Ksh. 3000/=

PUBLIC AGRICULTURAL RESEARCH AND DEVELOPMENT EXPENDITURES AND ECONOMIC GROWTH IN KENYA

MALUKU STEPHEN MWONGELA

K102/13092/2009

A RESEARCH PROJECT SUBMITTED TO THE SCHOOL OF ECONOMICS IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR AWARD OF MASTERS OF ECONOMICS (ECONOMETRICS) DEGREE OF KENYATTA UNIVERSITY

OCTOBER, 2013

DECLARATION

This research project is my original work and has not been presented for a degree award in any university.

SIGNATURE------------------------ DATE 4/12/2013

MALUKU STEPHEN MWONGELA

Bachelor of Science (Applied Statistics), Maseno University

K102/13092/2009

This research project has been submitted for examination with our approval as University supervisors.

SIGNATURE------------------------ DATE 4/12/13

DR. SUSAN OKERI

DEPARTMENT OF ECONOMETRICS & STATISTICS

SIGNATURE------------------------ DATE 10/12/2013

DR. CHARLSE OMBUKI

DEPARTMENT OF ECONOMIC THEORY

DEDICATION

To my loving wife, Joyce and daughter, Natasha

ACKNOWLEDGEMENTS

I would like first to thank God for his sufficient strength and grace that has brought me to this far. Secondly, I am indebted to some individuals and institutions that facilitated the completion of this study. Uppermost, I am highly indebted to my supervisors, Dr. Okeri and Dr. Ombuki for their time, advice and valuable comments which enabled the successful completion of this research project. They have undoubtedly been the beacon of this study. My gratitude also extends to my colleagues, whose company from the very beginning contributed a lot in ensuring that my studies proceeded smoothly.

Some institutions also deserve some mention. I thank the Ministry of State for Planning, National Development & Vision 2030 for granting me a study leave to undertake the studies. I also deeply appreciate the financial support extended to me by the Government of Kenya and the African Development Bank, which contributed greatly to the completion of this study. I thank the Kenya National Bureau of Statistics (KNBS), through their librarians, for allowing me to access the much required information.

Lastly, I wish to extend my appreciation to my parents for their upbringing and educational motivation. Special thanks to my loving wife, Joyce and daughter, Natasha for their moral support. To them I say, "Thank you so much".

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

OPERATIONAL DEFINATION OF TERMS

Co-integration: Co-integration is a statistical property of time series variables. Two or more time series variables are co-integrated if they each share a common type of stochastic shift: that is, to a limited degree they share a certain type of behaviour in terms of their long-term fluctuations, but they do not necessarily move together and may be otherwise unrelated(Granger,1987).

Error Correction Model: Error Correction Model is a dynamical system with the characteristics that the deviation for the current state from its long-run relationship will be fed into its short-run dynamics.

Public Agricultural R&D Expenditures: Public agricultural R&D expenditures comprise both public and private expenditures in public agricultural R&D institutions.

Granger Causality Test: Granger causality test is a statistical hypothesis for determining whether one time series is useful in forecasting another.

Innovation: Innovation is a complex development of discoveries and inventions brought into the business and social environment that hopefully leads to diffusion. Innovation can be classified as either product innovation, process innovation or behavioural innovation (Hasan & Cumhur, 2007).

Public agricultural R&D intensity: Public agricultural R&D intensity is total expenditures both public and private in public agricultural R&D institutions as a share of agricultural Gross Domestic Product (Ag GDP).

Research & Development: Research and Development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. R&D covers three activities namely, basic research, applied research, and experimental development. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed (Hasan & Cumhur, 2007).

LIST OF ACRONYMS AND ABBREVIATIONS

ADF	Augmented Dickey Fuller
AERC	African Economic Research Consortium
PAR&DI	Public Agricultural R&D intensity
ASTI	Agricultural Science and Technology Indicators
ECM	Error Correction Model
ERS	Economic Recovery Strategy
EU	European Union
EIRMA	European Industrial Research Management Association
ERS	Economic Recovery Strategy
GDP	Gross Domestic Product
GDPG	Gross Domestic Product Growth
GERD	Gross Expenditure on Research & Development
GNP	Gross National Product
GOK	Government of Kenya
ICIPE	International Centre for Insect Psychology & Ecology
ICRAF	International Centre for Research in Agro Forestry
ICT	Information Communication Technology
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
KARI	Kenya Agricultural Research Institute
KEBS	Kenya Bureau of Standards
KEFRI	Kenya Forestry Research Institute

KEMFRI	Kenya Marine Fisheries Research Institute
KEMRI	Kenya Medical Research Institute
KEPHIS	Kenya Plant Health Inspectorate
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KIRDI	Kenya Industrial Research and Development Institute
KMFRI	Kenya Marine Fisheries Research Institute
KNBS	Kenya National Bureau of Statistics
MDGs	Millennium Development Goals
MoHEST	Ministry of Higher Education, Science & Technology
MRI	Midwest Research Institute
MS&T	Ministry of Science & Technology
MTEFR	Medium Term Expenditure Framework Report
NCST	National Council for Science & Technology
OECD	Organization for Economic Co-operation & Development
R&D	Research and Development
SRA	Strategy for Revitalizing Agriculture
S&T	Science and Technology
ST&I	Science, Technology & Innovation
SRS	Strategy for Revitalizing Agriculture
TFP	Total Factor Productivity
TVET	Technical Vocational Education Training
US	United States

ABSTRACT

Research and Development (R&D) plays a fundamental role in economic growth in that it provides impetus for new knowledge and technologies which contributes to growth of the economy. Existing literature identifies knowledge expansion prompted by expenditures on R&D as a key propellant of economic growth. The literature provides evidence that R&D investments translates to discoveries which transforms resources into products, processes and services and thus leads to growth of the economy. Inspired by the desire to grow the economy, the public and the private sector in Kenya has overtime allocated resources to finance public agricultural R&D. In the 1980s, the expenditures varied significantly ranging from between 2.3 and 3.5 billion shillings which improved in the 1990s to range at between 3.5 and 4.1 billion shillings. In the 2000s, agricultural R&D expenditures fluctuated at between 3.9 and 4.4 billion shillings. The study sought to determine whether the expenditures on public agricultural R&D impact on GDP growth in Kenya. The study's guiding question was, does investments on public agricultural R&D impact on GDP growth in Kenya? The study used a causal research design and published annual data on public agricultural R&D intensity and GDP growth for 31 years between 1980 and 2010. Diagnostic unit root tests, co integration tests, Error Correction Models (ECMs) estimation and an advanced Granger causality test within an ECM were conducted in an effort to establish whether public expenditures on agricultural R&D impact on GDP growth in Kenya. The co integration test results and the ECMs estimation results indicated that public agricultural R&D intensity and GDP growth have a long run relationship. A Wald F test on the ECMs showed lack of short run causal effects between the variables. The estimated coefficients in both ECMs established a long run unidirectional causality in that public agricultural R&D intensity causes GDP growth and not vice versa.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

Investment in R&D, leading to innovation and productive benefits to the economy, has been and is a major concern for governments around the world (European Industrial Research Management Association [EIRMA], 2005). There is a general agreement among countries worldwide that devoting more resources to R&D yields discoveries which are fundamental to economic growth (Romer, 1986). This has prompted governments worldwide to invest in R&D so as to spur economic growth. Kenya on which the study focuses is no exception.

1.1.1 Role of R&D in driving growth

The role of R&D in driving and sustaining economic growth cannot be overemphasized as ably captured by A. Gurr'iad, 2010. A. Gurr'iad singled out knowledge as a key driver of today's global economy and urged countries to harness innovation so as to boost growth and employment. This view takes prominence in the new growth theory and in particular the innovation based theory of growth which emphasises that economic growth is as a result of investment in human capital, innovation and knowledge (Romer, 1990, Grossman and Helpman, 1991 and Aghion and Howitt, 1992). The theoretical evidence of the importance of R&D is supported by empirical evidence. Litchetberg, 1992, Birdsall and Rhee, 1993 and Yuen Ping, 2003 established a positive relationship between R&D expenditure and growth.

Investment in R&D contributes to growth in diverse ways. Foremost, investment in R&D leads to discoveries which impact positively on economic growth (Solow and Swan, 1956). In view of Solow and Swan, 1956, economic growth is as a result of increases in labour, capital and technology progress were technology progress is as result of intentional actions of the people such as investments in R&D (Romer, 1990). A vital contribution of investments in R&D to growth is that it leads to creation of new goods or services that are better in quality and are more competitive. The new goods and services prompts for new markets and new marketing strategies in effect leading to new jobs (Mc Kelvey, 2001). ∘

Investments in R&D also bring in efficiency in production (Hasan & Cumhur, 2007). This is through adoption of innovative production and management processes which reduces the cost of production leading to more profits. Also through R&D, the trade performance of an economy is enhanced. This is through adoption of technologies that reduce the domestic relative value of goods making them cheaper and thus more competitive (Smith, 1776). The competitiveness of the products promotes exports which attracts foreign exchange and thus contributes to economic growth (Gruber, 1967).

On the social front, R&D elevates the knowledge base of the people which impacts positively on their productivity. The outcome of an elevated knowledge base of the people is a vibrant R&D sector which attracts additionally highly skilled personnel into related fields of innovation such as Manufacturing, Pharmaceuticals and ICT. This leads to spill over of technology which further increases the knowledge base of the people and thus boosts productivity.

1.1.2 Policy and Institutional Origin of R&D

The institutional origin of R&D in Kenya dates back to colonial times, with research programmes primarily focused on the agricultural sector supporting cash crops and livestock production (Ministry of Higher Education, Science & Technology [MoHEST], 2009). A variety of institutions were set up to support these areas of research. After independence, Kenya's national development goals and philosophy were elaborated in Sessional Paper No. 10 of 1965 on "African Socialism and its Application to Planning in Kenya". The paper identified poverty, illiteracy and disease as the main challenges facing the country by then. It highlighted the need for Science and Technology(S&T) in-puts to address the challenges.

The Sessional paper necessitated a rapid expansion of S&T in Kenya prompting the need for a mechanism to co-ordinate and promote S&T activities (MoHEST, 2009). This lead to the enactment of the Science and Technology Act Cap. 250 of Laws of Kenya in 1977. The Act aimed at providing guidance to the development of S&T and ensuring its integration in national, social and economic development. The government later on enacted the Sessional Paper No. 1 of 1986 on "Economic Management for Renewed Growth". The essence of the session paper was to integrate S&T in national development. Some of the key strategies in the Sessional Paper were the need to increase R&D funding from $6.9 million to $10 million and to confine R&D operations costs to 60% to enable researchers do an effective work.

In an effort to strengthen the R&D policy framework, the Government formulated the Technical Vocational Education Training (TVET) bill, the University bill and the Science, Technology and Innovation (ST&I) bill in 2010. The bills were aimed at transforming Kenya into a knowledge based economy were the creation, adaptation and use of knowledge will be among the most critical factors for rapid economic growth (Republic of Kenya, 2007, p.19). The government intends to create and implement a Science, Technology and innovation (ST&I) framework and devote more resources to scientific research and technical capabilities of the workforce (Republic of Kenya, 2007, p.9). This would probably transform Kenya into a knowledge based economy and possibly assist the country attain the 10 percent growth rate envisaged in Vision 2030.

1.1.3 Institutions Conducting R&D

Though the private sector contributes to R&D in Kenya, R&D is mainly concentrated in public research institutions (MoHEST, 2009). The key public research institutions are: Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI), Kenya Industrial Research and Development Institute (KIRDI), Kenya Bureau of Standards, Kenya Institute for Public Policy Research and Analysis (KIPPRA), Kenya Plant Health Inspectorate Service, Kenya Marine Fisheries Research Institute(KEMFRI) and the Kenya Medical Research Institute. Universities in Kenya both public and private are also involved in R&D activities (MoHEST, 2009). Kenya's R&D sub sector is majorly agricultural with public agricultural R&D being the most vibrant both in funding and capacity (KARI, 2009). KARI is the main agricultural R&D institute in Kenya and accounts for half of the funding and researchers in Kenya (KARI, 2009). Other research agencies namely KEFRI, KMFRI, KIRDI, KIPPRA and non-profit organizations namely the Coffee Research Foundation and the Tea Research Foundation comprise about one-quarter of the total public spending and capacity (KARI, 2009). Kenya's recognition of the importance of R&D has attracted the establishment of international research facilities to augment the R&D capacity of the country (MoHEST, 2009). These international research institutes includes the International Livestock Research Institute, the International Centre for Research in Agro Forestry , the International Centre for Insect Physiology and Ecology and the African Economic Research Consortium.

