used for the global comparison of innovation performance across countries. In January 2007, Heads

of State and Government of African Union in a summit held at Addis Abba stated "African people are now more determined to banish poverty, combat diseases, improve public health, increase agricultural production, and achieve the Millennium Development Goals (MDGs)". With this vision, governments in the region affirmed their commitment to spend at least 1 percent of their GDP on research and development to boost innovative activities in SSA compared to the average 2 percent spend on R&D in the industrialized countries (see African Innovation Outlook, 2010).

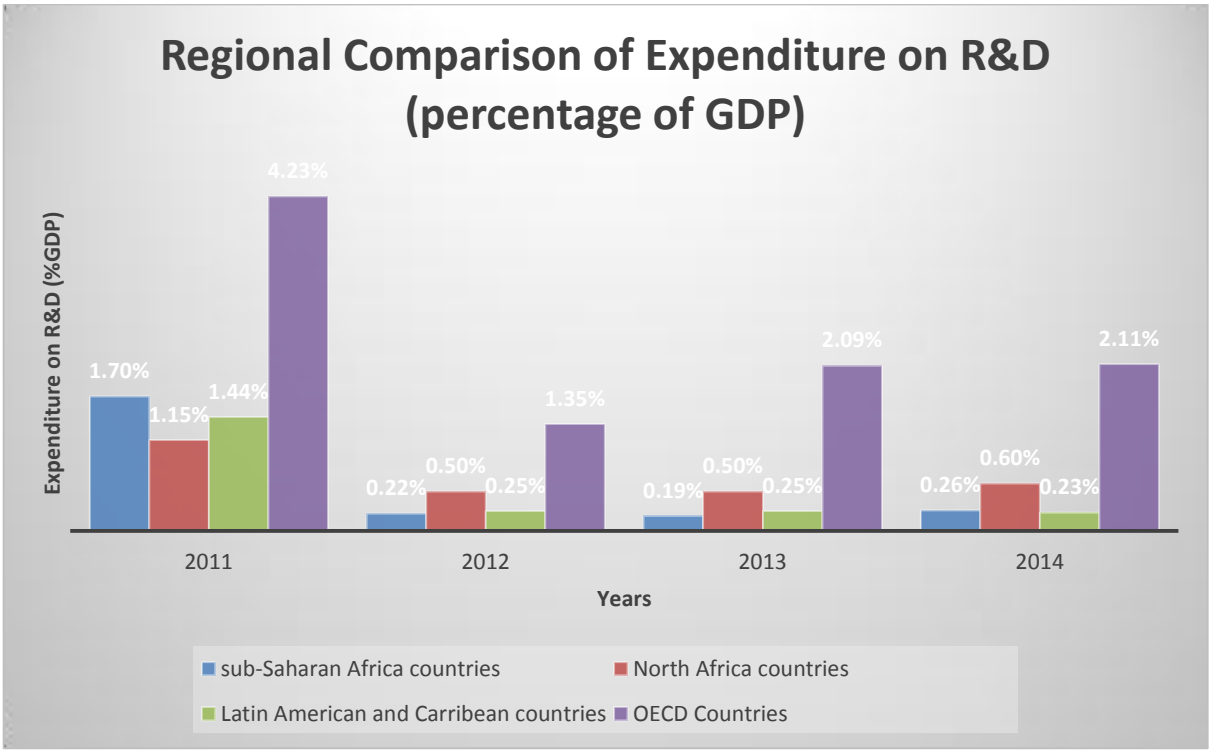
Table :(3.1): Average expenditure on R&D (percentage of GDP) by countries in SSA

Country	Average expenditure on R&D (% GDP)(2011-2014)
Angola	0.025
Burkina Faso	0.6
Gambia	0.025
Ghana	0.2
Mozambique	0.2
Mali	0.3
Madagascar	0.7
Mauritius	2.1
Namibia	0.02
Niger	0
Nigeria	0.15
Senegal	0.65
South Africa	3.6
Sudan	1.5
Togo	0.08
Tanzania	0.3
Kenya	0.45
Ethiopia	0.9
Rwanda	0.02
Swaziland	0.2
Gabon	0.3
Zambia	0.2
Zimbabwe	0.4
Uganda	0.18

Source:Author's computation 2015, from the Global innovation index report (2011-2014).

A survey by African Science Technology and Innovation Initiative (ASTII, 2010) in thirty-five (35) sub-Saharan African countries indicate that investment in research and development (R&D) in most African countries is still far below the African Union target of 1 percent. It is only South Africa which has met the African Union target of spending at least 1 percent of GDP on R&D, the rest of the countries in the region continues to spend between 0.1 and 0.5 percent of their GDP on R&D (see table 3.1 above). Additionally, figure (3.1) illustrates the global comparison of expenditure on research and development.

Fig. (3.1): Global comparison of Expenditure on R&D (% GDP)



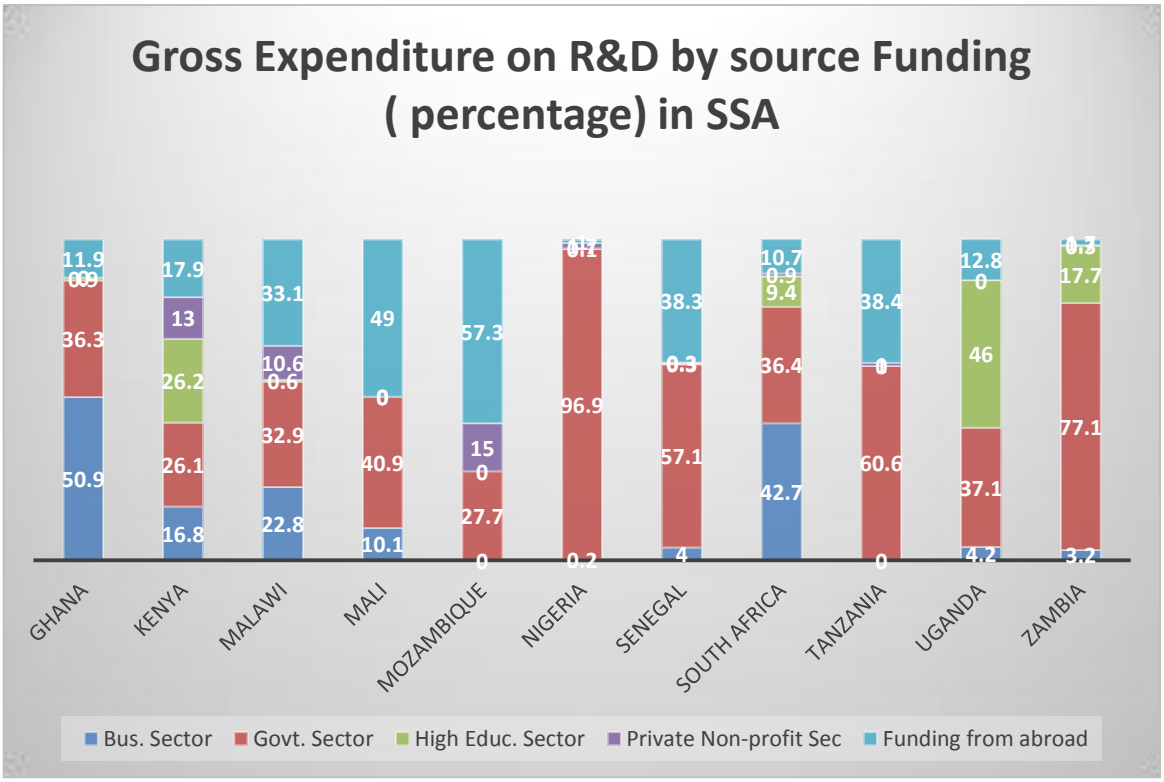
Source: Authors own calculation from the Global Innovation index (2011-2014).

It can be clearly observed from the figure 3.1 that, in 2011, expenditure allocated to R&D in SSA was higher than North Africa, Latin America and the Caribbean. However, from 2012-2014, the amount invested in R&D, continues to dwindle compared to other regional blocks as shown in the diagram 3.1 above.

3.6 Sources of Funding of Gross Expenditure on R&D in SSA

Financing R&D in SSA does not come from one source. Governments have however been the major financier of R&D activities in SSA (see ASTII, 2008).

Fig (3.2): Gross Expenditure on R&D (percentage of GDP) by Source Funding



Source: Author's computation from African Science, Technology and Innovation Initiative survey (2008).

From figure (3.2) above, the large proportion of expenditure allocated to R&D (percentage of GDP) in SSA is financed by government. In (2008), 96.9 percent of R&D activities was financed by government in Nigeria and 77percent in Zambia. The financial contribution by the business sector to R&D activities has not been adequate in most countries in SSA as shown in figure (3.2) above. For example, in Nigeria only 0.2 percent of the R&D activities was financed by the business sector, Mozambique, 0 percent, Tanzania, 0 percent, and Zambia 3.2 percent per survey in (2008). The few

exception is Ghana and South Africa where large percentage of the R&D activities is financed by the business shown in the figure (3.2) above. The higher education sector also represent another source of funding of R&D in SSA, however, their impact has been very low as indicated in the figure (3.2)

Funding of R&D from abroad remains one of the essential sources of R&D. 33.1 percent of funds allocated to R&D in 2008 by Malawi was generated from foreign donor support, Mali, 49 percent, Tanzania 38.4 percent, Mozambique 57.3 percent, and Senegal 38.3 percent. Despite the fact that foreign support in the development process is appropriate, continuous reliance on foreign donor support could be detrimental to SSA in this initial stage of building capacity for innovation as such financial support is expected to decrease over time. The private non-profit institutions support research and development activities in the region, though their support has not been adequate as exhibited in figure (3.2) above.

3.7 Tertiary Education and Skills development in SSA

Technological innovation and advancement requires literate workforce who will be able to generate their own ideas (as in Romer, 1990a) to boost innovation and also imitate other innovative ideas beyond the borders of the domestic economy as in (Nelson and Phelps 1966). Gross enrolment in tertiary education has grown faster in sub-Saharan Africa than any other continent in the world over the past four decades. While there were fewer than 200,000 tertiary students enrolled in the various tertiary institutions in the 1970s in the region, this number has soared to more than 4.5 million in 2008, more than 20 fold increase as revealed in the Global Education Digest report (2010). However, in comparison of gross tertiary enrolment and the enrolment graduation ratio with the rest of the world, SSA is the lowest 0.66 shown in table (3.1) below.

Table :(3.2) Global comparison of average tertiary enrolment ratio and enrolment graduation ratio

Region	Total tertiary student enrolment	Enrolment graduation ratio
World	158,308,000	1.08
Arab States	7,308,000	0.97
Central and East Europe	21,137,000	1.28
Central Asia	2,108,000	1.1
East Asia and Pacific	48,608,000	1.01
Latin America and Caribbean	19,723,000	1.25
North America and West Europe	34,423,000	1.32
South and West Asia	2,088,000	0.76
sub-Saharan Africa	4,517,000	0.66

Source: Global Education Digest (2010): www. UNESCO institute for Statistics.org

3.8 University-Industry research collaboration in SSA

Collaboration between the university and the industrial sector constitute an essential feature of a dynamic National Systems of Innovation. The process determines the extent to which the university and the industrial sector collaborate in research activities and how scientific knowledge are transferred from the universities to the firms. The mechanism has been both formal and informal approaches including meetings, joint research projects with funding from firms and companies. University–industry research collaboration provides the platform for students at the tertiary level to obtain practical skills training at the industrial sector whiles schooling through internship and work attachment and offer the opportunity of testing educational curriculum of the country. In 2014, whiles Switzerland was ranked first in terms of university- industry research collaboration globally in the Global innovation index report, majority of countries in SSA were ranked low (see table 3.2 above). Mugabe (2009) observed that the low

research collaboration between the universities and industrial sector in Africa is the result of underfunding of the university research and this has resulted in research conducted by the universities not directed to the interest of the industrial sector (see Mugabe, 2009).

