AN EVALUATION OF THE SCIENCE SYSTEM IN KENYA

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Declaration

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Abstract

Evaluation of science systems has been on the increase in the recent past following government calls for accountability of the public investment in research development. The government and other funders also call for the evaluation of science for decision making on the amounts to invest in research development. This study set out to conduct an evaluation of the Kenyan science system. Using a case study research design, the study combined standard research and development indicators, bibliometric data, survey data and interview data to evaluate Kenya's research investment, research capacity and research performance – research output, research collaboration, and citation impact. The standard research and development indicators revealed minimal investment in research development in Kenya, an investment that is still below the government's target of investing about 1-2% of GDP to research and development. The R&D indicators also show that the human resources available for research are low in relation to the government's target and a comparison of other selected sub-Saharan countries. The government intends to increase the number of researchers by training more PhD students.

It was also the objective of this study to assess and describe the trends in Kenya's research performance. Bibliometric data on publications revealed a steady increase in scientific output over the past decade across all scientific fields. The study also found high scientific output in the agricultural and health sciences. Analyzing the co-authorship data revealed an increase in international collaboration with minimal inter-continental and national collaboration. Minimal national collaboration might imply a weak national science. The study also found that Kenya specializes in agricultural and the health sciences which is important for Kenya's overall scientific output. Citation analysis showed that the citation impact of Kenya's scientific output had increased steadily for the past two decades, registering a citation impact that is above the world average (i.e. above 1), which implies that it generates at least similar citation rates than other countries.

Examining the factors that enable or constraint research performance, the study found no huge age differences that emerge in relation to respondent's collaboration with different researchers. On the other end, male scientists were more likely to collaborate internationally as compared to female researchers. In relation to research output, in general, my findings show age, gender and scientific field are key predictors of reported scientific output. Statistically significant differences between age categories, although small, and research production were found as older scientists reported higher publication output in some fields and publication forms as compared to the younger scientists. Several scientific career challenges

were identified in this study, which includes minimal funding support, lack of research networks, lack of mentoring, training and support in career decision and fundraising.

The contribution of this study was both empirical and methodological. Using the research performance evaluation framework, this study provides a comprehensive evaluation of Kenya’s science system on the following aspects: research investment, research capacity and research performance (research output, research collaboration and citation impact). Apart from the evaluation, the study also provides information on the perceptions of scientists on research funding, research collaboration and career challenges. Methodologically, the study uses a case study research design, which allows triangulation of the standard R&D data, bibliometric data, survey data and interview data, to provide an in-depth understanding and evaluation of Kenya’s science system. Given that different methods have different limitations, the different data sources supplement each other.

Opsomming

Regerings dring toenemend aan op die toerekeningsvatbaarheid van openbare besteding in navorsingsontwikkeling en dit het gelei tot ‘n opwaartse groei in die evaluering van wetenskapsisteme. Regerings en ander befondsers doen ook ‘n beroep op wetenskapsevaluasie vir insae tot besluitneming vir finansiële beleggings in navorsingsontwikkeling. Die studie onderneem om ‘n evaluasie uit te voer van die Keniaanse wetenskapsisteem. Na aanleiding van ‘n gevallestudie navorsingsontwerp kombineer die studie standard navorsings- en ontwikkelingsindikatore, bibliometriese data, opname- en onderhoud-data om Kenia se investering, kapasiteit en prestasie in navorsing (navorsingsuitsette, navorsingsamewerking en sitasie-impak) te evalueer. Die standard navorsings- en ontwikkelingsindikatore dui op ‘n minimale investering in navorsingsontwikkeling in Kenia. Die huidige investering in navorsingsontwikkeling is steeds minder as die regering se teiken van 1-2% van die BBP. Die N&O indikatore dui ook op lae beskikbare menslike hulpbronne kapasiteit vir navorsing in verhouding tot die regering se teiken en in vergeleke met ander geselekteerde lande in sub-Sahara. Die regering beplan om die getal navorsers te bevorder deur meer doktorale studente op te lei.