1.1.4 Overview of the Agriculture Sector and Public Agricultural R&D

The agriculture sector is the mainstay of the Kenyan economy. The sector contributes annually about 26 per cent of the GDP directly and another 25 per cent indirectly (Government of Kenya, 2010). The sector accounts for 65 per cent of Kenya's total exports and provides more than 70 per cent of the informal employment in the rural areas (Government of Kenya, 2010). In view of the importance of the agriculture sector in support of growth of the economy, the government has overtime developed and enacted policies to support growth of the sector. An early effort after independence was the enactment of the Sessional Paper No. 10 of 1965 on "African Socialism and its Application to Planning in Kenya" (MoHEST, 2009). The policy was designed to revolutionalize agriculture by utilizing unused and underused land through land consolidation, extension services and training as well as introduction of modern methods of farming and marketing (KARI, 2009).

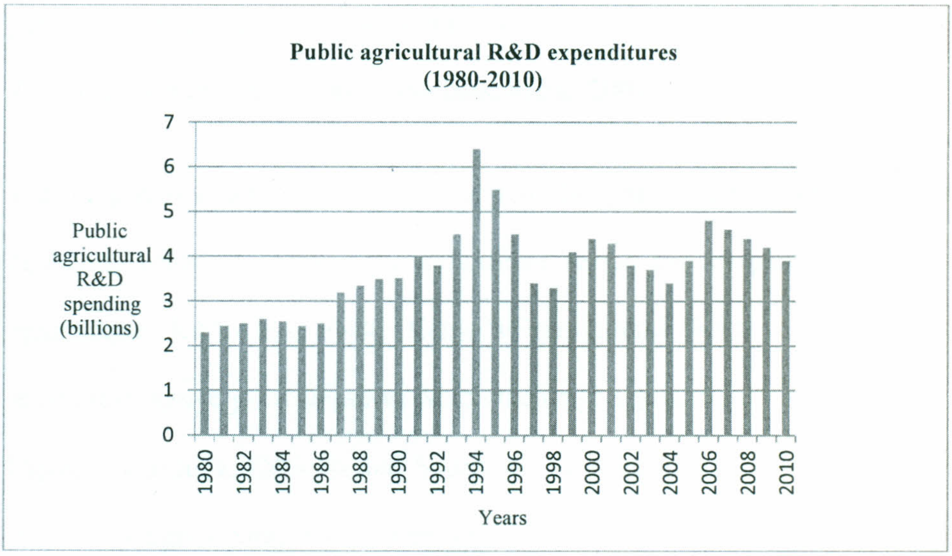
Later on, the government launched the Economic Recovery Strategy (ERS) for Wealth and Employment Creation in 2003. The ERS emphasized economic growth and creation of wealth and employment as means of eradicating poverty and achieving food security (Government of Kenya, 2007). The strategy identified agriculture as the leading productive sector for economic recovery. In addition, the strategy recognized revival of agricultural institutions and investment in agricultural research and extension as critical and essential for sustainable economic growth (Government of Kenya, 2010).

In March, 2004, the Government launched the Strategy for Revitalizing Agriculture (SRA). The strategy of the SRA was built on the lessons learned from the implementation of the ERS. The strategy aimed at transforming Kenya's agriculture into a profitable, commercially-oriented and internationally and regionally competitive economic activity that provides high-quality, gainful employment to Kenyans (Government of Kenya, 2010). This was to be achieved within the framework of improved agricultural productivity and farm incomes. The Government's vision in this strategy pointed to a paradigm shift from subsistence agriculture to agriculture as a business that is profitable and commercially oriented. On the policy direction that needed to be taken to achieve the vision, revamping agricultural R&D was given prominence.

In a departure from the predominant short term policies, the Government launched Kenya's long-term development blueprint for the country, Vision 2030 in June, 2008. The vision aspires a country which is globally competitive and prosperous with a high quality of life by 2030 (Republic of Kenya, 2008. The vision identified agriculture as one of the key sectors to deliver the 10 per cent annual economic growth rate envisaged under the economic pillar. To achieve the sectors' role in the attainment of the vision, agricultural R&D was identified as critical.

In recognition of the importance of the agriculture sector to the economy and the role agricultural R&D must play to support growth, the public and private sector have invested substantially on agricultural R&D with public agricultural R&D spending constituting a large share of the country's total public R&D spending (KARI, 2009). Figure 1.1 presents Kenya's public agricultural R&D spending trends between 1980 and 2010.

o



Source: ASTI-KARI, 2009 and Beintama, Murithi and Mwangi, 2003

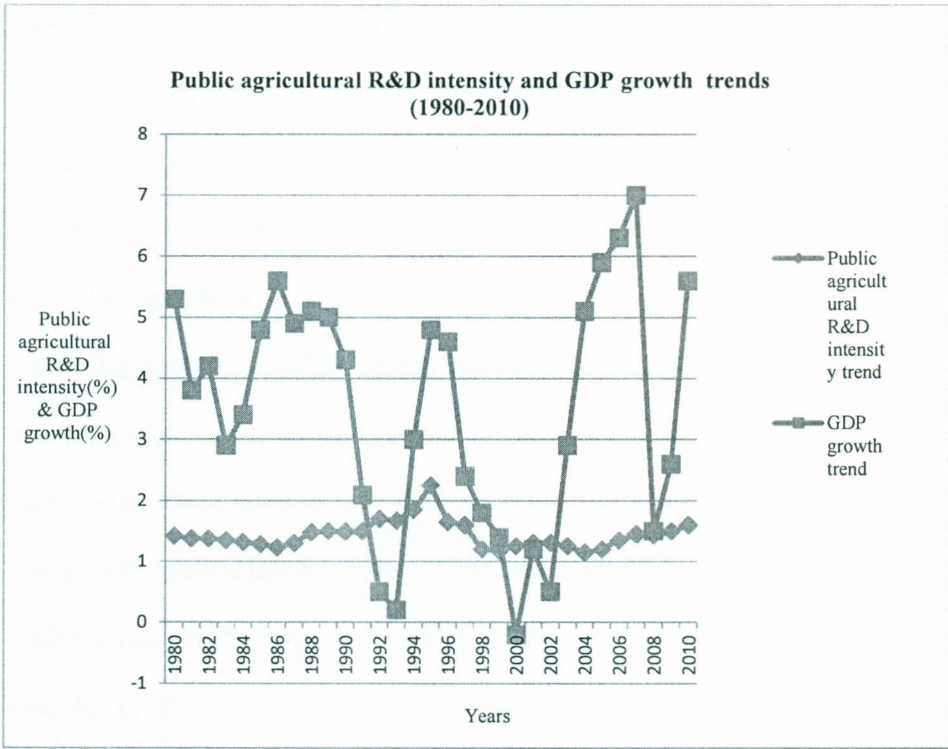
Figure 1.1: Public agricultural R&D spending in Kenya (1980-2010)

Kenya's public agricultural R&D expenditures fluctuated continuously over the period 1980 to 2010. In the 1980s, the expenditures varied significantly ranging between 2.3 and 3.5 billion shillings. The increase in the public agricultural R&D spending in the 1980s was as a result of establishment of other non-profit agencies such as the Coffee Research Foundation and the Tea Research Foundation. The increase in the expenditures is also attributed to an increase in higher education agencies involved in agricultural R&D (KARI, 2009). During the 1990s, the expenditures fluctuated at between 3.5 and 4.1 billion shillings. The fluctuations in this period are attributed to fluctuations in donor funding. In the 2000s, agricultural R&D expenditures ranged at between 3.9 and 4.4 billion shillings. The relatively high spending on public agricultural R&D during this period was due to progressive policies which banked on agricultural R&D to drive growth of the sector. Some of the key policies were the Economic Recovery Strategy of 2003 and the Strategy for Revitalizing Agriculture which was launched in 2004.

The progressive agricultural policies and the public and private sector's deliberate effort to support the agriculture sector and in particular public agricultural R&D has made Kenya's agricultural R&D compare well regionally. Kenya joins countries which include Nigeria, South Africa, Ghana, Uganda, Tanzania, Ethiopia and Sudan who are the main drivers of regional growth in agricultural R&D spending. The countries account for 70% of regional public agricultural R&D (KARI, 2009). Also, Kenya's agricultural R&D has contributed a lot to the global scientific knowledge affecting agriculture worldwide.

1.1.5 Public Agricultural R&D spending versus GDP growth

A comparison of public agricultural R&D intensity and GDP growth trends between 1980 and 2010 reveals existence of both parity and disparity in the movement of the trends. Figure 1.2 presents Kenya's public agricultural R&D intensity and GDP growth trends between 1980 and 2010.



Source: ASTI-KARI(2009), Beintama, Murithi and Mwangi(2003) and GOK(2010)

Figure 1.2: Public agricultural R&D intensity and GDP growth trends in Kenya (1980-2010)

An analysis of the trends show instances where the trends move together and other periods where the trends move in the opposite direction. Between 1980 and 1981 both the trends falls but move in the opposite direction between 1981 and 1982 were as the R&D trend falls, the GDP growth trend rises. Both trends fall between 1982 and 1983 but move away from each other between 1983 and 1987 where as the R&D trend falls and rises, the GDP growth trend rises and falls. The trends rise together between 1987 and 1988. Between 1988 and 1989, the R&D trend rises contrary to the GDP growth trend which falls. Both trends fall between 1989 and 1990 but move away from each other between 1990 and 1992 were as the R&D trend rises, the GDP growth trend falls. The trends move together between 1992 and 1999. Between 1999 and 2000, while the R&D trend rises, the GDP growth trend falls. The trends rise together between 2000 and 2001 but move in opposite direction between 2001 and 2004 where as the R&D trend rises and falls, the GDP growth falls then rises. Both trends move together between 2004 and 2010.

An in depth analysis of the trends indicates that in some periods the trends move together in that as R&D intensity increases, GDP growth increases and vice versa. These periods are 1980 and 1981(R&D intensity fell by 0.04% while GDP growth fell by 1.5%) , 1982 and 1983 (R&D intensity reduced by 0.02% while GDP growth reduced by 1.3%), 1987 and 1988 (R&D intensity rose by 0.18% while GDP growth rose by 0.2%), 1989 and 1990 (R&D intensity fell by 0.01% while GDP growth fell by 0.7%), 1992 and 1995 (R&D intensity rose by 0.55% while GDP growth rose by 4.3%), 1995 to 1999 (R&D intensity fell by 1.07% while GDP growth fell by 3.4%), 2000 and 2001 (R&D intensity rose by 0.05% while GDP growth rose by 1.4%), and 2004 and 2010 (R&D intensity rose by 0.45% while GDP growth rose by 0.5%).

In other periods, the trend move in opposite direction in that as R&D intensity increases, GDP growth decreases and vice versa. The periods are 1981 and 1982 (R&D intensity fell by 0.01% while GDP growth rose by 0.4%), 1983 and 1987 (R&D intensity fell by 0.05% while GDP growth rose by 2.0%), 1988 and 1989 (R&D intensity rose by 0.02% while GDP growth fell by 0.1%), 1990 and 1992 (R&D intensity rose by 0.21% while GDP growth fell by 3.8%), 1999 and 2000 (R&D intensity rose by 0.07% while GDP growth fell by 0.6%), 2001 and 2004 (R&D intensity fell by 0.15% while GDP growth rose by 3.9%) and 2007 and 2008 (R&D intensity rose by 0.08% while GDP growth fell by 5.5%). Though the public and private sector have continuously allocated resources to support R&D in agriculture development as evident from the R&D funding trends, no study has been done to find out empirically if the investments impact on the Kenyan economy. This study sought to fill this knowledge gap.