Table :(3.3): Rankings of university –industry research collaboration in SSA

Country	University-Industry Collaboration	Rank
Switzerland	80.67%	1
South Africa	59%	28
Kenya	54.67%	37
Uganda	45.50%	56
Rwanda	45.17%	57
Gambia	44.17%	61
Zambia	42.50%	68
Tanzania Rep.	41.83%	72
Ethiopia	41.83%	73
Ghana	41.50%	76
Seychelles	40.33%	78
Nigeria	38.17%	89
Mauritius	38.00%	91
Madagascar	37.83%	92
Mozambique	37.83%	92
Burkina Faso	37.33%	96
Botswana	37.13%	97

Source: Global Innovation index Report, 2014

3.9 Intellectual Property Protection Laws in SSA

An important factor that is likely to drive innovation is intellectual property protection. Intellectual property right is the rights granted to individuals, companies, firms or countries for creativity in the form of patents, copyrights and trademarks. Pouris and Pouris (2009) in a review of intellectual property laws in Africa indicate that majority of countries in Africa have intellectual property right laws and institutions and are also

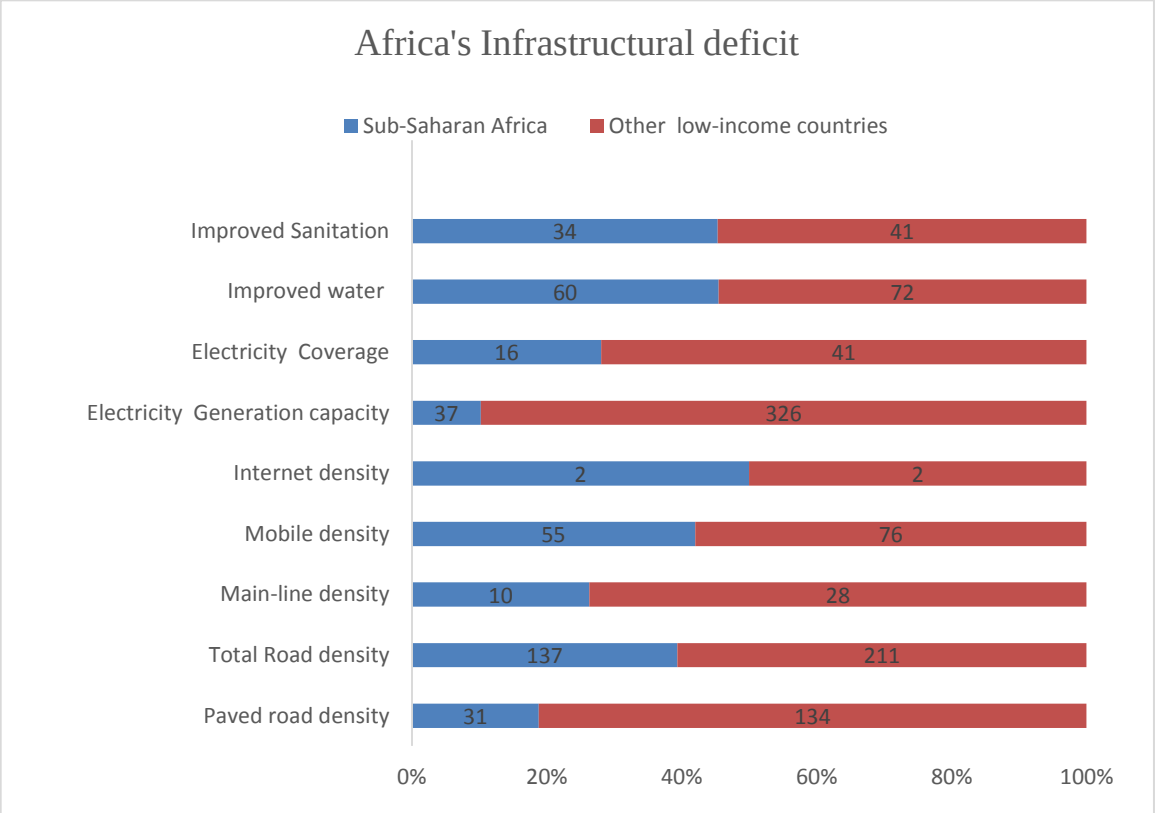
parties to international treaties such as Paris Convention (Industrial Property), The World Intellectual Property Organization (WIPO), African Intellectual Property Organization, (ARIPO), The Patent Cooperation Treaty (PCT), The Hague Agreement, The Madrid Protocol and the Lusaka Agreement. The review also observed that the laws governing the intellectual property protection in most countries in SSA are outdated and do not encourage creativity for innovation for fear of imitation.

For example, Swaziland's Patents, Designs and Trademarks Act No.72 of 1936 was last amended in 1969, Rwanda's Patents legislation was amended in 1967, Seychelles Patents Act, 253 was last amended in 1976 (see Pouris and Pouris, 2009). In addition to the above, the World Patent report (2008) indicates that in 2006, sub-Saharan Africa accounted for less than 1 percent of the World's total patents registration, indicating that the property right laws in the region are not robust to encourage creativity to promote innovation. Also, more than 60 percent of the region's patents are registered to South Africa (see WIPO report, 2008).

3.10 Infrastructure in Sub-Saharan Africa

The relationship between infrastructure, innovation and productivity growth is an issue which has received much recognition in the current growth process. Infrastructure includes services such as water, energy, transport, information communication technologies and other trade logistics applied in the productive activities. About 99 percentage points of per capita economic growth in Africa from 1990 to 2005 was attributed to physical infrastructural development compared to the 68 percentage point for other structural policies (see Calderon, 2008). However, comparing infrastructure quality and quantity with the rest of low-income developing countries in the world, SSA countries lag behind in the infrastructural development.

Fig :(3.3): Comparison of infrastructure Deficit in SSA to other Low-income regions in the world



Source: www. Africainfrastructure.com

Alvaro *et al.*, (2009) posits that the poor infrastructural deficits is a major constraints on doing business in SSA and depresses innovative investment by about 40 percent.

Not only is Africa's infrastructural deficits and coverage impact negatively on productive investment, the prices of infrastructural services are exceptionally higher compared to the global standard as shown in table (3.3) below. World Bank (2009) indicate that the poor state of infrastructure in SSA, electricity, water, roads, and information technologies reduces national economic growth by 2 percent point every year and business production by as much as 40 percent (see World Development indicators report,2009).

Table :(3.4) Comparison of SSA Infrastructural services cost to other developing regions

Infrastructure sector	Sub-Saharan Africa	Other developing regions
Power tariffs ($ per Kilowatts-hour)	0.02-0.46	0.05-0.10
Water tariffs ($ per Cubic-meter)	0.86-6.56	0.03-0.60
Road Freight tariff ($ per ton-Kilometres)	0.04-0.14	0.01-0.04
Mobile Telephony ($ per basket per month)	2.60-21.00	9.9-0.00
International telephony ($ per 3-minutes call to U.S)	0.44-12.50	2-0.00
Internet dial-up services ($ per Month)	6.70-148.00	11-0.00

(Source: Africons, 2008. Unit costs of infrastructure services in SSA)

CHAPTER FOUR

METHODOLOGY AND DATA SOURCES

4.0 Introduction

The chapter elaborates on the conceptual framework and the econometric techniques applied to the study. The chapter is in five sub-sections including the discussions on the econometric framework, model for the empirical estimation, an a priori expectation, estimation techniques, some diagnostic tests, data sources and definitions of variables.

4.1 Econometric Framework

Recent theories of economic growth draw primary attention to endogenous technological change to explain the growth patterns of world economies. From the endogenous growth model, Romer, (1986 and 1990a) and Aghion and Howitt, (1992) the human capital is the main engine of growth through innovation. Romer, (1990a) indicates that, technical change (innovation) is driven by people who are intentionally searching for new ideas or knowledge motivated by market incentives. The core objective of developing those models was to understand the mechanism through which resources are transferred into new ideas or innovation. From the above theoretical support, an innovation function is postulated as:

$$A = f(A, H) \qquad (4.1)$$

The equation (4.1) means that innovation flow (A) depends on the existing stock of knowledge (A) and the stock of human capital (H) devoted to searching for new ideas.

By augmenting the endogenous growth conceptual framework in equation (4.1) to introduce other important variables into the model, this study postulate that innovation in SSA is influenced by Institutional quality, gross expenditure allocated to R&D

(percentage of GDP), human capital (skilled workforce),quality of physical infrastructure, Intensity of domestic trade and competition, net foreign direct investment inflows (percentage of GDP), university-industry research collaboration and domestic credit to private sector,(percentage of GDP) and ease of starting new businesses in SSA. From the above postulation, a simple innovation equation is then stated as:

$$Inno = f(IQ, GERD, HC, QPI, IDTC, FDI, UIC, DCPS, ESB) \quad (4.2)$$

Where, Inno is an index of innovation score (in percentage), IQ- Institutional Quality index, GERD- Gross expenditure on R&D (percentage of GDP), HC-Human capital index, QPI- Quality of physical infrastructure index, IDTC- Intensity of domestic trade and competition index , FDI- Net foreign direct investment inflows (percentage of GDP), UIC-University-Industry research collaboration index, DCPS –Domestic credit to private sector (percentage of GDP) and ESB- represent the Ease of starting a new business in SSA.

4.2 Econometric Model Specification

From equation (4.2) the dynamic panel model to be estimated is therefore written as:

$$Inno_{it} = \beta_0+\beta_1 IQ_{it}+\beta_2 GERD_{it}+\beta_3 HC_{it}+\beta_4 QPI_{it}+\beta_5 IDTC_{it}+$$
$$\beta_6 FDI_{it}+\beta_7 UIC_{it}+\beta_8 DCPS_{it}+ \beta_9 ESB_{it}+ V_{it} \quad (4.3)$$

Where;

$Inno_{it}$ = Innovation score (in percentage) for each country at time t

IQ_{it} = Institutional quality index for each country at time t

$GERD_{it}$ = Gross expenditure on R&D (percentage of GDP*)* for each country at time t

HC_{it} = Human capital index for each country at time t

QPI_{it} = Quality of physical infrastructure index for each country at time t

$IDTC_{it}$ = Intensity of domestic trade and competition for each country at time t

FDI_{it} = Net foreign direct investment inflows (percentage of GDP) for each country at time t

UIC_{it} = University- Industry research collaboration index for each country at time t

$DCPS_{it}$ = Domestic credits to private sector (percentage of GDP) for each country at time t

ESB_{it} = Ease of starting a new business index for each country at time t

V_{it} = Idiosyncratic error term,

Where $\beta_0, \beta_1, \beta_2, \beta_3, \ldots\ldots, \beta_9$ represents the parameters to be estimated.

4.3 A priori Expectation

- Strong institutions are important for innovation as it mitigates the costs, risks and uncertainties surrounding innovative activities by providing regulations that governs economic agents and contract enforcement (see Oyelaran-Oyeyinka, 2004). Independent judicial system, rule of law, political stability, good governance and press freedom are important determinants of quality institutions. Lower corruption and less bureaucratic chains act as incentives to private sector growth. Political unrest, poor public and civil service delivery and lack of independence of the judicial

system will certainly limit investment opportunities and limit innovative activities of firms. This study expect the coefficient of institution to be positive, implying that higher political stability, independence of the judicial system, public and civil service will act as safety net to private investors and encourage more risky investment which is a characteristics of innovation, the coefficient of the institution variable is expected to be positive. (i. e. $\beta_1 > 0$).