Dit is ook die doelwit van die studie om tendense in Kenia se navorsingsprestasie te evalueer en beskryf. Bibliometriese publikasie data toon die afgelope dekade ŉ bestendige toename in navorsingsuitsette in alle wetenskaplike dissiplines. Die studie het ook hoë navorsingsuitsette in landbou- en gesondheidswetenskappe gevind. Analises van die mede-outeurskap data het ŉ toename getoon in buitelandse samewerking met min inter-kontinentale en nasionale samewerking. Die minimale nasionale samewerking kan dui op ŉ swak wetenskapsisteem. Die studie het gevind dat Kenia spesialiseer in landbou- en gesondheidswetenskappe wat geblangrik is vir die totale navorsingsuitsette van Kenia. Sitasie-analise toon dat die sitasie-impak van Kenia se navorsingsuitsette bestendig toegeneem het die afgelope twee dekades. Die sitasie-impak is hoër as die wêreld-gemiddeld (m.a.w. meer as 1) wat impliseer dat Kenia ten minste soortgelyke sitasie-impak as ander lande genereer.

Die studie ondersoek faktore wat navorsingsprestasie bevorder of belemmer en het geen groot ouderdomsverskille gevind in respondente se samewerking met ander navorsers nie. Daar is gevind dat meer manlike navorsers internasionaal saamwerk met ander navorsers in vergeleke met vroulike navorsers. Wat die navorsingsuitsette betref, wys die bevindinge van die studie dat ouderdom, geslag en wetenskaplike dissipline die belangrikste aanduiding gee van navorsingsuitsette. Alhoewel daar klein statisties beduidende verskille is tussen die verskillende ouderdomskategorieë, toon die bevindinge wel dat ouer navorsers hoër navorsingsuitsette het in sekere wetenskaplike dissiplines in vergeleke met jonger navorsers. Die studie het verskeie wetenskaplike beroepsuitdagings gevind wat minimale befondsingsondersteuning, ŉ gebrek aan navorsingsnetwerke, ŉ gebrek aan mentorskappe en opleiding asook ŉ gebrek aan ondersteuning in die beroepskeuses en fondswerwing insluit. Die bydrae van die studie is beide empiries en metodologies. Die studie bied ŉ omvattende evaluering van die Keniaanse wetenskapsisteem op die investering, kapasiteit en prestasie in navorsing (navorsingsuitsette, navorsingsamewerking en sitasie-impak) deur gebruik te maak van ŉ navorsingsprestasie-evaluasie raamwerk. Buiten die evaluasie, voorsien die studie inligting oor die persepsies van navorsers oor die befondsing van navorsing, samewerking met ander navorsers en beroepsuitdagings. In terme van metodologie word ŉ gevallestudie navorsingsontwerp implementeer wat voorsiening maak vir die validering van standaard N&O, bibliometriese, opname- en onderhoudsdata. Gegee dat die verskillende tegnieke verskillende beperkinge het vul die verskillende databronne mekaar aan om ŉ in-diepte begrip en evaluering van die Keniaanse wetenskapstelsel te verskaf.

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List of Abbreviations

ACEG - African Centre for Economic Growth

AERC - African Economic Research Consortium

AU-African Union

NEPAD – African Union New Partnership for Africa's Development

AIDS – Acquired Immunodeficiency Syndrome

ARC - Agricultural Research Council

ARAC - Agricultural Research Advisory Council

ACEG - African Centre for Economic Growth

AERC - African Economic Research Consortium

AESA - Accelerating Excellence in Science in Africa

APHRC - The African Population and Health Research Centre

ASEAN – Association of South East Asian Nations

ASRC - Agricultural Sciences Research Committee

ASTI – Agricultural Science and Technology Indicators

ASTII – African Science Technology and Innovation Indicators

BMZ - The Federal Ministry of Economic Cooperation and Development

BRS - Beef Research Station

ACE - African Centers of Excellence

ACE– PTRE - African Centers of Excellence - Centre of Excellence in Phytochemical, Textile & Renewable Energy

CCAAHFR - Committee for Colonial Agricultural, Animal Health and Forestry Research

CDC – Centre of Disease Control

CEO – Chief Executive Officer

CEBIB - Centre for Biotechnology and Bioinformatics

CERM-ESA - Centre of Excellence for Educational Research Methodologies and Management

CESAAM - Centre of Excellence in Sustainable Agriculture and Agribusiness Management