1.2 STATEMENT OF THE PROBLEM

The Neo classical growth models emphasised that economic growth is a result of technological progress prompted by investments in R&D (Solow and Swan, 1956 and Romer, 1986). This view is echoed in the innovation based theory of growth which implores innovation and new knowledge as significant contributors to economic growth (Romer, 1990, Grossman and Help Man, 1991 and Aghion and Howitt, 1992). In view of the theory, the way to grow rapidly is not to save a large fraction of output but to devote a large fraction of output to R&D. The theoretical evidence of the importance of R&D in driving growth is also supported by empirical evidence. Litchetberg, 1992, Birdssal and Rhee, 1993, Goel and Ram, 1994 established a strong positive relationship between expenditures on R&D and economic growth.

Motivated by the evidence on the critical role of R&D in driving growth, the government has overtime enacted policies to support public agricultural R&D. One of the early efforts was the enactment of the Sessional Paper No. 10 of 1965 on "African Socialism and its Application to Planning in Kenya". This sessional paper aimed to revolutionize agriculture through research and training and through promotion of agricultural extension services. As a follow up to the Sessional Paper No. 10 of 1965, the government enactment the Sessional Paper No. 1 of 1986 on "Economic Management for Renewed Growth". A notable recommendation in the Sessional Paper was the need to increase R&D funding from $6.9 million to $10 million. Other policy efforts were the launch of the Economic Recovery Strategy in 2003, the Strategy for Revitalization of Agriculture in 2004 and Vision 2030 in 2008. The policy commitments identified the agriculture sector and specifically public agricultural R&D as critical in driving growth of the country.

The impact of the policy effort is that funding to public agricultural R&D institutions has improved gradually overtime. In the 1980s, the expenditures varied significantly ranging from between 2.3 and 3.5 billion shillings. The R&D expenditures improved in the 1990s to range at between 3.5 and 4.1 billion shillings. In the 2000s, agricultural R&D expenditures fluctuated at between 3.9 and 4.4 billion shillings. Though resources have continuously been committed to support public agricultural R&D as evident from the R&D funding trends, no study has been done to determine empirically if the investments impact on Kenya's economic growth. This study sought to fill this knowledge gap. The findings would inform the formulation of a R&D policy on resource allocation to the R&D sector so as to support growth.

1.3 GENERAL OBJECTIVE

The study sought to determine empirically how public agricultural R&D intensity impacts on GDP growth in Kenya.

1.4 SPECIFIC OBJECTIVES

To achieve the general objective, the study specifically intended:-

(a) To determine how public agricultural R&D intensity and GDP growth relate in the long run in Kenya.

(b) To examine causality between public agricultural R&D intensity and GDP growth.

(c) To draw policy implications based on (a) and (b) above.

1.5 RESEARCH QUESTIONS

To address the specific objectives, the study was guided by the following questions:-

(a) How does public agricultural R&D intensity and GDP growth relate in the long run in Kenya?

(b) What is the nature of causality between public agricultural R&D intensity and GDP growth?

(c) What policy implications could be drawn from (a) and (b) above?

1.6 SIGNIFICANCE OF THE STUDY

To realise optimal returns from expenditures on R&D, a sound and an effective R&D policy is essential (Government of Kenya, 2008). According to Zegreld, 2000, R&D funding without an effective policy ends up with negligible contribution to economic growth. The importance of a R&D policy is that it provides a framework for harmonized and coordinated approach to create a robust knowledge based economy that is centred on self-reliance and equitable development (Government of Kenya, 2008). Despite the underlying importance of a R&D policy, Kenya lacks a policy on R&D (Government of Kenya, 2010). To fill this gap, the Government recommends formulation of a strong and sound R&D policy to propel Kenya into knowledge based economy (Government of Kenya, 2007). The findings of this study can thus inform the formulation of a sound and an effective R&D policy framework.

To achieve the aspiration of a globally competitive country envisaged in Vision 2030, R&D must play a critical role in transforming Kenya into a knowledge based economy where the creation, adaptation and use of knowledge will be among the most critical factors for rapid economic growth (Republic of Kenya, 2007, p.19). To this end, the Government intends to devote more resources to scientific research and technical capabilities of the workforce (Republic of Kenya, 2007, p.9). The findings of this study can thus inform the allocation of resources to R&D flagship projects under Vision 2030 which support growth of the economy and possibly assist attain the 10 percent target of growth envisaged in the vision.

For substantial R&D effort in Kenya, there is need to allocate significant resources to R&D. To achieve this target, the private R&D sub sector must play a significant role in supplementing public R&D financing (Republic of Kenya, 2008).The study findings can inform resource allocation by the private sector which can influence overall R&D financing in Kenya. Finally, the study findings will provide important literature on the relationship between investments on R&D and economic growth in Kenya which can be useful to researchers wishing to conduct further research on the subject.

1.7 SCOPE OF THE STUDY

The study focussed on the relationship between public agricultural R&D expenditures and GDP growth leaving out expenditures on R&D in other sectors. The focus on public agricultural R&D was informed by the reason that public agricultural R&D is the most vibrant both in funding and capacity compared to R&D in other sectors. Public agricultural R&D expenditures comprises of what the public and private sectors allocates to finance R&D in public agricultural R&D institutions.

The study utilized national annual public agricultural R&D intensity and GDP growth data. The focus on national public agricultural R&D intensity and GDP growth data was because reliable data on the same can only be found at the national level were the government generates such data. The focus on only annual data was because public agricultural R&D intensity and GDP growth data was generated annually.

The study period is 1980 to 2010. The choice of the time period was based on the fact that in the late 1980's, the R&D sector in Kenya was vibrant powered by the enactment of the Science and Technology Act Cap. 250 and also adoption of sessional Paper No. 1 of 1986 on "Economic Management for

Renewed Growth". The sessional paper outlined critical areas for which the application of Science & Technology was important and further made far reaching recommendations key among them the increase of R&D funding from $6.9 million in 1984/85 to $10 million. Further, the period 1980-2010 captures current period and thus a study based on the period would give a closer picture of how the R&D sector has impacted on economic growth in Kenya.

1.8 LIMITATIONS OF THE STUDY

The study utilized secondary data as opposed to primary data. This was necessitated by the limiting cost constraint associated with primary data collection. Primary data would have been more current and informative. The limitation of time also prompted the use of secondary data for the analysis. However, the secondary data was adequate, reliable and valid for the study, although limiting in terms of information.

Though economic growth is a function of many factors, the study focussed on the relationship between public expenditures on agricultural R&D leaving out expenditures in other R&D sectors. The focus on public agricultural R&D was because Kenya's economy is majorly agricultural and further, agricultural R&D is the most vibrant both in funding and staffing compared to R&D in other sectors.

The study adopted a national approach rather than a firm level approach which would have been more informative. This was necessitated by the fact that reliable public agricultural R&D intensity and GDP growth data can be found at the national level were the Government generates the data. Such data is aggregated nationally.

1.9 ORGANIZATION OF THE STUDY

The rest of the study is organized as follows; chapter two reviews the relevant theoretical and empirical literature. The empirical literature reviews both empirical literature from other countries and empirical literature specific to Kenya. The chapter further presents an overview of literature. Research methodology which covers research design, theoretical model, empirical model, definition of variables, target population, sampling technique, data collection methodology and data analysis comprise chapter three. Chapter four comprises data presentation, analysis and discussions. Summary, conclusions and policy recommendations comprise chapter five. Appendices and the references cited in the research project feature after chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This section looks at both the theoretical and empirical literature on the relationship between expenditures on R&D and GDP growth. The review of literature falls in two categories, first, theoretical literature and secondly empirical literature. The empirical literature reviews both empirical literature from other countries and empirical literature specific to Kenya which is the focus of the study. Finally, an overview of literature gives a summary of critical findings emanating from both the theoretical and empirical literature reviewed.

2.2 THEORETICAL LITERATURE

Theories of what really drives economic growth have for a long time baffled economists and have remained an area of interest up to today. The aspect of what should be done to grow economies has had economists critique existing theories, improve existing or develop entirely new theories of growth. Notable theories of growth and which are given prominent attention in this review are the Classical theory of growth, Neo classical growth theory and the Endogenous growth theory also known as the New growth theory.

2.2.1 Classical Theory of Growth

The classical theories of growth comprise initial attempts in the 1980s by classical economists to explain what really drives economic growth. The theory associated with Smith (1776), Ricardo (1817), Malthus (1820) and Mill

(1842) takes cognize of free trade and international competitiveness as critical for economic growth. Smith (1776), attributed growth to competitiveness in that under competition, owners of resources use them most profitably resulting in an equal rate of return for all uses in equilibrium. Ricardo (1817) exemplified free trade as critical for growth in that there is mutual benefit from trade even if one party is more productive in every possible area than its trading counterpart. According to Ricardo (1817), the mutual benefit aspect holds as long as one concentrates in actions were one has relative productivity advantage. The theory of free markets found support in Mill (1842) who advocated the philosophy of free markets as essential for economic growth.

2.2.2 Neo classical Growth Theory

The classical school of thought on what really drives growth did not satisfy a group of economists who included Solow and Swan (1956) and Romer (1986). Solow and Swan and Romer felt that there was more to economic growth than the neo classical theories advanced by the classical economists. This led to the neo classical theory of growth which tried to explain growth by linking productivity, capital accumulation, population growth and technological progress. Initial works by Solow and Swan produced what came up to be known as the Solow-Swan growth model. In the model, aggregate output is given as;

$$Y_t = f(K_t, A_t L_t) \quad \ldots\ldots 2.2.1$$

The aggregate output function can be represented by a Cobb-Douglas aggregate production function of the form;

$$Y_t = K_t^{\alpha}(A_tL_t)^{1-\alpha} \quad \ldots\ldots 2.2.2$$

In the model, Y_t, K_t, L_t and A_t denote aggregate output, the capital stock, labor supply and the level of technology, respectively. α is a production parameter. Factor inputs in the model have positive and diminishing marginal returns. Capital accumulation per effective labour is given as;

$$\dot{\tilde{k}} = sf(\tilde{k}_t) - (\eta + g + \delta)\tilde{k}_t \quad \ldots\ldots 2.2.3$$

In model the model, $\dot{\tilde{k}}$ is capital accumulation per effective labour, $sf(\tilde{k}_t)$ is the proportion of output saved and thus invested, η is population growth rate, g is technological progress and δ is capital depreciation rate. In view of Solow and Swan, capital per effective labour accumulates if the proportion of output saved and thus invested is higher than the break even investment defined as the amount of capital needed to cover depreciation, population growth and technological progress. In a steady state, capital accumulation per effective labour in the model is constant and thus capital accumulation ceases as shown below;

$$\dot{\tilde{k}} = 0 => sf\left(\bar{\tilde{k}}_t\right) = (\eta + g + \delta)\,\bar{\tilde{k}}_t \quad \ldots\ldots 2.2.4$$

According to Solow and Swan in the steady state of growth, only a change in technological progress has any influence on the long run growth of per capita output as depicted in the equation below;

$$\bar{\tilde{y}} = f\left(\bar{\tilde{k}}_t\right) = c = g \quad \ldots\ldots 2.2.5$$

On the basis of the initial works by Solow and Swan (1956), Romer (1986) observed that the determinants of long run economic growth are crucial issues far more than mechanisms of business cycles and the countercyclical effects of monetary and fiscal policies. According to Romer (1986), technological progress which is due to intentional actions of people such as investing in R&D, is key in accounting for sustained increase in output per worker.

2.2.3 Endogenous Growth Theory

In the late 1980's, it emerged that the standard neo-classical growth model was theoretically unsatisfactory to explore the determinants of long run growth. This was because in the model the economy will eventually converge to a steady state with zero per capita growth. Modern economists argued that the only way an economy can escape from zero per capita growth was through technological progress in the form of new ideas. It thus became a priority to go beyond the treatment of technological progress as exogenous and thus explain technological progress within the model of growth. The essence of the endogenous growth theory was to overcome the loopholes in the neo classical growth theory. The endogenous growth theory postulates that economic growth is primarily as a result of endogenous and not external forces. The endogenous growth theory can be classified into the AK theory of growth and the innovation growth theory.