- From the empirical literature, an important variable used for measuring the innovation intensity or performance of countries is the expenditure allocated to R&D (percentage of GDP) Most empirical studies have demonstrated the positive effect of R&D on innovation (see Becheikh, 2006). Hence, Ceteris Paribus, the higher the expenditure allocated to R&D (percentage of GDP), the more ideas will be generated and the higher will be the rate of innovation. ($i. e. \beta_2 > 0$).

- The human capital is resolutely observed to drive innovation by the endogenous growth theory. First it facilitate the imitation of technologies developed somewhere and also promote technical change. The higher the level of human capital base, the more innovative ideas which can be created. With the current increase in the tertiary enrolment in SSA which is appropriate for innovation, the coefficient of human capital on innovation is expected to positive ($i. e. \beta_3 > 0$).

- Quality physical infrastructure such as paved roads and constant supply of electricity is likely to lower the logistical, production, and transaction cost of economic activities and free resources to the private sector for reinvestment into productive innovative activities. On the contrary, poor road network and erratic power supply will increased cost of production and certainly reduce productive investment of the private sector. Thus, “all other things being equal" the higher the quality of physical

infrastructure, the higher the innovative investment. The coefficient of the physical infrastructure is expected to be positive. (i.e. β_4 >0).

- Domestic trade and competition is concept which theoretically received considerable attention in the works of Schumpeter, (1911 and 1939) Arrow,(1962) and currently by Aghion *et a*l., (1997). More specifically, Aghion *et al.,* (1997) indicate in the "escape effect" theory that firms deliberately increased their expenditure on research and development to escape from competition of their rival firms. In the case of SSA where innovation is very low, this study expects that higher competition in the domestic market will encourage the firms to allocate more funds to conduct R&D to increase their profit margins and maintain their market shares. Therefore, the coefficient of domestic trade and competition is expected to be positive.($i.e.\beta_5 > 0$).

- An important mechanism through which foreign technologies of multinational enterprises are communicated to the domestic economies is through foreign direct investment. From the empirical literature survey, incoming FDI on the domestic innovation depends on the local absorptive capacity. In the case of SSA where domestic absorptive capacity is generally low, the coefficient of net FDI inflows (percentage of GDP) is expected to be negative. ($i.e.\beta_6 < 0$).

- Collaboration between the university and the industrial sector for joint research represent a dynamic Innovative system of an economy. When new and scientific ideas are created at the university and research centres, it has to trickle down to the industrial sector for application and usage. Higher collaboration between the universities and industries in terms of joint research and sharing of innovative ideas promote innovation especially at the firm level where the innovation takes place

most. The coefficient on University -Industry collaboration is expected to be positive. Thus, "Ceteris Paribus", the higher the collaboration between the university and industrial sector, the higher will be the transfer of new ideas from the knowledge production sector to the industrial level. (i.e. $\beta_7 > 0$).

- Firms requires strong financial institutions to provide financial resources needed to expand their scale of production to ensure the Schumpeterian process of "creative destruction". Financial institutions also represent an important component of the national innovation system. For this study, the coefficient on domestic credits allocated to private sector (percentage of GDP) is expected to be positive. Thus, "All other things been equal" the higher the accessibility of credits by the private sector, the higher will be investment in innovative activities. (i.e. $\beta_8 > 0$).

- Businesses in the industrialized countries performs very well due to the conducive business climate in those countries. The coefficients on the Ease of starting a new business is expected to be negative. Ceteris Paribus, lower cost of registering new businesses, conducive business environment including quality provision of customs clearance, appropriate government policies that support business growth, lower bureaucratic chains, lower durations for registering and staring new business ventures will boost investors' confidence and promote more investment opportunities and hence promote innovation. In the extant literature, there is little guidance on the ease of starting a new business, however, the lower the cost, duration and bureaucratic chains of starting a new businesses will positively drive innovative investment. With this, the coefficient of the variable is expected to be negative (i.e. $\beta_9 < 0$).

4.4 Estimation Techniques

To ensure consistency and robustness of the estimation, both the Pooled OLS and Systematic Generalized Methods of Moments would be employed to estimate equation (4.3) to ensure the reliability of the estimates from both estimation results. Similar model specification is employed by (Ulku, H, 2004) in analyzing the effect of R&D on innovation and the impact of the latter on economic growth in 20 OECD and 10 Non-OECD countries.

4.4.1 Pooled OLS

The Pooled OLS regression involves running a simple Ordinary Least Squares (OLS) on the panel data to assess the effects of the explanatory variables on the dependent variable without taken cognizance of the panel structure of the data. Though, the System GMM is the main estimation technique applied in this study, however, the pooled OLS which ignores the country effect would assist in consistency check of the signs of the explanatory variables in the System GMM.

Consider a linear panel data model

$$Inno_{it} = X_{it}'\beta + \varepsilon_{it} \qquad \text{i= 1 …, N , t = 1 …, T} \qquad (4.4)$$

This model may appear overly restrictive because β is the same in each time period. Parameters changing over time can however be allowed for by appropriately choosing X_{it} . The fact that X_{it} is written for some elements does not mean those elements may not be time varying. The usual assumptions for cross section data analysis is assumed for the model.

The two assumptions required for pooled OLS to consistently estimate β are follows:

Assumption 1: $E\ x_t, \varepsilon_t\ = 0\ , t = 1,2 \ldots \ldots, T$

Assumption 2: rank $[\ \sum_{t=1}^{T} E(x_t{}'\, x_t)] = K$,

While assumption 1 does not talk about the relationship between x_s and ε_t for s≠ t, the idea of perfect linear dependencies among explanatory variables is ruled out by assumption 2. In order to apply the usual OLS statistics from the pooled OLS regression across *i* and *t*, homoscedasticity and no serial assumptions must be assumed. The weakest forms of these assumptions are the following:

Assumption 3: (a) $E({\varepsilon^2}_t \mid x_t{}'x_t) = \sigma^2 E(x_t{}'x_{t)}, t = 1,2, \ldots\ldots, T$, where $\sigma^2 = E({\varepsilon^2}_t)$ for all *t;*

(b) $E\ \varepsilon_i\varepsilon_s {x'}_t x_s\ = 0, t \neq s, t, s = 1, \ldots\ldots, T.$

The first part of the assumption (3) is a fairly strong homoscedasticity assumption; sufficient is $({\varepsilon_t}^2 \mid x_t) = \sigma^2$, for all t .This implies that not only does the conditional variance not depend on x_t , but also, unconditional variance in every period. The conditional covariance of the errors across different time periods is restricted to be zero by assumption (3b). In fact, since x_t almost contains a constant, assumption (3b) requires at a minimum that $E(\varepsilon_i\varepsilon_s = 0$, t≠ s. Sufficient for 3b is $E\ \varepsilon_i\varepsilon_s \mid x_t{}'x_s\ = 0$, t≠ s, t,s= 1, …..,T.

Assumption (3) implies more than just a certain form of the unconditional variance matrix of $u = (u_1, \ldots\ldots\ldots\ldots, u_T)'$. Assumption (3) also implies $E(u_i{u'}_i) = \sigma^2 I_T$ denoting constant unconditional variances and covariances. Heteroscedasticity and serial correlation can be accounted for to guarantee correct inferences and estimates.

4.4.2 The System Generalized Methods of Moments

The Dynamic Panel regression is seen to be more appropriate for empirical study as it allows the inclusion of lagged dependent variables as explanatory variables in the model to capture its effects on the dependent variable. The Dynamic Panel model is specified as:

$$Inno_{it} = \alpha Inno_{it-1} + X_{it}\beta + \varepsilon_{it} \quad (4.5)$$

Where $Inno_{it}\ is\ innovation\ score$, $Inno_{it-1}$ is the lag of the dependent variable, X_{it} in the equation (4.5) is a matrix of all the explanatory variables, (ε_{it}) is the error term which can be decomposed into two components: The first component measures the unobserved country-specific effects μ_i and the second component is the idiosyncratic error term v_{it} , thus;

$$\varepsilon_{it} = \mu_i + v_{it}$$

Equation (4.5) can therefore be re-written as;

$$Inno_{it} = \alpha Inno_{it-1} + X_{it}\beta + \mu_i + v_{it} \quad (4.6)$$

The Generalized Methods of Moments procedure is best for the reason that it resolves the Dynamic panel bias problem resulting from the endogeneity associated with such models. In the literature however, two estimator procedures are considered as special case of the GMM estimation technique, the instrumental variable (IV) and the Two Stage Least Squares (2SLS) estimation when dealing with the endogeneity problem. However, this technique involves the use of ‘external instruments', the problem with the external instruments is that they are usually weak and hardly satisfy the conditions of “validity and relevance" in order to yield unbiased estimates. Additionally, it may also be difficult

to obtain instruments which correlate with the endogenous variables and at the same time uncorrelated with the stochastic error term.

The literature therefore pinpoints two (2) types of GMM estimation procedures. The differenced GMM introduced by Arellano and Bond, (1991) and the System GMM introduced by Arellano and Bover, (1995) and Blundell and Bond, (1998).

The differenced GMM estimator procedure resolves the inconsistency problem resulting from the endogeneity associated with of some of the regressors in equation (4.5). This procedure eliminates sources of the inconsistency in the estimation by applying the first differenced operator to the estimation. After differencing, this equation is subsequently estimated by the differenced GMM by including the lags as regressors.

The differenced equation is of the form:

$$Inno_{it} - Inno_{i\,t-1} = \alpha_1(Inno_{i\,t-1} - Inno_{i\,t-2}) + \alpha_2(X_{it}-X_{it-1}) + (v_{it}-v_{it-1}) \qquad (4.7)$$

Equation (4.7) thus eliminates the unobserved country–fixed effects (μ_i) by taking first difference of the equation (4.6) and in the process deal with the inconsistency and biases resulting from the endogeneity of the explanatory variable by using lagged values of the endogenous explanatory variables as instrument. The differenced GMM estimator is based on the following moment conditions under the assumption that the regressor is weakly exogenous and not serially correlated:

$$\in [Inno_{it-1}\ v_{it} - v_{it-1}\ ] = 0 \text{ , for t= 3, 4, 5, …, T} \qquad (4.8)$$

$$\in [X_{it-1}\ v_{it} - v_{it-1}\ ] = 0 \text{ , for t= 3, 4, 5… ,T} \qquad (4.9)$$

The standard GMM estimation which eliminates the unobserved country-specific effects have been found to produce unsatisfactory results because the process may pose serious

biases when the dependent variable is highly persistent, and there is a weak correlation between instruments and the endogenous variable. The weak instruments actually increase the variance of the coefficients and bias the coefficients in the small sample. However, the System GMM estimator designed by Arellano and Bover, (1995) and Blundell and Bond, (1998) rectify this problem of weak instruments associated with the differenced GMM estimator by a system of two equations namely the level equation and the difference equation. The System GMM has been shown to perform much better (less bias and more precision) especially when the dependent variable is persistent.

Roodman, (2009) argues that the efficiency of the estimation equation would be greatly improved when the moment conditions of its level form and first difference forms are combined. Hence, the system GMM estimator is preferred to the differenced GMM when the dependent variable is persistent.