CIMMYT - International Maize, and Wheat Improvement Centre

CGIAR - Consultative Group for International Agricultural Research

CHIVRI - Centre for HIV Prevention and Research

CREST - Centre For Research on Science and Technology

CUE -Commisison of University Education

CHIVRI - Centre for HIV Prevention and Research T

DELTAS - The Developing Excellence in Leadership, Training and Science Africa

DOA - Department of Agriculture

DSIR - Department of Scientific and Industrial Research

DST - The Department of Science and Technology

EAA - East African Academy

EAC - East African Community

EAAFRO - East African Agriculture and Forestry Research Organization

EAAPP – East Africa Agricultural Productivity Project

EACMR - East African Council for Medical Research

EACSO - East African Common Services Organization

EAVRO - East African Veterinary Research Organization

EAMFRO - East African Marine Fisheries Research Organisation

EAIRO – East African Industrial Research Organization

EANHS - East African Natural History Society

EANRRC – East Africa Natural Resources Research Council

EAMRC – East Africa Medical Research Council

ERC – Energy Regulation Council

GTI - Government Training Institute

GDP – Gross Domestic Product

GERD - Gross Expenditure on Research and Development

GoK – Government of Kenya

GLoSYS – The Global State of Young Scientists

HEI- Higher education

HIV – Human Immunodeficiency Virus

IARC - International Agricultural Centres

IBR - Institute for Biotechnology Research (

ICRAF - International Council for Research in Agro-Forestry

ICIPE - International Centre for Insect Physiology and Ecology

ICRISAT - International Potato Centre, the International Crops Research Institute for Semi-Arid Tropics

IDRC - International Development and Research Centre

INITID - Institute of Tropical and Infectious Diseases

ILRI - International Livestock Research Institute

IPR - Institute of Primate Research

JKUAT - Jomo Kenyatta University of Agriculture and Technology

JKAT - Jomo Kenyatta College of Agriculture and Technology

JICA - The Japanese International Co-operation Agency

KALRO – Kenya Agricultural Livestock Research Organization

KAPAP – Kenya Agricultural Productivity Project

KARI – Kenya Agricultural Research Institute

KEFRI - Kenya Forestry Research Institute

KENIA – Kenya National Innovation Agency

KEMFRI - Kenya Marine and Freshwater Fisheries Institute

KEMRI - The Kenya Medical Research Institute

KESREF - Kenya Sugar Research Foundation

KMFRI – Kenya Maritime and Fisheries Research Institute

KETRI - Kenya Trypanosomiasis Research Institute

KIPPRI – Kenya Institute for Public Policy Research and Analysis

KIPI - Kenya Industrial Property Institute

KIRDI - Kenya Industrial Development Research Institute

KNH – Kenya National Hospital

KWS – Kenya Wildlife Services

MCRS - Mwea Cotton Research Station

MNCS – Field Normalized Citation Score

MOEST - Ministry of Education, Science and Technology

MMUST - Masinde Muliro University of Science and Technology

MTRH – Moi Teaching Referral Hospital

MRC - Medical Research Council

NACOSTI - National Council of Science and Technology

NCST - National Council for Science and Technology

NAL -National Agricultural Laboratories

NESC - National Economic and Social Council

NEMA – National Environment Management Authority

NIS - National Innovation System

NMK - The National Museums of Kenya

NMKSP - National Museums of Kenya Support Programme

NMKEF - The National Museums of Kenya Endowment Fund

NRM - Natural Resource Management

NARL - National Agricultural Research Laboratories

NCRC - National Crime Research Centre

NSRS - National Sugar Research station

NSRS - National Sugar Research station

NSQRC - National Seed Inspection Services

NRF – National Research Fund

NPM – New Public Management

OECD – Organization for Economic Development and Development

OSSREA - Organization for Social Science Research in Eastern and Southern Africa
PAST - The paleontological Scientific Trust
PBRF - Performance-Based Research Funding
RSTI - Research, Science, Technology and Innovation
SAGA - semi-autonomous Government Agency
SAL - Scott Agricultural Laboratories
SDGs – Social Development Goals
SIDA - The Swedish International Development Cooperation Agency
STI – Science, Technology and Innovation
SMEs - Small and Medium Enterprises
TRF - Tea Research Foundation
TVET – Technical Vocational Education and Training
UK – United Kingdom
UNDP – United Nations Development Program
UNEP – United Nations Environment Program
UNESCO – United Nations Education, Science and Cultural Organization
UPHD - Urbanization, Poverty, and Health Dynamics
UON - University of Nairobi
USA – United States of America
USAID - United States Agency for International Development
VSNU - Association of the Netherlands Universities
WECO - Western College of Arts and Applied Sciences
WHO - World Health Organization
WRA – Water Resource Authority
WUCST - Western University College of Science and Technology
WARREC - Water Research and Resource Centre