2.2.3.1 AK theory of Growth

The AK theory of growth was one of the initial attempts to overcome the ever present diminishing marginal product of capital which curtails long run growth. In the AK approach to economic growth, physical and human capital is lamped together with intellectual capital that is accumulated when innovations occur. According to the theory no labour augmenting technological change is required to sustain per capita growth because growth can be sustained if capital accumulation is greater than depreciation or through raising savings. (Frankel, 1962 and Romer, 1986). In the AK approach, aggregate output is represented by the production function given below;

$$Y(t) = AK(t) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 2.2.6$$

where, $Y(t)$ is aggregate output at time t, $K(t)$ is capital accumulation at time t and A is a positive constant which includes physical capital, human capital and technological progress. In the AK model, capital and output will grow at the rate, $sA - \delta$ were s is savings and δ is capital depreciation rate. As long as $sA > \delta$ and savings are on an upward trend, per capita income will grow indefinitely. From the general version of the AK model different versions also emerged. An early version of the AK model was by Frankel (1962) who postulated that the aggregate production function can exhibit a constant or even increasing marginal product of capital. This is because when more capital is accumulated, some of it will be intellectual capital that creates technology progress which will offset the tendency of marginal capital to diminish. Other versions of the AK theory were by Uzawa, 1965, Lucas (1988) and Rebelo,1990. Uzawa, 1965, assumed that human capital and technological knowledge are one and the same thing. Lucas (1988) focussed on human capital rather than physical capital. As for Rebelo (1990) aggregate production function is linear in the only input capital and which has constant returns to scale.

2.2.3.2 Innovation based theory of Growth

The innovation based theory of growth was a follow up to the AK theory and indicated that in a steady state the only way to ensure long run growth is through technological progress in the form of new ideas. The theory recognised intellectual capital, the source of technological progress as distinct from both human and physical capital. The theory holds that physical and human capital is accumulated through saving and training but intellectual capital grows from innovation. An initial version of the theory was by Romer, 1990 who assumed that aggregate productivity is as an increasing function of the degree of product variety. According to Romer, 1990, innovation causes productivity growth by creating new but not necessary improved versions of products. The theory is represented by the following production function.

$$Y = L^{1-\propto} \int_0^A x(i)^{\propto} di,\ 0<\propto< 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2.7$$

In model, L is aggregate supply of labour, x(i) is the flow of input of intermediate product i and A is the measure of different intermediate products that are available for use. In the model, an increase in product variety is measured by A which represents levels of technology.

A later version of innovation based theory of growth was by Aghion and Howitt, 1990 and Grossman and Helpman, 1991.The model is represented by an aggregate output function of the form;

$$Y(t) = A(t)\big(x(t)\big)^{\propto} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2.8$$

where A(t) denotes technology level at time t. In the model there is a constant labour force, L and the share of labour force devoted to R&D is denoted by ŋ.

The units of labor units devoted to producing the intermediate input x is L- η . Every unit of labor devoted to R&D generates a innovation in A(t) at rate λ. The innovations generated create improved versions of products or new products which contribute to growth. The theory indicates that the way to grow rapidly is not to save a large fraction of output but to devote a large fraction of output to R&D. The theory is explicit about how R&D activities are influenced by various policies, who gains from technological progress, how the gains and losses depend on social arrangements, and how such arrangements affect society's willingness and ability to create and cope with technological change, the ultimate source of economic growth.

2.3 EMPIRICAL LITERATURE

The observed theoretical evidence that R&D expenditures impacts on economic growth is supported by empirical evidence. A Midwest Research Institute (1970) examined the relationship between R&D expenditures and technology-induced increases in GNP. The study found out that each dollar spent on R&D returns an average of slightly over seven dollars in GNP over an eighteen-year period following the expenditure. Assuming that NASA's R&D expenditures produce the same economic payoff as the average R&D expenditure, the study concluded that the $25 billion spent on civilian space R&D during the 1959-69 period returned $52 billion through 1970 and will continue to stimulate benefits through 1987, for a total gain of $181 billion.

Analyzing the effect of privately funded R&D on productivity growth by using cross-sectional data from 98 countries, Lichtenberg (1992) estimated a non linear production function which had the rate of investment in labour, physical capital and research as repressors. The study found out that privately funded research had positive significant effects on growth of productivity.

In a related study, Birdsall and Rhee (1993), examined the link between R&D expenditure and economic growth both in the OECD and developing countries. The study employed a cross country regression of data from both OECD and developing countries. Birdsall and Rhee found out that R&D expenditure and economic growth were positively correlated in the OECD countries and that there was insignificant relationship in the developing countries. The findings by Pessoa and Birdsall and Rhee agree that R&D spending and GDP growth has a positive relationship in the OECD countries. The finding by Birdsall and Rhee of insignificant relationship in developing nations is expected mainly due to the minimal R&D funding.

Though many studies around the world focus on R&D in the context of were R&D is undertaken and diffused in production, Goel and Ram (1994) broke from tradition and investigated the effects of R&D outlays/spill overs on economic growth. The study used data from a cross section of 52 countries in the late 1970s and early 1980s to analyse how R&D outlays impacts on economic growth. The study estimated a growth model which had labour, capital and R&D expenditure as the variables. Goel and Ram established that the impact of R&D outlays on economic growth was positive with a low statistical significance.

Bwisa and Gacuhi (1999) examined how technology generated in Kenya is utilised for development. The findings showed that most of the research findings remain unapplied. Bwisa and Gacuhi attributed this to little interaction between R&D institutions with the intended users of the results. The study noted that due to the lack of interaction, some innovations do not address the real needs of the intended users and others are never known by the indeded users. The study recommended that a national policy on S&T could help dissipate the problems.

Adding a new dimension to the study by Lichtenberg (1992), Gullec and van Pottelsberghe de la potterie (2001) examined the effects of R&D investments on productivity growth in the private sector, Gullec and van Pottelsberghe de la potterie (2001) used panel data of 16 OECD countries between 1980 and 1998. The study separated the contribution of public, private and foreign R&D investment in the analysis. Gullec and van Pottelsberghe de la potterie found that all the three forms of R&D investment were positively and significantly related to productivity. Though Lichtenberg (1992) looked at overall productivity growth and narrowed down to only privately funded research, Pottelsberghe de la potterie (2001) looked at productivity growth in the private sector and narrowed down to public, private and foreign R&D investments. Though the studies adopted different approaches the findings were in agreement that R&D investments impacts positively on productivity growth.

Yuen Ping (2003) studied the impact of R&D expenditures on the Singapore economy for 24 years. The study used annual data on Total Factor

Productivity (TFP) and R&D capital stock in Singapore for the years 1978-2001. Yuen Ping conducted a co-integration test which confirmed the existed of a long run relationship between TFP and expenditures on R&D. A short run Error Correction Model (ECM) was then estimated to determine the impact of R&D capital stock on TFP. The study found out that in the short run, one percent increase in the stock of R&D capital lead to a 0.013 percent increase in the GDP and in the long run, one percent increase in the stock of R&D capital lead to a 0.0814 percent increase in the GDP.

Moyi and Njiraini (2005) looked at Kenya's ranking on technological progress and innovation compared to other countries. The study (as cited in World Competitiveness Report, 2005) found that Kenya ranked position 75 out of 104 countries on technological competitiveness and position 87 out of 104 countries on innovation. Moyi and Njiraini (2005) also noted that though Kenya had made big achievements in agricultural R&D, achievements in the industrial sector has been limited due to low funding. The study revealed that low funding translated to low capability for industrial research, making Kenya a net importer of foreign industrial technology. The view by Moyi and Njiraini found support in Ikiara (1988).

Li Peng (2007) examined the relationship between R&D expenditures and economic growth of China. The study used causal research design to relate R&D expenditure and GDP growth for 21 years between 1987 and 2007. Li Peng conducted a co-integration test which indicated that a long run equilibrium relationship existed between R&D intensity and GDP growth. A causality test was conducted to determine the nature of the long run relationship. The study found out that R&D intensity causes GDP growth with an elasticity of R&D intensity to GDP growth of 0.9243. The study concluded that R&D was a key factor in economic growth in China. Though Yuen Ping (2003) chose TFP as the depended variable and estimated an Error Correction Model, Li Peng (2007) chose GDP growth as the depended variable and conducted a causality test. Despite variation in methodology, the studies showed that R&D expenditure impacts positively on economic growth.

Pessoa (2007) examined the relationship between R&D intensity and GDP growth in the OECD countries. The study assumed that R&D carried out by researchers leads to a new idea, which becomes a new product, for which a production process is developed by industrial engineers, and for which a marketing plan is set up. Pessoa plotted R&D intensity measured by GERD (Gross Domestic Expenditure on R&D) as a percentage of GDP in 2004 against the GDP per capita in 2005 for 29 OECD countries. The study established that there was a positive correlation between R&D intensity and GDP growth.

Pessoa (2007) further studied the relationship between growth of knowledge occasioned by expenditures on R&D and economic growth for US, Ireland and Sweden. The study assumed that in equilibrium the value of resources devoted to R&D equals the value of the newly developed technologies. Pessoa used data from OECD (2006) to estimate knowledge stock growth rates. The estimated growth of knowledge was, Ireland (-0.00138), Sweden (0.10616) and US (0.03455). The study assumed that in equilibrium once attained, the steady-state path of growth of knowledge will equal growth of output (Romer, 1990, Grossman & Helpman, 1991). The estimates on growth of knowledge and GDP growth were US(0.03455) compared to GDP growth of 0.034, Sweden (0.10616) compared to GDP growth of 0.039 and Ireland (-0.00138) compared to a GDP growth of 0.041. Pessoa noted that the discrepancy for Sweden and Ireland was occasioned by in accuracy of the parameters used in the study.

2.4 OVERVIEW OF LITERATURE

In the theoretical literature reviewed, most of the advanced theories concluded that R&D generates economic growth. The neo classical growth theory associated with Solow and Swan (1956) and Romer, 1986 implores technological progress as a key factor in economic growth. The endogenous theory of growth owed to Romer(1990), Aghion and Howitt (1992) and Grossman and Help Man(1991) firmed up the critical role technological progress plays in economic growth held by the neo classical theory of growth. The endogenous growth theory is quite explicit that investment in human capital, innovation and knowledge are significant contributors to economic growth. The empirical literature reviewed also provides evidence that R&D contributes to economic growth. Birdsall and Rhee (1993) and Pessoa (2007) showed that there was a positive correlation between R&D expenditure and economic growth. Lichtenberg (1992) and Gullec and van Pottelsberghe de la Potterie (2001) established that R&D investments had significant positive effects on productivity growth. MRI (1960), Chase (1971), Goel and Ram (1994), Yuen Ping (2003) and Li Peng (2007) revealed that R&D expenditure impacts positively on economic growth. Bwisa and Gacuhi (1999) noted that technology generated in Kenya remains unapplied. Moyi and Njiraini (2005) established that Kenya ranked position 75 out of 104 countries on technological competitiveness and on innovation position 87 out of 104 countries and further revealed that Kenya spends little on industrial R&D a view strengthened by Ikiara(1988). Despite the diversity of the methodologies the findings were in agreement that R&D contributes to economic growth. The theoretical literature and the empirical literature reviewed provide evidence that expenditures on R&D has a great bearing on economic growth.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The study sought to determine whether public agricultural R&D expenditures impact on economic growth in Kenya. The methodology described below was used in an attempt to arrive at the purpose of this study. This chapter covers research design, theoretical framework, empirical model, definition of variables, target population, sampling technique, data collection methodology and data analysis.

3.2 RESEARCH DESIGN

The study used a non experimental research design and more particular causal research design in an attempt to arrive at the goal of the study. The choice of the design was informed by the nature of the study which is theory driven. The study is based on the innovation based theory of growth which indicates that technological progress prompted by expenditures on R&D contributes to long run growth (Romer, 1990, Aghion and Howitt, 1992 and Grossman and Help Man, 1991). Theory-driven research is exclusively concerned with causal relationships. Further, the variables of study are time series in nature, a pre requisite requirement in the choice of a causal research design. Causal research design was thus an appropriate design to deliver the overall goal of this study.