4.5 Diagnostic Tests

4.5.1 Unit Root

A common characteristic of macroeconomic panel time series data is that variables may increase, or less frequently decreases over time as a result of economic shocks. Applying OLS on a non-stationary panel data is more likely to produce spurious regressions where the parameter estimates of the regressors are biased and not reliable (see Maddala and Kim, 1998). To avoid obtaining wrong and biased estimates resulting from the non-Stationarity of the explanatory variables, the Fisher-type of unit root test will be conducted to ascertain Stationarity status of the regressors.

4.5.2 Autocorrelation and Heteroscedasticity

The Dynamic panel model in equation (4.5) is associated with two main forms of persistence over time. At the outset, there is the case of autocorrelation as a result of the presence of the lagged dependent variable been used as regressor. This is the case because if the dependent variable is a function of a component of the error term, then its lag is also a function of the error term. Taking lag of equation (4.5) gives the following equation:

$$Inno_{i,t-1} = \alpha Inno_{i,t-2} + X_{i,t-1}\beta + \mu_i + v_{i,t-1} \quad (4.10)$$

From equations (4.5) and (4.10), we observe that the dependent variable and its lag are both functions of the country-specific time invariant component of the error term. That is:

$Inno_{it} = f(\mu_i)$ and $Inno_{i,t-2} = f(\mu_1)$. This means that the lag dependent variable is also correlated with the error term in the model. However, the Dynamic panel model thus solves the problem associated with the problem of autocorrelation.

4.5.3 Fixed effects and Random effects

Two important assumptions pertaining in the econometrics literature is the correlation existing between the time-invariant error term (μ_i) and the explanatory variables. The random effect (RE) specification in equation (4.5) assumes that $E(\mu_i)$= 0 and E (μ_i/X_{it}) = 0, and thus the simple OLS on the pooled data is unbiased. Contrary, the fixed effects (FE) assumes otherwise that the time-invariant specific effect correlate with the regressors and as such estimate from simple OLS on the pooled data is biased and inconsistent. Thus, $E(\mu_i/X_{it}) \neq 0$. The Hausman test is used in choosing between the

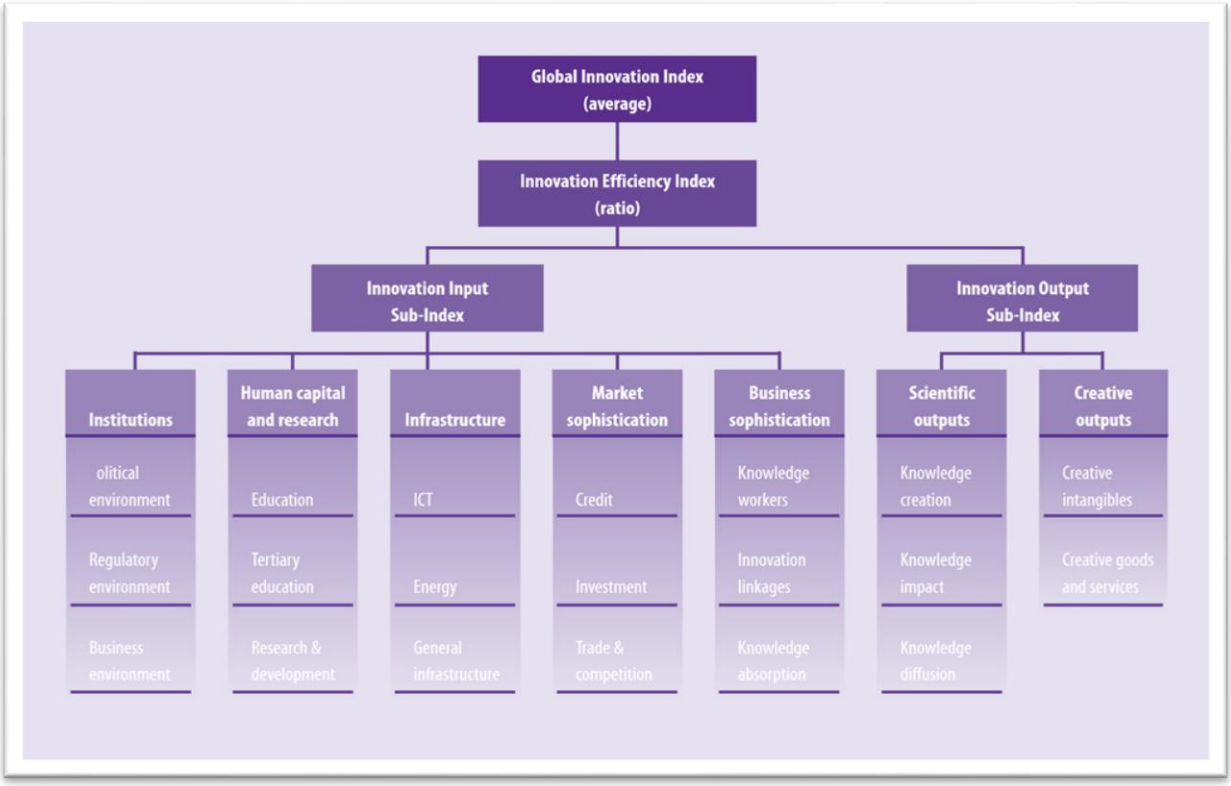
RE and FE. However, the System GMM estimation technique would yield more reliable estimates when the data fit for fixed effect.

4.6 Data Sources

The study employed mainly panel data from 2011 to 2014 of a sample of 30 Sub-Saharan African countries. The choice of the countries and variables included in this study is generally based upon data availability of innovation for those countries. All the data used in the analysis are indices extracted from the Global innovation index (GII) reports (2011-2014). The innovation score for each country is built from composite variables with weight attached to each variable used in calculating the innovation score. Variables used in the GII are obtained from United Nations-COMTRADE database, UNESCO Institute for Statistics, World Governance Indicators-World Bank Database, World Bank Database on Doing Business indicators, IMF Database, World Bank Ease of Doing Business indicators, World Telecommunication database and other qualitative data from the World Economic Forum, Annual Executive Opinion Survey.

4.7 Framework for computing the innovation score

Fig: (4.1) Diagram showing the framework for computing the innovation score



Source: Global Innovation Index report (2011-2014)

The figure (4.1) above is the framework adopted in the Global Innovation Index report for the calculation of the innovation score for each country. The model above uses a combination of both objective and subjective data drawn from the various sources as indicated in section (4.7). The steps involved in calculating the innovation score for each country are outlined below:

- The model in the first instance collects between ninety (90) to one-hundred and thirty (130) variables based on their qualitative relevance to the Global Innovation Framework.
- The next step was grouping the data collected under each variable into two sub-indices, namely, the innovation input-sub index and innovation-output sub-index.

- All the variables under the two sub-indices are further grouped into eight (8) pillars: (1) Institutional policies, (2) Human capacity, (3) General ICT and infrastructure, (4) Market sophistication, (5) Business sophistication, (6) Knowledge, (7) Competitiveness and (8) Wealth as shown in the figure (1.4).
- Since the data for each variable which defines each pillar has been collected, the next step was to select a final set of countries to be included or excluded. The main criterion used in selecting the countries was the desired level of availability of data for the selected variable. Data on those variables which had less than 50% of the variables were dropped. Only countries whose number of missing entries was less than 50% of the total number of variables were included. Variable data was normalized in such a way that the range was from 1-7.

For the final computation, it was taken that, a mean of the variables in each pillar gives the respective pillar. A simple mean of the five input pillars gives the innovation input pillar. Similarly, a simple mean of the three output pillars gives the innovation output pillar. Finally, a simple mean of the innovation-input and the innovation-output pillars was used to arrive at the innovation score for each country.

4.8 Variable Definitions

4.8.1 The Dependent variable (Innovation Score)

The innovation score is the overall score attained out of 100 percent in innovation advancement relative to other countries in the Global innovation Index. The score indicate the extent to which countries in SSA are able to generate new knowledge or ideas to implement new and significantly improved products (goods or services), process (improved production methods), marketing method and organizational method to improve their competitiveness in the global market.

4.8.2 Explanatory Variables

- **Institutional quality index**

The institutional quality index is a composite variable captured by the perceptions of political stability, public and civil service quality and rule of law in each country. The political stability a as an indicator of quality institution captures the perceptions of likelihood that democratically elected government will not be destabilized or overthrown by unconstitutional means, including politically motivated violence and terrorism. The quality of public and civil service indicate how the public services implement policies to support private sector activities and the degree of their independence from political pressures. The variable also indicate economic agents confidence in the rule of law that prevails in aspects such as contract enforcement, property rights laws, police and security enforcement and independence of the judicial system.

- **Expenditure on R&D (percentage of GDP)**

The Gross Expenditure on R&D (percentage GDP) is a variable which measures the total domestic expenditure on R&D activities during a given year as a percentage of GDP in each country. In both the theoretical and empirical literature, the expenditure on research and development, (percentage of the Gross Domestic Product) is used as yardstick for measuring the innovation performance of countries as it makes it easy for cross country comparison.

- **Human Capital index**

The human capital index represents the skilled workforce employed in the production process by the firm. The variable is a composite measure captured by tertiary enrolment ratio and graduates in science and engineering employed. The variable thus represent the total number of people who are enrolled in tertiary education as a ratio of people in the age group that officially corresponds to the tertiary level of education plus graduates in science and engineering employed in the manufacturing, engineering and construction over all the tertiary graduates in the country.

- **Quality physical infrastructure index**

The quality infrastructure variable is captured by the supply quality of physical infrastructure which supports the innovative activities as defined in the GII report. The variable is mainly measured by generation of electricity output produced from the various sources of energy, and the quality of trade-transport related infrastructure such as road networks, ports, railways.

- **Intensity of domestic trade and competition index**

Stemming from the Schumpeter-Arrow debate 1934 and 1962 and currently Aghion *et al*., 1997, an important factor theoretically observed to drive firm's innovative activities is the extent of domestic trade and competition among firms. The variable is obtained from the World Economic Forum Executive opinion survey which indicates the intensity of domestic trade and competition in the various local markets.

- **Net foreign direct investment inflows (percentage of GDP)**

The net FDI inflow (percentage of GDP) variable indicates new foreign investment less foreign disinvestment in the reporting economy from foreign investors as a percentage of the country's GDP. The variable thus captures the amount of investment generated through multinational cooperation establishment in the domestic economy less amount of investment taken away from the reporting domestic economy by foreign investors all over the total GDP of the country over years in review.

University- Industry research collaboration index

New ideas created at the university through research become usable if it is transferred from the university to the firm and industries through collaboration. This variable indicates the extent to which the university collaborates with the industrial sector through research activities. The collaboration also shows how the industrial sector support academic research at the university in terms of provision of fund and the role played by industry in curriculum development of the university.

- **Domestic credit to private sector (percentage of GDP)**

The domestic credit to private sector (percentage of GDP) variable measures the financial resources provided to the private sector such as loans, trade credits, venture capital funds and other accounts receivable that establish a claim for repayment. The variable also captures the combined gross microfinance loan portfolio (percentage of GDP) allocated to the private sector.

- **Ease of Starting a new business index**

The ease of starting a business variable captures the average number procedures, duration (days), bureaucratic chains and costs required to complete business registration. The variable indicates the procedures officially required of entrepreneur to start up and formally operate an industrial or commercially business including all necessary licenses and permits.