Chapter 1 Introduction

1.1 Global trends

Globally, interest in the evaluation of science systems has been on the increase (Butler, 2010; Butler & Mcallister, 2009; Geuna & Martin, 2003; Hicks, 2012) because of two main reasons. First, the increased demand by governments for the evaluation of the outcomes of public investments, including research and development (Organization for Economic Co-operation and Development [OECD], 2010: n.p.). Governments want to know how much, where to invest, and how these investments benefit the public or society. Second, governments have increased or intend to increase public investments in research and development, despite several constraints. Governments' financial support of the performance of research and development in the different sectors – higher education, business and government – has resulted in the increased demand for evaluation of the performance of these sectors or the system. Over the past three decades, there has been an increased call for the evaluation of national science systems and institutions (Butler & Mcallister, 2009; Geuna & Martin, 2003:277). This increasing interest is happening against the background of the increase in "global demands for greater accountability"[1] (Geuna & Martin, 2003:277) as well as the consequences of declined funding of science in many countries. The advent of "accounting practices" has also arisen following the "emergence of an audit society" (Power, 1994). The emergence of the audit society refers to "the spread of a distinct mentality of administrative control in which there is increasing demand for accountability and transparency and […] models of quality assurance" (Power, 1994:3). The expansion of the audit society into different contexts – including higher education and research institutions – is not only "a technical response to problems of governance and accountability" (Power, 1994:5)… but also entails articulation, rationalization and reinforcement of public images of control. Therefore, given the tenets of the audit society, research can be characterised by a period of accountability (Elzinga, 2012), often driven by the norms of efficiency and accountability.

The increased emphasis on accountability – also in the sphere of science, technology, and innovation – is another manifestation of the emergence of the "New public management (NPM)" paradigm (Arnold, 2004; Elzinga 2012; Hicks, 2012; Meek & Davies, 2009:43; Pollitt, 2007). The NPM paradigm has been described as a move towards a governance approach that emphasises accountability, transparency, efficiency and performance in the management

[1] Accountability here refers to the [current] pressures from the government and other funding agencies to the public sector to demonstrate that the money allocated for research is well spent. It raises the question of "efficiency and effectiveness"(Fatemi and Behmanesh, 2012:48), which is, how economically or cheaply and how well (goal achievement) can research be produced?

of public entities (including universities and research institutions), public sector employees and managers (Elzinga, 2012; Geuna & Martin, 2003). As a result of these developments, the interest in the value, impact and efficiency of research arose from the need "to get the best out of the research system at the least cost" (Hardeman *et al.*, 2013:15). Increasingly, there are calls for austerity, where there are demands for researchers to produce more with less. The increase of accountability measures in public entities from the 1980s onwards resulted in the upsurge of performance measurement in academic contexts (Elzinga, 2012; Wilsdon, Allen, Belfiore, Campbell, Curry, Hill, Jones, Kain, Kerridge, Thelwall, Tinkler, Tiney, Wouters, Hill, 2015). Performance measurement (also in the sphere of science) is associated with targets, the increased use of indicators and especially research performance metrics (Elzinga, 2010; Fatemi & Behmanesh, 2012). These would include performance metrics for measuring research production, research collaboration, research impact and quality and funding. Although the use of metrics to assess performance has been on the rise, Wilsdon *et al.* (2015:vi) note that metrics or "indicators are positioned as tools that drive competition, instrumentality and privatisation strategies" and steer research institutions and researchers to be more like "market-oriented actors". Indicator use may thus result in "strategic behaviour and goal displacement" (Wilsdon *et al.*, 2015:iv) where a higher score on a given performance measure has become a goal in itself, instead of a means of assessing the attainment of a given performance level. Second, it may also result in task reduction where a certain task is 'abandoned' with more focus given to publication in international, peer-reviewed journals. Lastly, the use of performance indicators may "influence the conditions under which research agendas are developed" (Wilsdon *et al.,* 2015:iv). The United Kingdom's Research Assessment Exercise, which began in 1986 (Butler & McAllister, 2010) (see Author, date), is a typical example of a research performance assessment at a country level. Other exercises followed in 1989, 1992, 1996, 2001 and 2006 (Butler, 2010; Butler & McAllister, 2009; Hicks, 2012). Since the launch of the UK's Research Assessment Exercises, other countries introduced similar research assessments (Hicks, 2012:251), namely –