3.3 THEORETICAL FRAMEWORK

The study was anchored on the new growth theory and in particular the innovation based theory of growth credited to Romer, 1990, Aghion and Howitt, 1990 and Grossman & Helpman, 1991. The essence of the theory is to address the problem of diminishing returns in factor inputs evident in the neo classical growth theory which curtails long run growth. To formulate the theoretical model of the study we begin with a simple aggregate output function that has diminishing returns to factor inputs of the form;

$$Y = f(K, L) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3.1$$

In the model, Y is aggregate output, K is capital and L is labour. The innovation based theory of growth, postulates that in a steady state, technology progress in the form of generation of new ideas is the only way an economy could escape diminishing returns and ensure long run per capita growth. Introducing technology progress denoted by A in model 3.3.1, we obtain.

$$Y = f(A, K, L) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3.2$$

The aggregate output function 3.3.2 can be represented by an aggregate Cobb-Douglas production function of the form;

$$Y = AK^{\propto}L^{1-\propto} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3.3$$

$$A > 0 \text{ and } 0 < \propto < 1$$

where Y is aggregate output, K is capital, L is labour, A is level of technological progress and $\propto$ is a production parameter. Taking logs of both sides, we obtain,

$$\log Y = \log A + \propto \log K + (1-\propto) \log L \ldots\ldots\ldots\ldots\ldots\ldots 3.3.4$$

In a steady state, K and L will be constant and thus model 3.3.4 reduces to;

$$\log Y = \log A \ldots\ldots\ldots\ldots\ldots 3.3.5$$

Model 3.3.5 depicts long run aggregate per capita growth as a function of technological progress. This is in tandem with the innovation theory of growth which holds that technological progress is the driver of long run per capita growth.

3.4 EMPIRICAL MODEL

Model 3.3.5 implies that aggregate output and technology progress are related in a long run relationship. The study thus hypothesizes that public agricultural R&D intensity and GDP growth are co integrated. According to Granger, 1983, if variables are co integrated then there must exist an Error Correction Model (ECM) conforming to the co integrating model. There is thus need to formulate an ECM to capture the co integrating possibility in the variables. We start by formulating the short run effects between the variables. The variables are suspected to be non stationery (see figure 1.2) but integrated of the same order, I_{∂}, were ∂ is the order of integration. The stationery variables are thus denoted by $\Delta^{\partial}\mathrm{GDPG}_t$ and $\Delta^{\partial}\mathrm{PAR\&}DI_t$ were $\Delta^{\partial}\mathrm{GDPG}_t$ and $\Delta^{\partial}\mathrm{PAR\&}DI_t$ represents stationery GDP growth and stationery public agricultural R&D intensity, at time t respectively. To obtain the short run relationship, we regress the stationery GDP growth at time t ($\Delta^{\partial}\mathrm{GDPG}_t$) with its lagged values ($\Delta^{\partial}\mathrm{GDPG}_{t-i}$) and the lagged values of stationery public agricultural R&D intensity ($\Delta^{\partial}\mathrm{PAR\&}DI_{t-i}$) to obtain,

$$\Delta^{\partial}\mathrm{GDPG}_t = \sigma_1 + \sum_{i=1}^{p} \theta_{1i}\, \Delta^{\partial}\mathrm{PAR\&}DI_{t-i} + \sum_{i=1}^{p} \lambda_{1i}\, \Delta^{\partial}\mathrm{GDPG}_{t-i} + \varepsilon_{\mathrm{GDPG}_t} \ldots\ldots\ldots\ldots (3.4.1)$$

where, θ_{1i} , λ_{1i}(i=1,2...p)and σ_1 are constants and ε_{GDPGI_t} denote error term at time t. The rationale of including the lagged values of stationery GDP growth ($\Delta^{\partial}GDPG_{t-i}$) as an explanatory variable in model 3.4.1 is informed by the fact that the vigour at which the economy grows in the previous period will affect growth of the economy presently. Further, the lagging of the public agricultural R&D intensity variable ($PAR\&DI_{t-i}$) is informed by the fact that R&D is a dynamic process and investments on R&D cannot impact immediately on GDP growth (Van Reenen, 1997). Model 3.4.1 represents the short run causal effects of lagged stationery public agricultural R&D intensity ($\Delta^{\partial}PAR\&DI_{t-i}$) and lagged stationery GDP growth ($\Delta^{\partial}GDPG_{t-i}$) on stationery GDP growth at time t ($\Delta^{\partial}GDPG_t$) . In the long run, model 3.4.1 will also depend on the lagged deviations from the long run relationship(Enders, 2004). The lagged deviations are as represented by equation 3.4.2 below

$$\varepsilon_{t_1-1} = GDPG_{t-1} - \lambda_0 - \lambda_1\ PAR\&DI_{t-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4.2)$$

The lagging of the errors once is because in equilibrium a process will depend on the previous gap from equilibrium (Enders, 2004). Model 3.4.1 will thus also depend on ε_{t_1-1} in equilibrium. In co-operating the lagged deviations as an explanatory variable in model 3.4.1 we've,

$$\Delta^{\partial}GDPG_t=\sigma_1 + \sum_{i=1}^{p}\theta_{1i}\,\Delta^{\partial}PAR\&DI_{t-i} + \sum_{i=1}^{p}\lambda_{1i}\,\Delta^{\partial}GDPG_{t-i} + \psi_{GDPG}\,(GDPG_{t-1} - \lambda_0 - \lambda_1\ PAR\&DI_{t-1}) + \varepsilon_{GDPGI_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4.3)$$

Were λ_1 is the long term equilibrium causal effect which occurs at a rate dictated by the adjusted parameter, ψ_{GDPG} (Keele & Boef, 2004). From equation 3.4.2, model 3.4.3 can also be written as,

$$\Delta^{\partial}\mathrm{GDPG_t}=\sigma_1+\sum_{i=1}^{p}\theta_{1i}\,\Delta^{\partial}\mathrm{PAR\&}DI_{t-i}+\sum_{i=1}^{p}\lambda_{1i}\,\Delta^{\partial}\mathrm{GDPG_{t-i}}+\psi_{GDPG}\tilde{\varepsilon}_{t_1-1}+\varepsilon_{GDPG_t}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.4.4)$$

Model 3.4.4 was estimated to determine unidirectional causality between the variables. Granger, 1983 indicates that co integrated variables can also exhibit bidirectional causality. To examine this possibility the study estimated the ECM below.

$$\Delta^{\partial}\mathrm{PAR\&}DI_t=\sigma_2+\sum_{i=1}^{p}\theta_{2i}\,\Delta^{\partial}\mathrm{PAR\&}DI_{t-i}+\sum_{i=1}^{p}\lambda_{2i}\,\Delta^{\partial}\mathrm{GDPG_{t-i}}+\psi_{R\&DI}\,\tilde{\varepsilon}_{t_2-1}+\varepsilon_{R\&DI_t}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.4.5)$$

Models 3.4.4 and 3.4.5 which were the empirical models of the study are owed to Engle and Granger (as cited in Ekanayake, 1999). The above ECMs were estimated to determine causality between public agricultural R&D intensity and GDP growth in Kenya.

3.5 DEFINATION OF VARIABLES

The study's variables are public agricultural R&D intensity and GDP growth. The meaning of the variables in the context of this study is explained below.

Public agricultural R&D intensity: Public agricultural R&D intensity comprises both public and private sector allocations to public agricultural R&D institutions as a percentage of agricultural GDP.

GDP growth: GDP growth also referred to as economic growth in this study is the increase of per capita GDP or other measures of aggregate income usually reported as the annual rate of change in real GDP.

3.6 TARGET POPULATION

The target population of the study consists of all annual data on public agricultural R&D intensity and GDP growth in Kenya. The choice of the target population was dictated by the following reasons; First, public agricultural R&D intensity and GDP growth were the only variables of the study. Secondly, data on public agricultural R&D intensity and GDP growth used in the study was generated annually and thirdly, the study analysed a sample of public agricultural R&D intensity and GDP growth data between 1980-2010. The variables of the study namely, public agricultural R&D intensity and GDP growth, the annual mode of generation of the variables' data and the utilization of a sample of the variables data in the analysis prompted the study to target all annual data on public agricultural R&D intensity and GDP growth rates in Kenya as the universe of the study.

3.7 SAMPLING TECHNIQUE

The study adopted a non probability sampling technique to obtain a sample of annual data on public agricultural R&D intensity and GDP growth rates in Kenya. Non probability in that data on public agricultural R&D intensity and GDP growth was not randomly selected but purposively selected to capture the most ideal study period to deliver the study's objective. Specifically, the study utilized convenience sampling to draw annual data for a period of 31 years (1980-2010). The unit of analysis was a one year period data on public agricultural R&D intensity and GDP growth. The sample size of the study was annual data for public agricultural R&D intensity and GDP growth between 1980 and 2010.

3.8 DATA COLLECTION METHODOLOGY

The study utilized published annual data on public agricultural R&D intensity and GDP growth for a period of 31 years. Data on public agricultural R&D intensity was obtained from the Agricultural Science and Technology Indicators (ASTI) developed by KARI. Data on GDP growth was obtained from the Economic Survey (1980-2010). The Economic Survey is published yearly by the KNBS and captures aggregated annual economic development data.

3.9 DATA ANALYSIS

The study conducted various tests in an attempt to answer the research questions. The tests are discussed in detail below.

3.9.1 Diagnostic Unit Root Tests

The study used the ADF test (Dickey and Fuller, 1979) and the PP test (Phillip and Perron 1988), to test for stationery in both variables. The use of both test methods was to ensure certaitnty of the test results.

3.9.2 Co-integration Tests

The study conducted both the Engle & Granger and the Johansen-Juselius co integration tests. The use of both methods was to strengthen the accuracy of the co integration test results (Islam & Ahmed, 1999)

3.9.2.1 Diagnostic Checks on the Co-integrating Models (EG and JJ Methods)

The study undertook a Breusch-Godfrey LM Test (Breusch & Godfrey, 1978), a Breusch-Pagan test (Breusch & Pagan, 1979) and a Jargue Bera test on the normality of the residuals.

3.9.3 Error Correction Model (ECM) Estimation

The study estimated the coefficients of the ECMs to determine the significance and further conducted a Wald F test to determine causality between the variables.

3.9.3.1 Model (ECMs) Diagnostic Checks

The study conducted a test on serial correlation of errors (Breusch-Godfrey test), a test on Heteroscedastic errors (Breusch Pagan test) and a test on Normality of errors (Jargue Bera test).

3.9.4 Granger Causality test within the ECM Framework

The study adopted the more advanced Granger causality test within an ECM as opposed to the standard Granger causality test. The study used the Wald F test to determine the joint significance of the coefficients in the ECMs.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter presents data on public agricultural R&D intensity and GDP growth used in the study. The data spans for a period of 31 years from 1980 to 2010. The chapter further presents unit root tests conducted on the public agricultural R&D intensity and GDP growth data, co integration tests, ECM estimation and an advanced Granger Causality test. Adequacy and stability test results of both co integration and ECM models are also presented in this chapter. Lastly, the chapter presents key deductions based on the statistical test results.

4.2 DATA PRESENTATION

The study used annual data on public agricultural R&D intensity and GDP growth for 31 years between 1980 and 2010 to arrive at the purpose of the study. Data on public agricultural R&D intensity was sourced from the Agricultural Science Technology Indicators developed by KARI while that on GDP growth was obtained from Economic Surveys. The public agricultural R&D intensity and GDP growth rates data is shown in table A.1 in Appendix I.

4.3 DIAGNOSTIC TESTS (Unit Root Tests)

The study conducted an ADF test and a PP unit root test on the R&D intensity and GDP growth data to determine the stationarity of both variables. The ADF and the PP test results are discussed below.

4.3.1 Augmented Dickey Fuller (ADF) Test

The ADF test was done under the null hypothesis that public agricultural R&D intensity and GDP growth had a unit root. To take care of sensitivity of lags, the test was done in five lags obtained though the Schwartz Information Criterion. The ADF test results for the public agricultural R&D intensity and GDP growth series are shown in table A.2 in appendix II. The ADF test statistics for the public agricultural R&D intensity for the five lags are less than the critical values at 5% significance level (1.929011<3.574244, 2.257372<3.580623, 2.207488<3.587527, 1.768561<3.595026, 1.923339<3.603202). For the GDP growth series the ADF test statistics for all the lags are also less than the critical values at 5% significance level 2.973632<3.574244,2.589183<3.580623,2.138268<3.587527,1.471118<3.595026, and 0.748688<3.603202). The study fails to reject the null hypothesis that public agricultural R&D intensity and GDP growth rates has a unit root.