CHAPTER FIVE

ANALYSIS OF EMPIRICAL RESULTS

5.1 Descriptive Statistics

The descriptive statistics relates to thirty (30) countries in SSA for the period 2011-2014. The statistics under consideration are the mean, standard deviation in addition to the minimum and maximum values of the variables. In all, nine (9) different variables have been employed in the study to test their effects on innovation advancement in Sub-Saharan Africa. The mean values indicate the average of the variables used in the study whereas the standard deviation illustrates how spread-out the variables are from their mean values. It also shows how the variables are scattered from their respective means. The difference between the minimum and maximum values of the variables used in the study gives the range of the values used for the study for period under consideration. The range is an indicator of the level of fluctuations in the variables. The larger the range values, the higher the level of fluctuations in a variable and vice versa.

Over the period 2011-2014, the average innovation score for the thirty (30) SSA countries understudy averaged 27 percent ranging from a maximum score of 40.9 percent and 12.7 percent showing high level of fluctuation. The range indicate that some countries in the region scored as low as 12.7 percent in technological innovation advancement within this period under consideration. The gross expenditure on R&D (percentage of GDP) averaged 1.03 percent. In most empirical studies on innovation, country's innovation performance is determined by the amount of expenditure allocated to R&D (percentage of the country’s GDP). As indicated in table (5.1) below, the

maximum value of this variable observed is 1.8 percent with minimum of 0 percent. This range shows that on the average, majority of countries in the region spend less of their GDP on research and development.

Table :(5.1): Descriptive statistics of variables

Variables	Mean	Standard Deviation	Minimum	Maximum
Innovation score (score is in %)	27	4.5	12.7	40.9
Gross expenditure on R&D (% of GDP)	1.03	2.69	0	1.8
Human Capital index	21.63	8.5	3.7	43.3
Physical Infrastructure index	3.03	0.25	1.82	3.7
Intensity of trade and domestic competition	59.5	8.25	30.3	78.4
Net Foreign Direct Investment (% GDP)	14.97	20.2	-3.8	35.2
Domestic credits to private sector (% of GDP)	23.64	22.1	1.5	48.2

Source: Author's computation, 2015

The low expenditure on research and development can be attributed to the low priority attached to technological innovation promotion in the region. The region's target is 1 percent of GDP allocated to R&D compared to the average 2 percent in the industrialized countries'. However, South Africa, Uganda, Kenya, Mauritius and Seychelles spends more than 0.5 percent of their GDP on R&D activities whiles the majority of countries in SSA continues to spend less than 0.5 percent. South Africa, currently spends more than 1

percent of it GDP on R&D. This observation therefore makes it not surprising that, the country is the star of Africa in terms of technological innovation, productivity growth and is the only country in SSA which is able to compete more favourably in the global market.

The human capital variable indicates the skilled workforce (tertiary enrolment ratio and graduates in science and engineering) employed in the production process. The average score on the human capital variable is 21.6 percent. The maximum value is 43.3 percent which indicate relatively high skilled workforce employed in the production process of some countries in the region. However, in some countries, the skilled workforce employed in the production process is as low as 3.7 percent of the total working population.

The ability of SSA countries to catch-up in the innovation advancement and bridge the technological divide with the West depends on the availability of quality physical infrastructure such as affordable electricity, accessibility of quality road and other trade-related services which support innovative activities. From table (5.1) above, the average score on the availability of quality physical infrastructure is 3.03 percent. The maximum score is 3.7 percent whiles the minimum is 1.87 percent. The relatively low average values indicate the infrastructural deficit in the region which is likely to impact negatively on industrial development and innovation promotion.

The descriptive statistics from table (5.1) also indicate that the domestic credits in the form of loans, trade credits, venture capital funds, gross microfinance loan portfolio (percentage of GDP) allocated to private sector investment in the region averaged 23.64 percent with a maximum score of 48.2 percent and the least been 1.5 percent

respectively. The high fluctuation between the maximum and minimum values of the variable indicates the weak financial portfolios earmarked for industrial development. The high standard deviation of 22.1 shows the high variation in the accessibility of financial resources by firms in the region.

Foreign direct investment is an important channel through which technology whether soft (information) or hard (machines and equipment) are transferred from the advanced countries to the developing countries. Within this period understudy, net FDI inflows (percentage of GDP) averaged 14.97 percent, with a maximum of 35.2 percent and a deficit of 3.8 percent.

5.2 Diagnostic Test Results

In this section, the results on the diagnostic tests conducted for Unit roots, heteroscedasticity, autocorrelation, over-identifying restrictions, and choice of fixed or random effects models are reported. Each of these tests is analyzed in the subsequent sub-sections. The main motive behind these tests is to ensure that the data fits the model and that the results from the system GMM estimation are valid and reliable.

5.2.1 Unit Roots Results

Choi (2001) argues that if the number of panels is finite, the inverse chi-squared test is applicable and more powerful. This statistic has a chi-squared distribution with 2N degrees of freedom and the decision rule suggests that if the probability of the inverse chi-squared of a variable is less than the level of significance, the null hypothesis is rejected and conclude that the variable is stationary. Hence the results of the Fisher-type unit roots test are presented in table (5.2) below. The null hypothesis that all panels contain unit roots is therefore rejected for all the variables on the basis of the inverse chi-

squared test in favour of the alternative hypothesis that at least one panel is stationary. The robustness of the inverse chi-squared test results is affirmed by the results of the inverse normal, the inverse logit and the modified inverse chi-squared test statistics.

Table :(5.2): Fisher-Type Stationarity (Unit Roots) Test

Variable	Inverse chi-sqd.		Inverse Normal		Inverse logit t		Modified inv.chi.sqd.	
	Statistic	Prob	Statistic	Prob	Statistic	Prob	Statistic	Prob
Quality Institutions	230.2132	0.0000	-12.3421	0.0000	-12.6537	0.0000	10.1123	0.0000
Exp. R&D %of GDP	275.5821	0.0000	-8.7412	0.0000	-8.7982	0.0000	7.6721	0.0000
Human Capital	220.6428	0.0000	-6.4477	0.0000	-8.8936	0.0000	9.4524	0.0000
Infrastructure	330.4321	0.0000	-14.6532	0.0000	-17.5825	0.0000	12.2252	0.0000
Net FDI % of GDP	402.3783	0.0000	-10.9823	0.0000	-10.9823	0.0000	8.7719	0.0000
University-Indus. Research Coll.	125.3321	0.0000	-5.9823	0.0000	-7.3421	0.0000	3.9612	0.0000
Domestic Credit to private sector % of GDP	450.7421	0.0000	-17.2345	0.0000	-20.9823	0.0000	14.8351	0.0000
Domestic trade and Competition	168.9132	0.0000	-4.2765	0.0000	-6.1134	0.0000	5.9312	0.0000
Ease of Starting a new business	299.1422	0.0000	-19.1124	0.0000	-14.8721	0.0000	19.6643	0.0000

Ho: All panels contain unit roots **Ha: At least one panel is stationary**
Source: Author's computation, 2015

Clearly, the panels are not associated with unit roots and there is no inclination for spurious or unrelated regressions.

5.2.2 Heteroscedasticity

The Breusch-Pagan/Cook-Weisberg test is conducted to test for the presence of heteroscedasticity. In the presence of heteroscedasticity, employing OLS estimation technique would yield biased and inconsistent estimates resulting in unreliable and misleading outcomes. The results of the Breusch-Pagan/Cook-Weisberg test for heteroscedasticity in table (5.3) reject the null hypothesis of no heteroscedasticity in the model at 5 percent significant level.

Table :(5.3): Breusch-Pagan /Cook-Weisberg test for heteroscedasticity

Ho: Constant variance
chi2 (9) = 12.67
Prob > chi2 = 0.0474

Source: Author's computation, 2015

Even so, the system GMM approach is developed such that it is able to yield consistent and unbiased estimates even in the presence of heteroscedasticity.

5.2.3 Autocorrelation

The test for autocorrelation for this study is carried out using the Arellano-Bond test for autocorrelation in the first difference errors. The test accepts the null hypothesis of no autocorrelation in the second order AR (2) for all the regressions indicating that the error terms are not correlated with each other i.e. MA(1) process. For this condition of no autocorrelation, employing the System GMM estimation is satisfied. The test results are reported together with the estimation results in table (5.5).

5.2.4 Validity of the Over-identifying Restrictions

The System GMM estimation technique requires that the instruments used must be valid in order to obtain consistent and efficient estimates. For this reason, the Sargan test of the over-identifying restrictions which tests the null hypothesis that the over-identifying restrictions are valid is employed. The test as reported in table (5.5) fails to reject the null hypothesis and this provides strong grounds that the instruments are valid for the regression model. Accordingly, the System GMM estimator should yield consistent and reliable estimates based on the evidence of no autocorrelation in the error term as observed in the previously together with the condition of validity of the instruments being satisfied.

5.2.5 Fixed Effects and the Random Effects

The results of the Hausman test performed to determine whether the fixed effects or random effects model fits the data for estimation are presented in table (5.4). By implication, the presence of heteroscedasticity would infer the existence of heterogeneity across countries and then affirm the assumption of the fixed effects model that the unobserved country-specific effects vary across countries.

Table :(5.4): Hausman test for Fixed versus Random Effects

Ho: Difference in coefficients not systematic (Random effects)		
Chi2 (9)	=	(b-B)'[(V_b-V_B) ^ (-1)] (b-B)
	=	80.00
Prob>chi2	=	0.0000

Source: Author's computation, 2015

The result of the Hausman test as exhibited in table (5.4) thus confirms the suitability of the fixed effects model by rejecting the null hypothesis that supports the random effects

model at 1 percent level significance. The System GMM estimation technique can therefore be applied to the model as it requires a model that fits the fixed effects model to yield consistent and reliable estimates.

5.3 Empirical findings and discussions

The section presents the estimation results of the explanatory variables from the pooled Ordinary Least Square regression and the System GMM results. Table (5.5) displays the regression results based on the thirty (30) SSA countries for the period 2011-2014 and shows significant Wald Chi-squared and F-statistics for all the regressions indicating that the explanatory variables are jointly significant. The Arellano-Bond test AR (2) in first differences accepts the null of no two period serial correlation in the residuals. Additionally, the Sargan test for over-identifying restrictions indicates that the over-identifying restrictions in the model are valid and as such the model is not weakened by too many instruments.

The outcome on the relationship between innovation and the explanatory variables namely: institutional quality, gross expenditure on R&D (% of GDP), Human capital, Quality physical infrastructure, Intensity of domestic trade and competition, Net FDI inflows (% of GDP), University-industry research collaboration, Domestic credits to private sector (% of GDP) and Ease starting a new business are discussed below.