- The Research Assessment Exercise (Slovak Republic, Hong Kong, China and Australia), *SEXENIO (*Spain);
- Parametric evaluation (Poland);
- Performance-based research funding (PBRF) (New Zealand, Research Unit Evaluation (Portugal);
- *Valutazione Triennale della Ricerca* (Italy);
- the Norwegian model for result-based university research funding (Norway);
- New model for allocation of resources (Sweden);
- Funding formula for allocation of university resources (Finland); and

- the 'Quality Assessment of Research' of the Association of The Netherlands Universities (VSNU) (Geuna & Martin, 2003; Hicks, 2012:252).

The United Kingdom, Finland, Australia and New Zealand use research performance evaluations to allocate funding. There is an assumption that the allocation of funds based on performance yields greater returns on the money invested. Countries like the Netherlands use research evaluations for developing research strategies (Geuna & Martin, 2003; Hicks, 2012:252).

1.2 Research evaluation in Africa

A preliminary review of the literature reveals that relatively few country-level research evaluation and assessment studies have been conducted on the African continent. The study by Gaillard, Khrishna and Waast (1997),[2] analysing "the status of science in Africa" (Gaillard *et al*., 1997:146) was one of the first comprehensive studies of this kind. According to Gaillard *et al.* (1997), most African countries almost lack a science and technology base. This is attributed to the financial crises that most African countries face, as they receive limited funding from the government, with supplements from international funding. Furthermore, Gaillard *et al.* (1997) examined "the problem of the emergence of scientific communities" (Gaillard *et al*., 1997:146) in Africa and made efforts to summarise historical trends, analyse the crises of science as a social institution, and explore the main features of science and society. Other studies analysing the scientific publication output of African countries showed a steady decline of Africa's contribution to world science as measured by the scientific papers published in ISI journals. In particular, another study showed that in a period of five years (1991-1996), Africa lost 20-25% of its relative capacity to contribute to world science, when compared to Europe or with the rest of the world (Gaillard, Hassan, Waast & Schaffer, 2005).

Tijssen (2007) conducted a comprehensive bibliometric analysis of the "characteristics of African science" (Tijssen, 2007: 303), further capturing the trend on the decline of Africa's share in world science. In his analysis, Tijssen showed how "Sub-Sahara Africa has fallen behind in its share of world science quite dramatically from 1% in 1987 to 0.7% in 1996 with no sign of recovery" (Tijssen, 2007:303). Tijssen attributed this decline to inadequate resources, poor investment in research and minimal coverage of the 'African science' in the international databases. However, Tijssen (2007:314) stated that these diminishing shares of

[2] In the present context of globalisation, only those countries are able to absorb the shocks of economic globalisation and derive benefits from the international flows of knowledge that have so far established national scientific communities and educational structures (Gaillard *et al*., 1997).

African science overall do not reflect a decrease in an absolute sense, but rather an increase in publication output less than the worldwide growth rate. Furthermore, the analysis of the research specialisation in the study shows that some fields like the medical sciences are internationally oriented and tend to attract international funds, partnerships, and opportunities to publish in the scientific literature. Given this finding, Kenya was the only country, among the "highly developed African countries with a strong concentration of international research within medical and life sciences" (Tijssen, 2007:314). This could be indicated by high international collaboration in the medical and life sciences, as well as, the influence of international organisations such as Wellcome Trust.

Another study undertook a "mapping of the science systems of the 14 SADC countries" (Mouton, 2008:6) and made several observations and findings on various indicators. First, the study observed huge variances in science and technology capacity comprising of robust and well-articulated systems (i.e. South Africa), systems with minimal but sufficient capacity (i.e. Tanzania and Malawi), systems making efforts to strengthen their capacity (i.e. Mozambique and Botswana) while some systems had minimal capacity concentrated in one or two public research institutions (Mouton, 2008). Second, in relation to knowledge production and scientific output, the study showed South Africa's dominance in the scientific output of the SADC region for the period analysed (2000-2007) as it produced at least 80% of the output. Importantly, the study showed most of other SADC countries had increased their output in the past three years (2005-2007).