4.3.2 Phillips-Perron (PP) Test

Same to the ADF test, the PP test was also done under the null hypothesis that public agricultural R&D intensity and GDP growth have a unit root. Table A.2 in appendix II presents the PP test results for the public agricultural R&D intensity and the GDP growth series. The PP test statistics for the public agricultural R&D intensity in all the lags are less than the critical values at 5% significance level (i.e. 2.062176, 2.165490, 2.192330, 2.14089, and 2.1008650 are all less than the critical value of 3.568379 at 5% significant level). For the GDP growth the PP test statistic is also less than the critical value (i.e. 2.656674, 2.631269, 2.560241, 2.431478, and 2.279196 are less than the critical value 3.568379 at 5% significant level). The study fails to reject the null hypothesis of a unit root in public agricultural R&D intensity and GDP growth rates. The results under the ADF and PP test are also confirmed by a time plot of public agricultural R&D intensity and GDP growth in levels and at first difference. The plots of both GDP growth and R&D intensity in figure A.1- A.4 in Appendix II, clearly show that public agricultural R&D intensity and GDP growth rates are non-stationery in levels but stationery at first difference. The study thus concludes that public agricultural R&D intensity and GDP growth are I_1 variables.

4.4 STATISTICAL TESTS

The study conducted an EG co integration and a Johansen-Jusselius test to determine presence of a long run relationship between public agricultural R&D intensity and GDP growth. The study further estimated an ECM and conducted a Granger Causality test within an ECM in an attempt to determine causality between public agricultural R&D intensity and GDP growth. The test results are discussed below.

4.4.1 Engel and Granger (EG) Co integration Test

The EG co integration test was conducted under the null hypothesis that public agricultural R&D intensity and GDP growth are not co integrated. The EG co integration test results which encompasses testing the null hypothesis of a unit root in the series, $\Delta\tilde{\varepsilon}_t = \sigma\, \varepsilon_{t-1} + \mu_t$(i.e $\sigma = 0$) from equation 3.4.1 are shown in table 4.1.

Table 4.1: t-test on the significance of the coefficient (σ)

Null hypothesis	Coefficient (σ)	t-value	Significance Level (5%)	P-value
Public agricultural R&D intensity and GDP growth are not co-integrated ($\widetilde{\varepsilon_t \sim I_1}$) or $\sigma = 0$ in $\widetilde{\Delta\varepsilon_t} = \sigma\, \varepsilon_{t-1} + \mu_t$	-0.390764	-2.632062	0.05	0.0135

The coefficient of ε_{t-1} has a value of -0.390764($\sigma = -0.390764$) and a t statistic of -2.632062 and a P value of 0.0135. The P value is less that 0.05 significant level. The study rejects the null hypothesis that the coefficient is not significantly different from zero. The series, $\Delta\widetilde{\varepsilon_t}$ is thus stationery in level ($\widetilde{\Delta\varepsilon_t \sim I_0}$). The study concludes that public agricultural R&D intensity and GDP growth have a long run equilibrium relationship (co integrated).

4.4.2 Johansen-Juselius (JJ) Co integration Test

The Johansen-Juselius Co integration test was conducted under the null hypothesis that there are zero co integrating equations ($r = 0$) against the alternative of existence of at most 1 co integrating equation ($r \leq 1$). The Johansen-Juselius Co integration test results are shown in table 4.2.

Table 4.2: Johansen-Juselius test results

Null hypothesis(No. of Hypothesised co integrating Equations(CEs)	Max-Eigen value	5% critical values	Trace Statistic	5% critical values
None (r=0)	20.46984	15.89210	27.78869	20.26184
At most 1 ($r \leq 1$)	7.318857	9.164546	7.318857	9.164546

Under the Eigen value test, the Max-eigen value (20.46984) is greater than the critical value at 5 %(15.89210). The null hypothesis of zero co integrating equations is thus rejected. On the alternative of at most one co integrating equation the Max-Eigen value (7.318857) is less than the 5% critical value (9.164546) and thus the study fails to reject the hypothesis of at most one co integrating equation. For the trace test, the trace test statistic (27.78869) is greater than the 5% critical value (20.26184) and thus the null hypothesis of zero co integrating equations is rejected. Alternatively, in the hypothesis of at most one co integrating equation, the trace statistic (7.318857) is less than the 5% critical value (9.164546). The study fails to reject the hypothesis of at most one co integrating equation. Both the Max-eigen value test and the trace test confirm the existence of one con integrating equation.

4.4.3 Stability tests on the Co- integrating Model

Several stability tests were conducted to determine the statistical soundness of the co integrating model . The tests are a Breusch-Godfrey LM test of non-autocorrelation, a Breusch-Pagan test of homoscedasticity and a Jarque Bera test of normality of the regression residuals. For the Jarque Bera test of normality, the skewness was -0.209009 which is close to zero. The kurtosis was 1.905492 which is not far from 3 and Jarque Bera statistic 1.773052 is less than 5.9. The residuals pass the normality test. For the Breusch Pagan test of Homoscedastice errors the F statistic, 0.174172 has a p value of 0.6795 which is greater than 0.05. The residuals also passes the Breusch Pagan test and thus the residuals are homoscedastic. The model fails the non autocorrelation test at lower lags but passes at the 9th lag were the F statistic from the Breusch Pagan LM test, 2.273119 has a p value of 0.0606 which is greater that the significance level of 0.05. The null hypothesis of non autocorrelation is thus not rejected. The residuals are thus not serially correlated at higher lags. The co integrating model is stable.

4.4.4 Error Correction Model (ECM) Estimation

The essence of the ECM estimation is to determine the significant of the regression coefficients, $\psi_{R\&DI}$ and ψ_{GDPG} and the stationarity of the regression residuals, $\varepsilon_{R\&DI_t}$ and ε_{GDPG_t} which are essential requirements under causality. Table 4.3 shows the estimated coefficients of the ECM represented by equation 3.4.4 and their significance.

Table 4.3: ECM represented by equation 3.4.4 estimated coefficients and the significance

Null hypothesis: The coefficients are not significantly different from zero	**Coefficient**	**t-value**	**P-value**
$\sigma_1 = 0$	$\sigma_1 = -0.007067$	-0.020990	0.9835
$\psi_{GDPG} = 0$	$\psi_{GDPG} = -0.623427$	-2.249888	0.0365
$\theta_{11} = 0$	$\theta_{11} = 1.597825$	0.802713	0.4321
$\theta_{12} = 0$	$\theta_{12} = 0.196839$	0.102126	0.9197
$\theta_{13} = 0$	$\theta_{13} = 0.129793$	0.067167	0.0954
$\lambda_{11} = 0$	$\lambda_{11} = 0.423061$	1.754604	0.0954
$\lambda_{12} = 0$	$\lambda_{12} = 0.023061$	0.095873	0.9246
$\lambda_{13} = 0$	$\lambda_{13} = 0.220007$	0.652105	0.5221

Foremost the speed of adjustment parameter is negative($\psi_{GDPG} = -0.623427$) and lies between 0 and 1 as expected. More the speed of adjustment parameter is significantly different from zero at 5% significant level (p value, 0.0365 is less than 0.05 and thus the null hypothesis that

$\psi_{GDPG} = 0$ is rejected). A test on the regression residuals (ε_{GDPGI_t}) indicate that they approximate a white noise ($\varepsilon_{GDPGI_t} \sim I_0$). That is β_1 in $\Delta\ \widetilde{\varepsilon_{GDPG_t}} = \beta_1\ \varepsilon_{GDPG_{t-1}} + \mu_t$ is statistically different from zero (i.e β_1=-0.968588 has a P value of 0.0001 which is less than the significant level of 0.05 and thus the null hypothesis that β_1 is not statistically different from zero is rejected). The null hypothesis of a unit root in ε_{GDPGI_t} is thus rejected. The results confirm the co integrating relationship established under the co integration test. A Wald F test on the joint significance of the other coefficients (θ_{11}, $\theta_{12}, \theta_{13}, \lambda_{11}, \lambda_{12}$ and λ_{13}) indicate that they are not statistically different from zero. The Wald F statistic, 0.666677 has a p value of 0.6775 which is greater than the significant level of 0.05 and thus the null hypothesis that they are not jointly statistically different from zero is not rejected. For the ECM represented by equation 3.4.5 the results are shown in table 4.4.

Table 4.4: ECM represented by equation 3.4.5 estimated coefficients and the Significance

Null hypothesis: The coefficients are not significantly different from zero	**Coefficient**	**t-value**	**P-value**
$\sigma_2 = 0$	$\sigma_2 = 0.012764$	0.326310	0.7478
$\psi_{R\&DI} = 0$	$\psi_{R\&DI} = 0.024319$	0.755450	0.4592
$\theta_{21} = 0$	$\theta_{21} = -0.008679$	-0.311291	0.7590
$\theta_{22} = 0$	θ_{22} =-0.035363	-1.265457	0.2210
$\theta_{23} = 0$	$\theta_{23} = -0.034249$	-0.873781	0.3981
$\lambda_{21} = 0$	λ_{21} =-0.135951	-0.587885	0.5635
$\lambda_{22} = 0$	$\lambda_{22} = 0.102183$	0.456336	0.6533
$\lambda_{23} = 0$	$\lambda_{23} = -0.038963$	-0.173553	0.8641

The speed of adjustment parameter ($\psi_{R\&DI} = 0.024319$) is not negative and is not significantly different from zero at 5% significance level (i.e. p value 0.4592 is greater than 0.05 and thus the null hypothesis, $\psi_{R\&DI} = 0$ is not rejected. A test on the regression residuals ($\varepsilon_{R\&DI_t}$) indicate that they approximate a white noise ($\varepsilon_{R\&DI_t} \sim I_0$). That is β_2 in $\Delta\ \widetilde{\varepsilon_{R\&DI_t}} = \beta_2\ \varepsilon_{R\&DI_{t-1}} + \mu_t$ is statistically different from zero(i.e β_2=-1.069044 has a P value of 0.0000 which is less than the significant level of 0.05 and thus the null hypothesis that β_2 is not statistically different from zero is rejected). The null hypothesis of a unit root in $\varepsilon_{R\&DI_t}$ is thus rejected. The joint significance of the other coefficients (θ_{21}, θ_{22}, θ_{23}, λ_{21}, λ_{22} and λ_{23}) is not different from zero. The Wald F statistic, 0.425987 has a p value of 0.85257 which is greater than the significant level of 0.05 and thus null hypothesis that they are not jointly statistically different from zero is not rejected.

4.4.4.1 Stability tests on the ECM models

The stability tests conducted were a Jarque Bera test of residual normality, a Breusch Godfrey LM test of non autocorrelation of residuals and a Breusch Pagan test of homoscedastic errors. The residuals from the ECM represented by equation 3.4.4 (ε_{GDPGI_t}) passed the Jarque Bera normality test. The skewness, -0.830440 is close to zero and the kurtosis, 3.161601 is close to 3 as required. The Jarque Bera statistic, 3.132731 is less than 5.9 as required. The residuals ε_{GDPGI_t} are thus normal. The residual also pass the Breusch Godfrey LM test of serial correlation of errors. The F statistic 0.143840 has a P value of 0.867 which is greater than a significant level of 0.05. The null hypothesis of non autocorrelation is thus not rejected. The residuals ε_{GDPGI_t} are thus not serially correlated. For the Breusch Pagan test of homoscedastic errors the residuals, ε_{GDPGI_t} also pass the test. The F test statistic, 0.569965 has a p value of 0.1712 which is greater than 0.05. The null hypothesis that the residuals are homoscedastic is not rejected. The residuals from the ECM represented by equation 3.4.5($\varepsilon_{R\&DI_t}$), passes the Breusch Godfrey LM test of non autocorrelation ,the Breusch Pagan test of homoscedastic errors and the Jarque Bera test of normality. For the Jarque Bera test the skewness is -0.453634 is close to zero while the kurtosis, 4.8445241 is not very far from to 3. The Jarque Bera statistic, 4.756558 is less than 5.9. The residuals are thus normal. For the Breusch Godfrey LM test the F test statistic 0.936671 has a p value of 0.41125 which is greater than 0.05. The null hypothesis of non autocorrelation is not rejected. For the Breusch Pagan test of homoscedastic errors the F statistic 1.868911 has a p value of 0.13187 which is greater than 0.05. The null hypothesis of homoscedastic errors is not rejected. The ECMs passes the stability tests and thus stable.