Gross expenditure on R&D (percentage of GDP): A priori, the coefficient of R&D (percentage of GDP) was expected to be positive from the theoretical perspective. Thus, ceteris paribus, the higher the expenditure allocated to searching for new knowledge or ideas, the higher will be the technological innovation. The coefficient of the R&D variable is positive and statistically significant as indicated in both estimations in table (5.5) below. Thus, holding

Table :(5.5): Pooled Results and System GMM results

Explanatory variables	**Pooled OLS**	**System GMM**
	(1)	(2)
Constant	12.7524	-4.5124
	(3.2652)	(10.9449)
Institutional quality	0.0526**	0.0649***
	(0.0213)	(0.0244)
Gross expenditure on R&D(% of GDP)	0.2834**	3.544**
	(0.1227)	(1.4192)
Human capital (skilled workforce)	0.1441***	0.1130**
	(0.0418)	(0.0503)
Quality physical Infrastructure	-0.0418	-0.0751
	(0.0669)	(0.0556)
Intensity of domestic trade and competition	0.1872***	0.1829***
	(0.0445)	(0.0263)
Net FDI inflows (% of GDP)	0.0114	0.0001
	(0.0593)	(0.0634)
University/Industry research collaboration	-0.0873	-0.1050***
	(0.0593)	0.0319)

Domestic credits to private sector (% of GDP)	0.1098***	0.1072***
	(0.0229)	(0.0143)
Ease of Starting a new business	0.0211	-0.0032
	(0.0274)	(0.0240)
F-Statistics	34.85	1344.75
Wald chi-squared (Pro>chi-squared)		0.0000
Arellano-Bond (AR(2),Prob>Z)		0.732
Sargan test (Prob> Chi-squared)		1.000
No. of Observations	62	62
No. of countries	30	30

Note: The dependent variable is Innovation score; the figures in parenthesis are the Robust Standard errors of the estimates whereas *** , ** , * represent the statistical significance of the estimates at 1%, 5% and 10%

Source: Author's computation, 2015

all other variables constant, a 1 unit increase in expenditure allocated to R&D increases innovation advancement in SSA by 0.2834 in the pooled results and 3.544 in the System GMM estimation which is consistent with other innovation studies such as Griffth *et al*., (2001), Rodriquez-Pose, (2004), Becheikh *et al.*, (2006).The positive and statistical significance of the R&D variable thus indicate that governments in SSA need to show more commitment to the allocation of at least the 1 percent of their GDP to research and development as agreed upon at African Union summit in 2007 to enhance the generation

of more innovative ideas to boost the product, process, marketing and organizational innovation to enhance the region's competitiveness at the global level.

Institutional quality: The coefficient of the institutional quality variable is rightly signed and corresponds to both the theoretical and empirical predictions on the effects of quality institutions on economic growth and innovation advancement. As displayed in table (5.5), the coefficient of institutional quality is positive and statistically significant in both the pooled OLS estimation and the System GMM results indicating that holding all the other regressors unchanged, 1 unit improvement in the institutions of SSA reduces the uncertainties and risks associated with innovative investment and boost innovative advancement by 0.0526 and 0.0649 as in the pooled and the system GMM respectively. The result confirms the study by Oyelaran-Oyeyinka, (2004); Waguespack *et al.*, (2005); Cull and Xu, (2005) and other empirical studies cited in the empirical literature. The positive and significant effect of quality institutions therefore suggest that for SSA countries to boost productivity through innovation advancement, stronger and well-functioning institutions has to be developed to encourage more investment which will inevitably promote innovation in the region.

Human capital (skilled workforce): The empirical literature surveyed observed that human capital of the country has two main faces, first promoting innovation adoption (imitation) and secondly stimulating technical change (generating new ideas). In the empirical estimation displayed in table (5.5) above, the coefficient of human capital is positive and statistically significant in both the pooled regression and the System GMM estimation. Thus, holding all other explanatory variables unchanged, a 1 unit increase in human capital base (i.e. tertiary enrolment ratio and scientist and engineers employed in

production and manufacturing sector) increases the rate of innovation advancement in SSA by 0.1441 and 0.1130 in the pooled OLS and System GMM estimation respectively. This observation thus violates Danquah and Quattara (2014) who observed the effect of human capital on innovation not to be significant in SSA.

Quality of physical infrastructure: Quality infrastructure has a pervasive influence in all areas of an economy. Low quality infrastructure especially transport and electricity supply increases the logistical and operational costs and restrain private sector investment. From the onset, the coefficient of infrastructure was expected to be positive. Thus, higher quality infrastructural development will promote industrial development and as such enhanced innovation. However, as shown in table (5.5) above, the coefficient of infrastructure is negative in both the pooled and system GMM estimations indicating deficit in infrastructural development. Holding all other explanatory variables constant, a 1 unit deterioration in infrastructure reduces innovative investment by (0.0418) in the pooled estimation and (0.0717) in the System GMM. The variable is significant in the Pooled result but insignificant in the System GMM result.

The above result confirm the study by Alvaro *et al.*,(2009) who argues that the poor infrastructural deficit depresses innovative investment in SSA by about 40 percent, and the World Bank (2009) report which stipulate that the infrastructural deficit reduces National economic growth by 2 percentage point every year in SSA.

Intensity of domestic trade and competition: The intensity of the domestic trade and competition was expected to be positive from theoretical point of view which is confirmed from the estimation results. Thus, holding all other explanatory variables constant, 1 unit increased in the intensity of domestic trade and competition through

competitive bidding, trade and business liberalization and promotion of private sector led-growth increases the rate of innovation by 0.1872 in the pooled OLS results and 0.1829 in the System GMM respectively. The positive relationship between domestic trade and competition means that for SSA where innovation is generally lower, promoting private sector led-growth where more of the productive economic activities are left in the hands of the private sector with limited government role would promote industrial development and promote innovation as well.

Net foreign direct investment inflows (percentage of GDP): Foreign direct investment is observed as a powerful mechanism for the transmission of technology to developing countries by financing new investment and also communicating information about technology to domestic affiliates by foreign firms and also facilitating the diffusion of technology to local. The sign of the net foreign direct investment inflows (percentage of GDP) was expected to be positive. However, the coefficient of net foreign direct investment inflows (percentage of GDP) is ambiguous and statistically not significant as the sign is negative in the Pooled result (-0.0114) and positive (0.0001) in the System GMM estimation. The empirical literature observes that the ability of FDI to drive innovation in the domestic economy depends on the domestic absorptive capacity such as quality human capital, quality infrastructure, regulatory quality and other complimentary factors which support innovative activities. However, the domestic absorptive capacity in SSA is generally low and this in part explains the statistical insignificance of the effect of FDI on innovation in the region. Most studies finds the effect of FDI on innovation significant in the industrialized countries but rather insignificant in developing countries. (see Lichtenberg *et al.* 1996; Connolly 2003 and Hagino, 2005).

University-Industry research collaboration: Collaboration between the universities and the industrial sector serves an important conduit for the transfer of new ideas or knowledge generated at the knowledge production sector to the industrial level. A priori, the coefficient of university-industry research collaboration was expected to be positive. Thus, the higher the collaboration between the industrial sector and university in terms joint research, the higher the ideas created at the university and research sector can trickle down to the industrial sector for usage. From the empirical estimation displayed in table (5.5) above, the coefficient of the variable contradict the a priori expectation. The pooled OLS result is -0.0873 and the System GMM -0.1050 and statistically not significant in both estimations. The results above confirms the study by Mugabe (2009) who identified in 19 Sub-Saharan Africa countries that most industries in region do not have any form of collaboration with the university in terms of research and development.

Domestic credit to private sector (percentage of GDP): The coefficient of the domestic credit to private sector (percentage of GDP) was rightly signed in both estimation results as displayed in table (5.5). The coefficient of the variable is positive and statistically significant in both the pooled OLS and the System GMM result. Thus, a 1 unit increase in the credits allocated to the private sector investment improves innovation by 0.1098 in the pooled OLS estimation and 0.1072 in the System GMM estimation. Firms needs to expand their production to increase innovation, however, the cost of borrowing has restrained most innovative investment in the region.

Ease of starting a new business: A favourable and supportive business environment encourages private sector to reinvest their earnings in the domestic economy despite the risks and uncertainties surrounding the innovative investment. The coefficient of the ease of starting a new business variable was expected to be negative; Thus, the lower the

administrative barriers such as low cost, duration, and bureaucratic chains imposed on new investors, the higher will be new business formation and the higher will be more innovative activities. The sign of the coefficient is consistent with the System GMM results -0.032, however, contradict the pooled OLS result which is negative 0.2110. From table (5.5) above, 1 unit increase in the cost of starting of a new business decreases the rate of innovation enhancement by -0.032 as shown in the System GMM estimation, however the variable is not statistically significant in both estimation results.

5.4: Concluding Remarks

The data for the estimation favour the fixed effects model which is a requirement for the use of the System GMM estimation procedure, besides other diagnostic tests such as the Unit roots test, autocorrelation, heteroscedasticity, over-identifying restrictions and the Sargan test yield results that are favourable for the use of the System GMM estimation technique. The estimation results show that, Institutional quality, gross expenditure on research and development (percentage of GDP), Human capital (skilled workforce), Intensity of domestic trade and competition and the Domestic credit channeled to private sector (percentage of GDP) have a positive effect on innovation enhancement in SSA. However, the physical infrastructure deficits (quality road networks and cheaper electricity supply), Ease of starting a new business in SSA and the poor collaboration between the university and the industrial sector in terms of research have a negative effect on innovation promotion. Foreign direct investment inflows to SSA though have a positive effect on innovation advancement, however, statistically not significant.

CHAPTER SIX

CONCLUSIONS, POLICY RECOMMENDATIONS AND LIMITATIONS

6.0 Introduction

This chapter summarizes and concludes the study. The first section looks at the summary of the study as well as the conclusions. The next section presents policy implications and recommendations that would be relevant for policy makers. The limitations of the study are discussed in the final section of this chapter.

6.1 Summary and Conclusion

The high variations in total productivity growth, economic wellbeing and global competitiveness between the industrialized and the developing countries have attracted enormous attention in development economics research in recent times. Most studies on innovation as observed in the extant literature is skewed towards the industrialized countries with extremely limited studies on drivers of innovation in the developing countries. Hence, the primary objective of this study is to identify the main drivers of innovation in the case of SSA including Ghana to ensure productivity growth and competitiveness at the global market. The various theoretical perspectives on innovation and empirical studies were reviewed and fully documented to ascertain the main drivers of innovation in the empirical literature. From the numerous literature reviewed, an empirical model that links innovation and its potential determinants was specified. Both the Pooled OLS and the System GMM estimation technique is employed in the empirical estimation procedure in order to achieve the set objectives of the study.

The technique is preferred to other techniques because it is perfect for a dynamic model that exhibit a number of sensitive characteristics such as endogeneity, fixed effects,

heteroscedasticity, serial correlation and other data challenges. The empirical results indicate that quality institutions matter significantly in innovation advancement process in SSA. Additionally, the expenditure on R&D (percentage of GDP), human capital accumulation (skilled workforce), and the domestic credits allocated to private sector (percentage of GDP), intensity of domestic trade and competition are significant drivers of innovation in the region.

However, the physical infrastructure (paved roads, and electricity supply) deficits affect negatively innovative investment in SSA including Ghana. Collaboration between the university and industrial sector for joint research is insignificant in innovation advancement in the region, net FDI inflows is positive, however, has no effect on innovation advancement in the region which can be attributed to the poor domestic absorptive capacity as shown in the empirical review.

6.2 Policy Recommendations

The empirical result obtained from the System GMM estimation is consistent with both theoretical predictions and empirical studies conducted about the drivers of innovation. With respect to the empirical findings observed in this study, the following policy recommendations are suggested:

Businesses and investment thrives better in the environment where there is quality institutional set-ups such as political stability, rule of law, independence of the civil, public and the judicial service. The empirical result from the System GMM confirms that quality institutions have a strong and positive effect on innovation. Entrepreneurs will always feel secured investing in countries where the institution are independent and support private investment given the high risks and uncertainties associated with innovative investment. On the policy wise, to boost private investment to generate more innovation in the SSA region,

governments must continue to strengthen the institutions (rule of law, independence of the judicial system, contract enforcement, protection of intellectual property) and formulates coherent and functional incentive regime that targets strategic and performance-based technology development , rather than pursuing discretionary policies that favour political business allies to the detriment of other industry players. Poor contract enforcement, lack of independence of the judicial system, poor protection of intellectual property rights will certainly limit risky innovative investment. To quote Barrack Obama-U.S President "Africa needs strong functioning institutions to boost productivity growth and not strong men".