Pouris and Pouris (2009) undertook a scientometric assessment of the state of science and technology in Africa (2000-2004). Their disciplinary analysis shows that few African countries have the minimum capacity of researchers needed for the proper "functioning of a scientific discipline" (Pouris & Pouris, 2009:297). Citing an example of the field of ecology, only four countries (South Africa, Egypt, Nigeria and Kenya) produce 300 or more publications between 2000-2004 (Pouris & Pouris, 2009). Another study (Adams, King, & Hook, 2010) supports the findings of Pouris and Pouris, as the African countries have minimum research capacity needed for the functioning of the research system. In addition, Uthman and Uthman (2007) noted that research production in African countries including Kenya is highly skewed across the nation and disciplinary fields.

Adams, King and Hook, (2010) conducted a bibliometric analysis of African research between 1999 and 2008, using the Web of Science databases. The analysis reveals that Kenya, the "leading research economy in the east of the continent" (Adams *et al*., 2010:5) produced just over 6 500 papers, compared to other dominating research producers: South Africa (47, 000), Egypt (30, 000) and Nigeria (10,000). More recent studies, however, have shown that publications authored by African scientists and collaborations were slightly on the increase (New Partnership for Africa's Development [NEPAD] Planning and Coordinating Agency [NPCA], 2010; 2014; Mouton & Boshoff, 2010). In the most recent study, the authors showed that "African science had turned the tide in recent years", indicated by: increase in research publications, increase in research collaborations with the rest of the world and a steady increase in the citation impact of Africa's scientific publication (Mouton & Blanckenberg, 2018:25). The studies discussed in this section have mainly focused on African science at large. There are a few studies that have focused on the Kenya's science system. I discuss these studies below.

1.3 Kenya

Bibliometric studies in Kenya have shown that the level of scientific output in terms of scientific publications have been on the increase in the past few years (Adams, 2010; Adams, King & Hook, 2014; Confraria and Godinho, 2014; Garfield, 1983; Narváez-Berthelemot, Russell, Arvantis, Waast & Gaillard, 2002; Shrum, 1997; Tijssen, 2007). Several other studies have assessed research output for various parts of; Africa including Kenya, with a focus on a scientific field (Onyancha & Ocholla, 2004; 2007). Onyancha and Ocholla (2004) using bibliometrics conducted a comparative study of the literature on HIV/AIDS in Kenya and Uganda. The study shows that "research funding plays a major role in the creation of relevant research centres in these countries and research affiliates" (Onyancha & Ocholla, 2004:434). In addition, most publications were co-authored with the majority focusing on women; and much of the publications on HIV/AIDS were produced out of Africa. A gap in this study was its inability to establish "the extent of foreign collaboration by institution or country" (Onyancha & Ocholla, 2004:434), following limited data. The use of the web of science database used in this current study will allow filling this gap since the databases provide data on co-authorship.

Another study conducted a citation analysis of the library and information science literature between the periods of 1986 and 2006 using data from the web of science (Onyancha and Ocholla, 2007). The study showed that Kenya came fifth in publication output with 37 papers after South Africa, Nigeria, Ghana and Botswana. Looking at the citation counts, South Africa had the highest citations, With Nigeria coming second, followed by Egypt (92), Botswana (48), Kenya (45), Ghana (38) and Ethiopia (38). With the 34 highly cited records South Africa produced 23 (67.6%), while Kenya and Egypt produced two (5.9%) each.

Another study focused on an institution, that is, Moi University (Rotich & Onyancha, 2017), to test Lotka's law, and found that most of the scientific output is produced by few researchers, while the majority of researchers produced one paper during the analysed period.

Another set of studies assessed research collaboration (Adams *et al.,* 2014; Boshoff, 2010; Onyancha & Maluleka, 2011). Boshoff (2010) found stronger links between Kenya and South Africa as well as Nigeria. The study by Adams *et al.* (2014) shows that Kenya has strong links with the countries in the East African region. Onyancha and Maluleka found minimal inter-continental collaboration between African countries and more collaboration with countries outside Africa. These collaborative ties are attributed to factors such as language, historical ties and geographical location (Adams *et al.*, 2014; Toivanen & Ponomariov, 2011).