4.4.5 Granger Causality Test within an ECM

This test is done under the null hypothesis that the joint significance of the coefficients in the ECM models, 3.4.4 and 3.4.5 are not statistically different from zero $(\text{i.e } \theta_{11} = 0, \ \theta_{12} = 0, \theta_{13} = 0, \lambda_{11} = 0, \lambda_{12} = 0 \text{ and } \lambda_{13} = 0 \text{ and } \theta_{21,} = 0, \ \theta_{22} = 0, \theta_{23} = 0, \lambda_{21,} = 0, \lambda_{22} = 0 \text{ and } \lambda_{23} = 0)$. The advanced Granger Causality within an ECM is done by use of a Wald F test to determine the joint significance of the coefficients. The Wald test results are shown in table 4.5.

Table 4.5: Wald F- test on the joint significance of coefficients (ECM 3.44 & 3.45)

Null hypothesis	F-value	P-value
The Joint significance of the coefficients in ECM 3.4.4 is not different from zero(1.e $\theta_{11} = 0, \theta_{12} = 0, \theta_{13} = 0, \lambda_{11} = 0, \lambda_{12} = 0$ and $\lambda_{13} = 0$	0.666677	0.67757
The Joint significance of the coefficients in ECM 3.4.5 is not different from zero(1.e $\lambda_{13} = 0$ and $\theta_{21,} = 0, \theta_{22} = 0, \theta_{23} = 0, \lambda_{21,} = 0\ \lambda_{22} = 0$ and $\lambda_{23} = 0$)	0.425987	0.85257

The study fails to reject the hypothesis that the joint significance of the coefficients in the ECM represented by equation 3.4.4 are statistically different from zero (i.e $\theta_{11} = 0, \theta_{12} = 0, \theta_{13} = 0, \lambda_{11} = 0, \lambda_{12} = 0$ and $\lambda_{13} = 0$). The Wald F statistic, 0.666677 has a p value 0.67757 which is greater than 0.05. The null hypothesis that the joint significance of the coefficients is not different from zero is not rejected. For the ECM represented by equation 3.45, the study fails to reject the hypothesis that $\lambda_{13} = 0$ and $\theta_{21,} = 0, \theta_{22} = 0, \theta_{23} = 0, \lambda_{21,} = 0, \lambda_{22} = 0$ and $\lambda_{23} = 0$). The Wald F statistic, 0.425987 has a P value, 0.85257 which is greater than 0.05 and thus the null hypothesis that the joint significance of the coefficients is not different from zero is not rejected.

4.5 CONCLUSIONS

The study sought to answer the following questions; first how does public agricultural R&D intensity and GDP growth relate in the long run in Kenya?

Secondly what is the nature of causality between public agricultural R&D intensity and GDP growth? And lastly what policy implications could be drawn from the answers to the above questions? On the first question, the EG-co integration tests showed that the regression residuals ($\Delta\widetilde{\varepsilon_t}$) were stationery in levels (i.e. $\Delta\widetilde{\varepsilon_t} \sim I_0$) indicating that public agricultural R&D intensity and GDP growth have a long run relationship (co integrated). The Johansen-Juselius has also confirmed existence of one co integrating equation. The co integrating model is also stable with stability tests on the co integrating residuals (ε_t) indicating that the residuals are normally distributed, homoscedastic and non-auto correlated at higher lags. The study thus concludes that public agricultural R&D intensity and GDP growth have a long run relationship (co integrated).

For the question on causality, the Wald F test on the joint significance of the coefficients in ECM 3.44 (θ_{11}, θ_{12}, θ_{13}, λ_{11}, λ_{12} and λ_{13}) and 3.4.5(θ_{21}, θ_{22}, θ_{23}, λ_{21}, λ_{22} and λ_{23}) indicate that the joint significance of the coefficients is not statistically different from zero. This effectively rules out short run causality in both ECMs. On long run causality, from the estimated results the adjustment parameter for the ECM represented by equation 3.4.4(ψ_{GDPG}) is negative, lies between 0 and 1 and is significantly different from zero as expected. The regression residuals (ε_{GDPG_t}) also pass all the stability tests. The implication of the results is that public agricultural R&D intensity causes GDP growth in the long run. For the ECM represented by equation 3.4.5 though the regression residuals($\varepsilon_{R\&DI_t}$) are stable the adjustment parameter($\psi_{R\&DI}$) is positive and not statistically different from zero. The implication of the results is that GDP growth does not causes public agricultural R&D intensity in the long run. The study concludes that long run causality between the variables runs from public agricultural R&D intensity to GDP growth and not vice versa (unidirectional causality).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY ECCOMMENDATIONS

5.1 INTRODUCTION

This chapter presents a summary of the study's key findings. The summary touches on diagnostic unit root test results and statistical test results on co integration tests, ECMs estimation and Granger causality test within an ECM. The chapter also presents the study's policy recommendations which are grounded on the study's key findings, experiences and lessons learnt in the course of the study.

5.2 SUMMARY AND CONCLUSIONS

This study examined how public agricultural R&D intensity impact on GDP growth in the long run. The diagnostic unit root tests indicated that public agricultural R&D intensity and GDP growth have a unit root but stationery at first difference. The co integration test results and the ECMs estimation results indicated that public agricultural R&D intensity and GDP growth have a long run relationship. A Wald F test on the ECMs showed lack of short run causal effects between the variables. This was expected as expenditures on R&D cannot impact immediately on GDP growth. The benefits of R&D expenditures are realized over long periods of time mainly because R&D is a dynamic process. The estimated coefficients in both ECMs established a unidirectional causality in that public agricultural R&D intensity causes GDP growth and not vice versa. The non establishment of causality running from GDP growth to public agricultural R&D intensity can be explained by Kenya's budgeting process anchored on the Medium Term Expenditure

Framework (MTEF). In the MTEF process, GDP growth does not guarantee more resources to all sectors of the economy because sectors have to lobby for resources with justification with unjustified priorities losing out of funding. In the MTEF framework, a sector can receive less funding than the previous year's funding even with a higher GDP growth.

5.3 POLICY RECOMMENDATIONS

The study provides empirical evidence that public agricultural R&D intensity impacts positively on GDP growth in Kenya. The study indicates that the amount of resources allocated to support public agricultural R&D activities have a great bearing on GDP growth in Kenya. Owing to this crucial revelation, the study makes the following policy recommendations; first, the government should develop policies aimed at boosting resource allocation to public agricultural R&D. This is informed by the evidence that R&D in public agricultural R&D institutes is a key factor in economic growth in Kenya.

Secondly, to boost public sector R&D, the government should come up with policy measures meant to stimulate public R&D in all the sectors of the economy. The policies should address motivation of researchers and public R&D funding in other sectors. Motivation of researchers can be done by development of a remuneration policy for researchers and full implementation of the intellectual and property right law to protect researcher's new ideas. Kenya's R&D is majorly agricultural with minimal R&D in the industrial and medical sectors. This policy measures would ensure a vibrant R&D sector with various sub sectors contributing to growth of the economy through R&D.

Thirdly, to boost overall R&D funding, the government should develop policies aimed at boosting both public and private sector R&D. The policies should be tailored to encourage private sector and external funding of R&D activities. This can be possible through creation of a national R&D fund were the public sector, the private and donors can contribute to one R&D resource basket. This would mean more funds will be available to support R&D activities. This would in turn help spur economic growth.

To encourage R&D in the private sector so as to complement public R&D, the government should establish policies to have tax cuts and subsidise R&D equipments and materials. This would be a motivation to the private sector who considers R&D as a public good and thus costly to invest in. The costliness of private R&D is based on the fact that knowledge occasioned by R&D is both non excludable and non rival and thus other competitors can thus access it and use it in production. Such measures would boost both public and private R&D and thus raise overall R&D in Kenya. This would contribute to economic growth.

REFERENCES

Aghion, P., & Howitt, P. (1992).A Model of Growth Through Creative Destruction. *Econometrica*, 60(2), 323-351.

Arrow, K. J. (1962). Economic Welfare and the Allocation of Resources to invention. In R.R. Nelson (Ed.), *The Rate and Direction of Economic Activity*. New York: Princeton University Press.

Baumol, W., & Wolff, E. (1983). Feedback from Productivity Growth to R&D. *Scandinavian Journal of Economics*, 85 (2).

Beintama, N. M., F.M. Murithi, and P. Mwangi. 2003. *Kenya ASTI Country Brief* No.8,Washington D.C. and Nairobi, IFPRI and KARI.

Birdsall, N., & Rhee, C. (1993). *Does Research and Development Contribute to Economic Growth in Developing Countries*?(Policy Research Working Paper No. 1221).Washington: The World Bank.

Breusch, T.S. (1979). Testing for Autocorrelation in Dynamic Linear Models. *Australian Economic Papers*, 17, 334–355.

Dickey, D.A., & Fuller W.A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association*, 74, 427–431.

Ekanayake, E.M.(1999). Exports and Economic Growth in Asia Developing Countries: Cointergration and Error Correction Models. *Journal of Economic Development*,24(2),46-56.

Enders, W.(2004). *Applied Econometric Time Series* (2nd ed.). United States: John Wiley & Sons.

Engle, Robert, F., Granger, & Clive, W. J. (1987).Co-integration and error correction: Representation, estimation and testing. *Econometrica*, 55(2), 251-276.

EIRMA. (2005) *Responsible Partnering: A Guide to Better Practices for Collaborative Research and Knowledge Transfer between Science and Industry*, version 1.0, January 2005.

Fargerberg, J.(1994). Technology and international differences in growth rates. *Journal of Economic interaction*, 32, 1147-1175.

Frankel, M. 1962. The production function in allocation and growth: a synthesis. *American Economic Review* 52, 995–1022.

Ghosh, A., Saidi, R., & Johnson, K.H.(1999). Who moves the Asia-Pacific stock markets– US or Japan? empirical evidence based on the theory of cointegration. *The Financial Review*, 34, 159-170.

Godfrey, L.G. (1978). Testing Against General Autoregressive and Moving Average Error Models when the Regressors Include Lagged Dependent Variables. *Econometrica*, 46, 1293–1302.

Goel, R. K., & Ram, R.(1994). R&D Expenditure and Economic Growth: A Cross Country Study. *Economic Development and Cultural Change*, 2,403-411.

Government of Kenya. (1965). *Sessional Paper No. 10 of 1965 on African Socialism and its Application to Planning in Kenya.* Nairobi: Government Printer.

Government of Kenya. (1977). *Science and Technology Act Cap.250 of Laws of Kenya.* Nairobi: Government Printer.

Government of Kenya. (1986). *Sessional Paper No. 1 of 1986 on Economic Management for Renewed Growth.* Nairobi: Government Printer.

Government of Kenya. (2005-2010). *Economic Survey (2005-2010).*Nairobi: Government Printer.

Government of Kenya (2005-2010). *Approved Budget Estimates (2005-2010).*Nairobi: Government Printer.

Government of Kenya. (2007). *Kenya Vision 2030:The Popular Version.* Nairobi: Government Printer.

Government of Kenya. (2008). *Science, Technology and Innovation Policy and Strategy.* Retrieved September 12, 2011 from http://www.ist-arica.org/home/files/Kenya_STI_policy_mar08.pdf

Government of Kenya. (2009). *Statistical Abstract*. Nairobi: Government Printer.

Government of Kenya. (2010). *Medium Term Expenditure Framework Report (2010-2011)*. Nairobi: Government Printer.

Guellec, D., & van Pottelsberghe de la Potterie,B.(2001). *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*(STI Working Paper No. 2001/3).Geneva: OECD.

Granger, C.W. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica*, 37 (3), 424–438.

Gruber, W., Mehta, D., & Vernon, R. (1967). The R&D Factor in International Trade and International Investment of United States Industries. *Journal of Political Economy,* 75, 20-37.

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

Hassan, T., & Cumhur, C. (2007). Innovation: Is the Engine for the Economic Growth? Retrieved January 16, 2012, from www.tcmb.gov.tr/yeni/iletisimgm/Innovation.pdf

Islam, A.M., & Ahmed, S. M. (1999). The Purchasing Power Parity Relationship: Causality and Co integrations Tests Using Korea-U.S. Exchange Rate and Prices. *Journal of Economic Development*, 24(2),95-111.