Improvement of education at all levels. Education has to be targeted more towards the needs of the private sector to reduce the skills-mismatch. As knowledge is changing fast the focus has to be on learning how to learn, which is usually associated with secondary education. This includes improved apprenticeship systems, support for on the job training within firms, and managerial skills. To strengthen the capacity and increase the quality of the tertiary education system it is necessary to introduce competitive allocation procedures, transparency and peer review, research evaluation and accountability for results. In general all stakeholders such as education and research institutions as well as the private sector should participate in the design and implementation of the education policy. The skills needs of the economy should be monitored. In addition, priorities in education and policies in other fields have to be coordinated (UNCTAD, 2005).

Creation of innovation networks. As a precondition, research institutions need to be strengthened in order to make them viable partners for innovating firms. Then they could provide meaningful consultancy services. Thus, research institutes should be given more autonomy, so they can react to demand in the private sector. To initiate networking

between firms and research institutes the mobility of employees for short time assignments should be increased. Once the R&D potential has increased Science and Technology Parks could be used to foster cross-fertilization of ideas between entrepreneurs and researchers for the purpose of enabling academic knowledge to be applied to effective commercial use. STPs can contribute to commercialising university-based knowledge and technology and can serve as an important link in the knowledge system.

Provision of start-up finance. Through the provision of venture capital firms are provided with equity instead of loans and are therefore better able to cope with the risk of innovations. Public-private partnerships between commercial investment funds and grant-financed technical service providers could fill the existing gap in Sub-Saharan Africa.

Better Infrastructure for advanced products. To enable firms to use new technologies it is not only essential that traditional infrastructure, especially electricity and communication is in place. To achieve high quality access to laboratories and standards institutions is essential. Certification through the International Standardization Organisation (ISO) will signal high quality especially to foreign buyers. Additionally, the cost of infrastructure service to firms are very expensive compared to the other developing world, especially high cost of electricity and unstable power supply has folded-up most firms, hence to improve innovation, cost of power must lowered in SSA to enhance industrial development which inevitably promote innovative investment. Improvement in the infrastructural capacity in the region improves the domestic absorptive capacity which in effect stimulate the attraction of more FDI to enhance innovation.

Marketing innovative products. To enable firms to produce products that are not only new and of higher quality but for which a market exists the interaction between producers and consumers has to be increased, for example through trade fairs. The provision of market intelligence of both exports and imports could also help firms to better target their potential customers. Through public procurement schemes firms can be encouraged to develop new products, which can subsequently be sold to the private sector as well.

The most important driver of innovation as observed in the industrialized and the OECD countries is the creation and implementation of a well- functioning National Innovation System (NIS) which coordinate and direct innovation in the country. A well-functioning NIS requires broad collaboration between the universities, research institutions, financial institutions, industrial sector and policy makers who deliberately work together to generate new ideas to innovate and diffuse the new idea into the market. For SSA to be able to generate the needed innovative capacity to innovate, governments in the region will have to adopt and implement NIS in their respective countries to deliberately promote the rate of innovation specifically to their country needs. The NIS dictate the policy direction which has to be implemented to boost the innovative capacity.

Additionally, and more significant as well, the empirical observation of this study confirms the theoretical predictions on the importance of domestic trade and competition on the innovation process as emphasize by Schumpeter, (1939), Arrow ,(1962) and Aghion *et al.*, (1997). On the policy perspective, to promote the intensity of the domestic trade and competition, trade and business liberalization should be encourage by governments in the region to put more of the productive economic activities in the hands of the private sector. The need for firms to meet consumer specifications when there is competition among neck-

to-neck firms has the tendency to persuade firms to invest more into research and development to meet specification demand and promote the rate of innovation in the region. Governments' in the region must therefore avoid the sole-sourcing approach of awarding contracts and rather strengthened the procurement process to foster competition among domestic firms to ensure innovation advancement.

6.3 Limitations of the study and areas for further research

The major limitation encountered typical of SSA countries is the limited availability of consistent data on innovation variables. Data on community innovation survey is mostly unavailable as most countries in the region do not collect information on firms' innovative activities. Given this peculiar challenge, the study has to depend solely on the global innovation index report which provides information about innovation at the global level. The data span therefore covers only four year period (2011-2014) with a sample of thirty (30) countries out of the 48 Sub-Saharan African countries. Additionally, in the Global Innovation index reports framework, all countries which has less than 50% of the variable data needed to calculate Though the data span is inadequate for panel analysis, the limited studies on innovation specifically to SSA made carrying on this study paramount. Also, given the above challenge, the study did not run causality tests whether the dependent variable also causes the explanatory variables mainly due to relatively smallness of the data span for the study. Causality test fall in the domain of panel time series analysis which requires time span of 30 years or better. The limitedness of the data span made it difficult to test for endogeneity of the regressors, even so the System GMM gives consistent and unbiased results even in the presence of endogeneity. Therefore, Future studies with large data span can adopt other estimation techniques such as panel Vector Auto-regressions (VARs) to further test

robustness of this study. More data span on the variables will also help improving robustness of the estimates of the variables and test for the endogeneity of the explanatory variables

REFERENCES

Arrow, K. (1962). Economic Welfare and the Allocation of Resources for Invention. Princeton University Press.

Arellanano, M., Bond, S.R. (1991). Some tests for specification in panel data: Monte Caro evidence and application to employment equations. *Journal of Economic Studies*, 58:277-297.

Aghion, P., Howitt, P. (1992). A model of Growth through Creative Destruction. *Econometrica*, 32-35.

Arellano, M., Bover, O. (1995). Another look at the instrumental variable estimation or error components models. *Journal of Econometrics*, 68(1):29-52.

Aghion, P., Harrison, C., Vickers, J. (1997). Competition and Growth: Step-by-Step Innovation. An Example . *European Economic Review, Elsevier*, 41(3-5):b771-782.

Asiedu, E. (2001). On the determinants of FDI to developping countries. Is Africa different? *Journal of World Development*, Vol.30, No.1.

Aitken, B.J., Harrison, A.E. (2002). Do domestic firms benefit from Foreign Investment? *Economic Review*, 89(3): 605-618.

Acemoglu, D., Aghion, P., Zilibotti, F. (2002). Distance to Frontier, Selection , and Economic Growth. *Journal of the European Economic Association*, 4(1): 37-74.

Arocena, R., Sutz, J. (2005). Science, Technology and Innovation in Developing Countries. Development Report 2005; Background paper series: UNIDO

Agenor, P.R., Moreno-Dodson, B. (2006). Infrastructure and Growth. New channels and policy immplications. *Policy Working Paper 4064, World Bank-Washington DC*.

Almeida, R., Fernandez, A.M. (2006). Openness and technological innovations in developing countries. Evidence from firm level. *Journal of Development studies*, 44(5), 70-72.

Almeida,R., Fernandez, A.M. (2008). Openness and Technological Innovation in Devrloping Countries. Evidence from firm-level. *Journal of Development Studies*, 44(5), pp.70-72.

Africon, (2008). Unit Cost of Infrastructure Projects in SSA.Background Paper. Africa Infrastructure Sector Diagnostic. World Bank, Washington, DC.

Aghion, P. Blundell, R., Griffth, R., Howitt, P., and Prantl, S. (2009). The Effects of Entry on Incumbent Innovation and Productivity. *The Review of Economics Statistics*, 91(1):20-32.

Alvaro,E., Guasch, J.L. Pena, J. (2009). Assessing the impact of infrastructure quality on firm productivity in Africa. Cross-country comparison based on investment climate survey from 1999-2005. *Economic Series (49)*, 9-86.

Akinwale. (2012). Understanding the Nexus of R&D, Innovation and Economic Growth in Nigeria. *International Business Research*, 5(1):187-196.

AfDB (African Development Bank), (2014). Economic Brief. African Development Bank Group, Tunis.

Barro, R. (1991). Economic Growth in a cross-section of countries. *Quarterly Journal of Economics*, Vol. 106. 407- 447.

Benhabib, J., Spiegel, M. (1994). The role of human capital in economic development; evidence from aggregate cross-country data. *Journal of Monetary Economics* , 34, 143-173.

Borenztein, E., Gregono, J., Lee, J.W. (1998). How does FDI atttract economic grwth? *Journal of International Economics* , 45(1) 115.

Blundell, R., Bond, S.R. (1998). Initial conditions and moments restrictions in Dynamic panel models. . *Journal of Econometrics*, 87: 115-143.

Brynjolfsson, E., Hitt, L.M. (2000). Beyond Computation: Information Technology , Organizational Transformation and Business Performance. *Journal of Economic Perspectives* , 14(4): 23-48.

Bilbao-Osorio, B. and Rodriquez-Pose, A. (2004). From R&D to Innovation and Economic Growth in the European Union. . *Growth and Change*, 35(4): 434-455.

Balzat, M. (2006). An economic analysis of innovation: Extending the of national innovation systems. *Edward Elgar*.

Becheikh, N., Landry, R., Amara, N. (2006). Lessons from Innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993-2003. *Technovation*, 26: 644-664.

Bitzer,J., Gorg,H. (2009). Foreign Direct Investment , Competition and industry performance. *World Economy*, 32(2): 221-233.

Bogliacino, F., Perani, G., Pianta, M., Supino, S. (2009). Innovation in Developing Countreies: Evidence from innovation Survey. *Paper read at the Italian National Research Programme (FIRB) Conference*, . Bocconi University, Milan.

Bruno, R. Bytchkova, M., and Estring. (2011). Insitutions Entry: Analysis in Russia. *Discussion Paper 55011*.

Buccirossi,P., Ciari, L., Duso, T., Vatale, C., and Spagnolo. (2012). Competition Policy and Productivity Growth. An Assessment. *Review of Economics Statistics*.

Cohen, W., and Levine, R. (1989). *Empirical Studies of Innovation and Market Structures. A Handbook of Industrial Organizations.* Edited by R. Schmalensee and R.D. Willis, 1059-1107. London.

Crepon, B., Duguet, E. Mairesse, J. . (1998). Research and Development , innovation and productivity and econometric analysis at the firm level. *Journal of New Technology*, 115-158.

Choi,I. (2001). Unit roots test for panel data. Journal of International Money and Finance.20:294-272.

Calderon, C. (2003). *The Growth Cost of Latin American Infrastructure Gap.* Princeton University Press.

Cantwell. (2003). *Innovation, Competitiveness and Growth. In Handbook of innovation* . Oxford University Press.

Cull, R., and Xu, L. (2005). Institutions , Ownership and Finance. The determinants of Profiits Reinvestment among Chinese Firms. *Journal of Financial Economics.* , Vol. 77. 117-145.

Crespi, G., Criscuolo and Haskel, J. (2007). Information Technology , Organizational Chanage and Productivity Growth: Evidence from UK Firms. *CEP Discussion paper*, No.783.

Calderon, C. (2008). Infrastructure and Growth in Africa: Africa Infrastructure Country Diagnosttic .*World Bank, Washington,DC.*

Das, S. (1987). Externalities and technology through Multinational Corporations . *Journal of International Economics* , 87(2): 323-336.

D'Aveni, R.A.(1994). Hypercompetition: Managing the Dynamic of Strategic Manoeuvring . New York: The Free Press

Du, J., Love, J.H. and Ropers, S. . (2007). The Innovation Decision: an economic analysis. *Technovation*, 766-773.

Dutta, A. a. (2008). Intellectual property rights and innovation in developing: Evidence from India. *The World Bank*.

Dutta, A., Sharma, S. . (2008). Intellectual Property rights and Innovation in developing countries: Evidence from india. *The World Bank*.

De Mel, S., Mckenzie, D. and Woodruff, C. (2009). Innovative firms and Innovative Owners: Determinants of innovation in Micro, Small and Medium Enterprises . *Washinton D.C. World Bank.*

Danquah, M. and Quattara, B. (2014). Productivity Growth, Human Capital and Distance to frontier in Sub-Saharan Africa . *Journal of Economic Development* , Vol. 39, No.4.

Esfahani, H.S. and Ramirez, M.T. . (2003). Institutions, infrastructure and economic growth. *Journal of Development Economics*, 70: 443-477.

Estache, A. (2005). *What Do We Know about SSA Infrastructure and its impact on 1990 Reforms?* World Bank report, Washington DC.

Eurostats, (2005). *Guidance for collecting and interpreting innovation data.* Organization for Economic Co-operation and Development.

Freeman. (1995). The National System of Innovation in historical perspectives . *Cambridge journal of Economics*, 19(1).

Fosfuri, A., Motta, M. and Rondee, T. (2001). Foreign Direct Investment and Spillovers through Workers mobility . *Journal of international Economics* , 53 (1), 205.

Fagerberg,. J., Mowery, DC. And Nelson, R. (2005). *The Oxford Handbook of Innovation.* New York Oxford University Press.

Fortainer, F. (2007). Foreign direct investment and host country economic growth. Does the investors country play a role? *Journal of international Economics*, 16(2): 68-72.

Grossman, G,M., Helpman, E. (1991). Innovation and Growth in the Global Economy. *Cambridge, MA, MIT Press*.

Griffth, R., Redding, S., Reneen, J. (2001). Mapping the two faces of R&D;productivity growth in panel of OECD industries. *Journal of Economic Development*, 60-72.

Gretton, P., Gali and Parham, D. (2004). The Effects of ICTs and Complimentary innovation on Australian Productivity Growth . *OECD Publishing JP*, 105-130.

Gago, D., and Rubalcaba,L. (2007). Innovation and ICT Service Firms: Towards Multidimensional Approach for Impact Assessment. *Journal of Evolutionary Economics*, 17. 25-44.

Islam, M. R. (2010). Human Capital Composition, Proximity to technology Frontier and Productivity Growth. *Discussion Paper*, 23/10

Jones, I. (2002). *Introduction to Economic Growth.* Standford University. 2nd. ed.

Jafari, A.S., and Arab, M. (2011). ICT and Total Factor Productivity, Evidence from selected countries in the world. *Middle-East Journal of Scientific Research* , 10(6): 768-776.

Krueger, A. B. and Lindhal, M. (2001). Education for Growth: Why and for Whom? *Journal of Economic Literature*, 39(4): 1101-1136.

Keller. W.W., Samuels, R.J. (2003). *Innovation and Asian Economies.* Cambridge University.

Koellinger, P. (2005). Why Information Technology Matters: An empirical study of E-business usage, innovation and firm performance. *German Institute for Economic Research*, No.495,DIW.

Lundval, B. (2002). Towards a Learning Society, Innovation Competence Building and Social Cohesion in Europe. *Edward Elgar publishing, Cheltenham, UK*.

Leeuwen, V. (2008). ICT, Innovation and Productivity. *Eurostats information Society*.

Mankiw, N., Romer, P., Weil, D. . (1992). Contribution to Emprics of Growth. *The Quarterly journal of Economics*, 407-438.

Madalla, G.S., Kim,I.M.(1998). Unit roots , Cointegration and Structural Change: Cambridge university Press.

Mokyr, J. (2002). *The Gift of Athena. Historical Origins of the Knowledge Economy, Princeton.* Princeton University Press.

Moreno, R., Surinach, J., Autant-Bernard, C., Manca, F., and Massard, N. (2009). The Difussion and Adoption of innovation in the internal market. *European Commision DG2 Economic Papers*, No.384.

Mugabe, J. (2009). *Knowledge and Innovation for Africas Development. Priorities, Policies and Programmes.* World Bank Working Paper, 2009.

Nelson, R.R., and Phelps, E. (1966). Investment in Humans, Technological Diffusion and Economic Growth. *American Economic Review*, 56: 69-75.

North, D. (1990). *Institutions, institutional change and economic performance, Cambridge.* Cambridge University Press.

Nelson, R. (1993). *National Innovation Systems: A comparative Analysis.* New York Oxford Press.

Nionsi,S., Bellon, B., and Crow, M. (1993). In Search for Workable Concept. *Technology in growth*, Vol. 15.

New Partnership for Africas, D. (2010 and 2014). *African Innovation Outlook.* AU-NEPAD, Pretoria.

Oyelaran-Oyeyinka, B. (2004). How can Africa Benefit from globalization? Global governance of technological and Africas global exclusion. Retrieved from Retrieved from:http://www.atpsnet.org/files/special-paper service-17-pdf.

OECD (1997). National Innovation Systems, OECD, Paris.

OECD/Eurostat (2005). Oslo Manual, Guidelines for Collecting and Interpreting Innovation Data, OECD, Paris.

OECD (2005c). Spending on Training and its impact on GDP growth

Oyelaran-Oyeyinka, B. (2006). Systems of Innovation and underdevelopment and institutional Perspective. *Science and Technology*, 11(2): 239-269.

Oluwatobi, S., Efobi U., Olurinola, I., and Alege, P. (2014). Innovation in Africa; Why institution matter. *South African Journal of Economics*.

Porter, M. (1990). *The Competitive Advantage of Nations.* New York, Free Press.

Pouris, A. and Pouris, A. (2009). The State of Science and Technology in Africa (2000-2004). *Scientometric Assessment*, Vol.79, No. 1.

Romer, P. (1986). Increasing Returns and Long-Run Growth. *Journal of Political Economy*, 94: 1002-1037.

Roeller, L., Waverman, L. (2001). Telecommunication Infrastructure and Economic Development: A simultaneous Approach. *American Economic Review*, 91(4): 909-923.

Romer, P. (1990a). Endogenous Technological Change. *Journal of Political Economy*, Vol. 98, S71-S102.

Roodman, D. (2009). How to Do Xtabond2: An Introduction to Differnce and System GMM in Stata. *The Stata Journal*, 9: 86-136.

Schumpeter, J. A. (1961). The theory of Eonomic Development.An inquiry into profits, capital, credit, interest and Business Cycles *Harvard University Press*.

Solow, R. (1957). Technical Change and Aggregate production Functions. *Review of Economics and Statistics*, 312-320.

Schiff, M. a. (2006a). North-South and South-South, Trade Related Technology Diffusion: An Industry-Level analysis of Direct and Indirect Effects. *Canadian Journal of Economics*, 39 (3): 831-844.

Soubobotina, T. P. (2006). *Generic Models of Technological Learning by Developing countries.* Draft: World Bank Science and Technology Programme. Washington, DC.

Sakala, Z. and Kolster, K. (2014). *Innovation and Productivity: Empirical Analysis for North African countries.* African Development Bank.

Silve, P., Plekhanov, A. (2014). *Institutions, Innovation and Growth: Cross- country evidence from Europe.* European Bank for Reconstruction and Dvelopmente.

Tidd, J. Bessant, J. and Pavitt, K. (2001). *Integrating Technological , Market and Organizational Change.* Chichester, Wiley and Sons Ltd.

Teixira and Fortuna. (2003). Human Capital , Innovation Capability and Economic Growth in Portugal. *Port. Economics*, J.3; 205-225.

Thurik, R. and Wennekers, S. (2004). Entrepreneurship, Small business and economic growth. *Journal of Small Business and Enterprise Development*, 11(1): 140-149.

Thiam, H. (2007). Foreign Direct Investment and Productivity: Evidence from Sub-Saharan Africa. *Research Statistical Branch of UNDP*.

UNIDO. (2003). *Competiting through Innovation and Learning.* Vienna: United Nations Industrial Development Organization.

Ulku, H. (2004). *R&D, Innovation and Economic Growth: An* Empirical Analysis. IMF working Paper. WP/04/185.

UNCTAD. (2007). *The Least Developed Countries report, 2007: Knowledge, Technological Learning and Innovation for Development.* United Nations Conference on Trade and Development. Geneva.

UNCTAD. (2008). *World Investment report, 2008: Transnational corporations and Infrastructure challenge, Pxvii.* United Nations Conference on Trade and Development, Geneva .

UNECA. (2008). *Economic report on Africa.* United Nations Economic Commision for Africa, Addis Ababa- Ethiopia.

UNIDO. (2009). *Industrial Development Report, 2009, Capability building for Catch-Up.* Vienna: United Nations Industrial Development Organization.

Van, L., Wiel, G.H. (2003). Do ICT Spillovers Matters? Evidence from Dutch Firm-Level Data. *Netherlands Bureau for Economic Policy Analysis*, Discussion Paper, No. 26.

Vandenbussche, J. Aghion, P.,Meghir, C. . (2006). Growth , distance to frontier and composition of human capital . *Journal of Economic growth*, 11: 97-127.

Vogel. (2012). The Two Faces of Economic R&D and Human cpital: Evidence from Western European countries.

Wang and Blomstrom, M. (1992). Foreign Direct Investment and Technology Tranfer. *European Economic Review*, 36(1): 137-155.

Wendy, C., Schaffer, M., Seabright, P. (2003). Infrastructure, Competition and Innovation: New Evidence from transition.

Waguespack, D.M., Birnir, J.K. (2005). Technical Development and Political Stability. Patenting in Latin America and the Caribbean. *Policy research 34*.

Waguespack, D.M., Birnir, J.K. and Schroeder. (2005). Technical Development and Political Stability: Patenting in Latin America and the Caribbean. *Policy Research 34*.

Wolf, S. (2007). Ecouraging innovation for Productivity Growth in Africa (ATTPC). *African Trade Policy*.

WIPO. (2008). World Patent Report: World Intellectual Property Organization. *Statistical Review* .

Xiaolan , Owusu, G., Hou, G., Mohnen, P. (2014). Innovation in the Low Income countries. *Innovation Survey Report*.

Xu, Q. (2007). Total Innovation Management: A novel Paradigm of innovation management in the 21st. century. *Journal of Technology transfer*, 32(1): 9-29.

APPENDICES

Appendix 1: Result of the Fixed Effects

Innovation	Coefficients
Constant	12.5684
	(9.1289)
Institutional quality	0.0206
	(0.1270)
Gross expenditure on R&D (% of GDP)	0.1830
	(0.1270)
Human capital	0.1684*
	(0.0763)
General Infrastructure	0.0751
	(0.0778)
Intensity of domestic competition	0.0319
	(0.0940)
Net FDI inflows (% of GDP)	0.0180
	(0.0397)
University/Industry research collaboration	0.1052

	(0.0784)
Domestic credits to private sector (% of GDP)	0.0985*
	(0.0569)
Ease of Starting a new business	0.0283
	(0.0234)
Prob>F	0.0019
Number of Observation	62
Number countries	30

The dependent variable is Innovation; the figures in parenthesis are the standard errors of the estimates whereas * represent the statistical significance of the estimates at 10%

Source: Author's Computation, 2015

Appendix 2: List of sampled countries

1. Namibia
2. Burkina Faso
3. Botswana
4. Côte d'lvoire
5. Gabon
6. Ghana
7. Lesotho
16. Angola
17. Benin
18. Cameroon
19. Ethiopia
20. Gambia
21. Kenya
22. Madagascar

8. Malawi
9. Mauritius
10. Niger
11. Senegal
12. Sudan
13. Tanzania
14. Uganda
15. Angola
23. Mali
24. Mozambique
25. Nigeria
26. South Africa
27.Swaziland
28. Togo
29.Zambia
30. Zimbabwe

Source: Global Innovation Index Report (2011-2014)