Johansen, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, 12, 231-254.

Johansen, S., & Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration with Application to the Demand for Money. *Oxford Bulletin of Economic and Statistics*, 52, 169-210.

Kenya Agricultural Research Institute (KARI) .2009.*Strategic plan*: 2009-2014. KARI.

Keel, L., & Boef, S. (2004). *Not Just for Co integration: Error Correction Models with Stationery Data*. Retrieved September 13, 2011, from http://www.nuff.ox.ac.uk/politics/papers/2005/ Keele%20DeBoef%20ECM%20041213.
pdf

Lichtenberg, F. R.(1992). *R&D Investment and International Productivity Differences* (NBER Working Paper No. 4161).National Bureau of Economic Research.

Li Peng. (2007). Study on the relationship between R&D expenditure and economic growth of China. *Proceedings of the 7th international Conference on Innovation and Management*, 1725,1-4.

Lucas, R. E. (1988). On the Mechanics of Economic Development. *Journal of Mon-etary Economics*, 22, 3-42.

Malthus,T.(1820). *Principles of Political Economy.* MGraw-Hill Kagakusha.

McKelvey, B. (2001). Energizing Order-Creating Networks of Distributed Intelligence. *International Journal of Innovation Management*, 5, 181–212.

OECD. (2006). OECD *in Figures* (2006-2007 Ed.). Paris: Author.

OECD. (2010). *Economics: Innovation Central to Boosting Growth and Jobs.* Retrieved January 3, 2011, from http://www.oecd.org/document/36/0,3746,en_2649_34273_ 45324068 1_1_1_1,00. html

Ricardo, D. (1817). *The Principles of Political Economy and Taxation.* Macmillan, London

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

Smith, A. (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations*. Edwin Canan, The Modern Library, Random House, New York.

Solow, R.(1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, 34, 312-320.

Solow, R.M. 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70, 65–94.

Swan, T.W. 1956. Economic growth and capital accumulation. *Economic Record* 32,334–61.

Ikiara, G.K. (1988). Towards technology models for MSEs in Kenya: Common Principles & Best Practices

Uzawa, H. 1965. Optimal technical change in an aggregative model of economic growth. *International Economic Review* 6, 18–31.

Pessoa, A. (2005). "Ideas" Driven Growth: The OECD Evidence. *Portuguese Economic Journal* ,4, 46-67.

Phillips, P.C.B., & Perron,P. (1988).Testing for a Unit Root in Time Series Regression. *Biometrika*, 75, 335–346.

Ping, Y.O. (2003). *The impact of R&D on the Singapore Economy: An Empirical Investigation.* Retrieved March 31, 2011, from http://www.nus.edu.sg/nec/publications/papers/WP 2003-10.pdf

World Economic Forum. (2004). *The Global Competitiveness Report 2004-2005.* Geneva: Author.

Yoo, S.H. (2004). Public R&D Expenditure and Private R&D Expenditure: A Causality Analysis. *Applied Economics Letters,* 11, 711–714.

Zegveld,W. (2000). Innovation in the Next Decade: The Need for Integrated Policies. In G. Sweeney (Ed.), *Innovation, Economic Progress and the Quality of Life*. Edward Elgar.

APPENDICES

APPENDIX I: DATA

Table A.1: Public agricultural R&D intensity and GDP growth rates

Year	Public agricultural R&D intensity	GDP growth rates
1980	1.42	5.3
1981	1.38	3.8
1982	1.37	4.2
1983	1.35	2.9
1984	1.32	3.4
1985	1.28	4.8
1986	1.23	5.6
1987	1.30	4.9
1988	1.48	5.1
1989	1.50	5.0
1990	1.49	4.3
1991	1.50	2.1
1992	1.70	0.5
1993	1.67	0.2
1994	1.85	3.0
1995	2.25	4.8
1996	1.65	4.6
1997	1.60	2.4
1998	1.20	1.8
1999	1.18	1.4
2000	1.25	0.2
2001	1.30	1.2
2002	1.31	0.5
2003	1.25	2.9
2004	1.15	5.1
2005	1.20	5.9
2006	1.35	6.3
2007	1.45	7.0
2008	1.43	1.5
2009	1.50	2.6
2010	1.60	5.6

Source: ASTI-KARI, 2009 and Beintama, Murithi and Mwangi, 2003 and GOK, 2010

APPENDIX II: DIAGNOSTIC UNIT ROOT TESTS

Table A.2: ADF and PP unit root test results for public agricultural R&D intensity and GDP growth rates

Variable	Specification	Lag	ADF critical values (5%)	ADF value	PP critical values (5%)	PP value
Public agricultural R&D intensity	With trend and intercept	1	3.574244	1.929011	3.568379	2.062176
		2	3.580623	2.257372		2.165490
		3	3.587527	2.207488		2.192330
		4	3.595026	1.768561		2.140891
		5	3.603202	1.923339		2.100865
GDP growth rates	With trend and intercept	1	3.574244	2.973632	3.568379	2.656674
		2	3.580623	2.589183		2.631269
		3	3.587527	2.138268		2.560241
		4	3.595026	1.471118		2.431478
		5	3.603202	0.748688		2.279196

Figure A.1: Plot of public agricultural R&D intensity

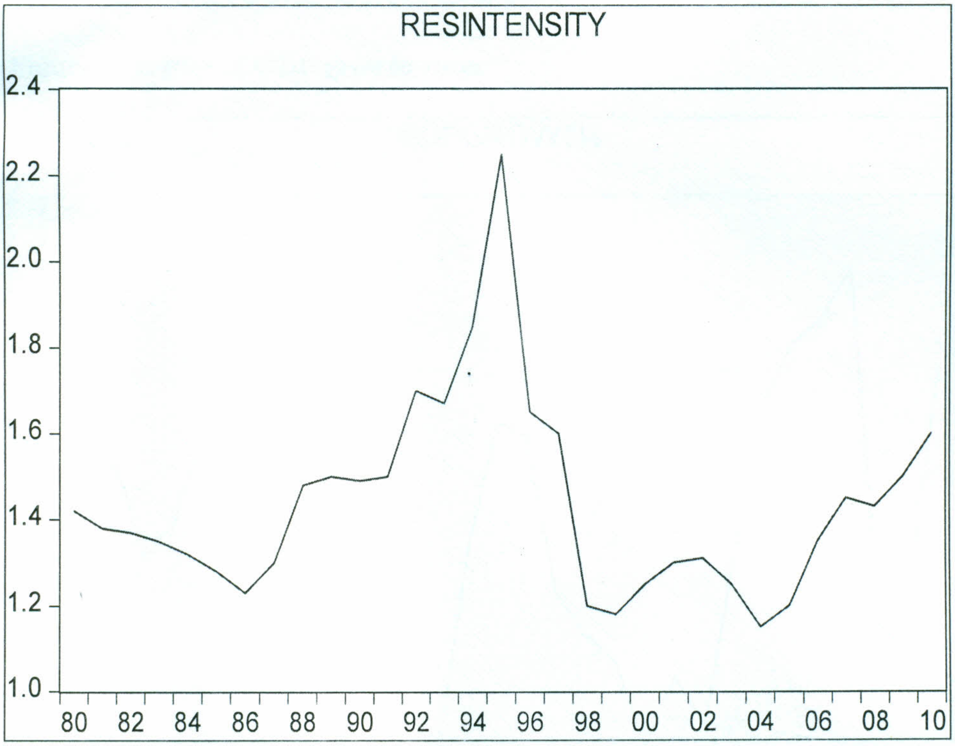


Figure A.2: Plot of differenced public agricultural R&D intensity

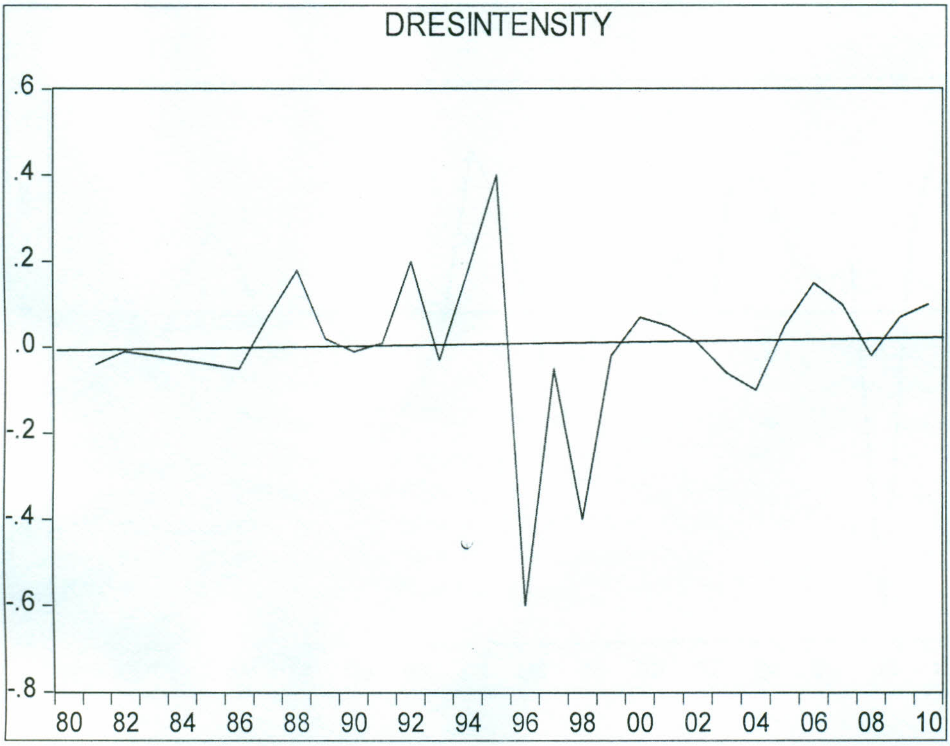


Figure A.3: Plot of GDP growth rates

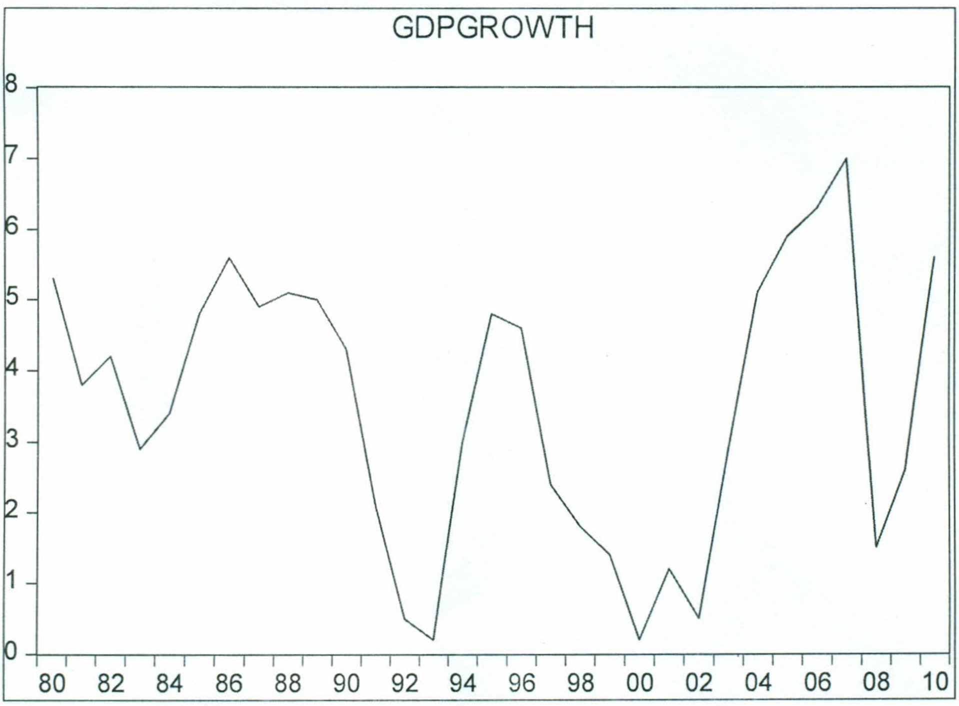


Figure A.4: Plot of differenced GDP growth rates