Another study by CREST analysing the collaboration between South Africa and Kenya for the period of 1990-2007 observed that "there was a visible increase (with fluctuations) in the number of publications between South Africa and Kenya" for the period between 1997 and 2007 (Imbayarwo, 2008:9). In general, the study showed that the collaboration output between the two countries was low. The slight increase in collaboration was attributed to the "opening up of South African Science and the signing of a formal agreement on cooperation in Science and Technology between the two countries signed in 2004" (Imbayarwo, 2008:1–3). Some of the scientific areas agreed on for collaboration between the countries included Square Kilometre Array, Nuclear energy, technology for competitiveness, Satellite technology, Human Health Research-HIV-Aids, cancer research and Agricultural research, among others (Centre For Research on Science and Technology [CREST], n.d.). Mouton and Waast (2005) conducted one of the most comprehensive and in-depth studies on national research systems in Africa and made the following observations about Kenya's research system. First, the dominance of higher education in the production of scientific output compared to public research institutes. Second, the dominance of the University of Nairobi in the number of scientific articles produced amongst the universities, followed by small contributions from Moi University and Egerton University. There was the contribution of one private university – Daystar University - to the scientific output. Third, the study found no evidence that universities collaborate with research institutes. Fourth, Moi University was the only university found to be collaborating internationally. Lastly, the analysis showed minimal collaboration between research institutes and international institutions, both outside Africa and in Africa (Mouton & Waast, 2005:199). Inasmuch as this study looked at various indicators, it did not analyse in detail the research capacity and research investment of Kenya, a gap which the current study addresses.

Another group of studies analysed the citation impact of science. Shrum (1997) analysed the visibility of the research by scientists in Kenya, Ghana and Kerala. The results of the study showed that the characteristics of the scientists whose work appeared in the international databases, that is, the "internationally visible" are generally unrepresentative of the scientists in the developing world (Shrum, 1997:1). Further, Shrum argued that international citation databases do not capture the characteristics of scientists, thus affecting the visibility of science in these countries.

Most of the evaluation studies discussed above used bibliometric methods to assess Africa's or Kenya's science systems. However, bibliometric studies only provide a partial picture of the different dimensions (research investment, research capacity and research performance) of the science system. The current study addresses this issue by combining bibliometric analyses with scientometric methods, survey data as well as interview data to assess the state of Kenya's science system.

2 Aims of the study

This study seeks to understand the state of science in Kenya through a systematic evaluation of its research capacity, research investment and research performance.

This analysis starts with a historical account that reconstructs the development of scientific research in Kenya: the early history of agricultural research, medical research, universities, museum and international research organisations. Secondly, using scientometric data, bibliometric data, survey data and interview data, the study subsequently assesses the research investment, research capacity and the research performance of Kenya's science system.

The specific objectives of the study were:

1. To reconstruct the history of the development of scientific research in Kenya: especially in agricultural and medical research
2. To analyse trends in research and innovation investment in Kenya
3. To analyse and assess the research capacity for science and technology in Kenya
4. To describe and assess the research performance of the Kenya's science system
    - i. To assess trends in publication output
    - ii. To assess trends and patterns in the research collaboration of Kenyan authors
    - iii. To assess the citation impact of Kenya's scientific output
5. To identify the reported factors that enable or constrain the research performance of young scientists in Kenya

3 Chapter Outline

Chapter 2: Science in Kenya: A Historical Analysis

The thesis commences with a historical analysis of Kenya's research system. This chapter outlines the establishment and key developments in research and research institutions in Kenya. The chapter focuses on the early history of agricultural research, medical research, universities and the museum and the international research organisations.

Chapter 3: Conceptual Framework, Research Design and Methodology

In the first section of the chapter, I discuss the National Innovation System Framework adopted for the study. In this section, I discuss the different dimensions and elements of the National Innovation System. I subsequently outline the dimensions and elements of Kenya's National Innovation System: research and innovation capacity, research and innovation investment, and research performance.

In the second section of the chapter, I discuss the research design and methodology of this study including the rationale of the triangulation of the different methods used: the historical review, secondary survey data analysis, scientometric methodologies, bibliometric methodologies and in-depth interviews (re-analysed). I discuss the advantages, disadvantages and limitations of the different research methods. I also provide information on how I analyse and re-analyse the bibliometric data, interview data, and bibliometric data.

Chapter 4: Science, Technology and Innovation Governance, Policy and Landscape

Chapter four is devoted to a discussion of Kenya's science and technology policies, the governance of the research system and the research institutional landscape. The discussion of the governance of science in Kenya entails outlining and discussing ministries that are involved in the governance of science and the STI agencies. In this chapter, I also discuss the science and technology policies in Kenya. In this case, I provide a brief history of the science policies and the establishment of the National Council of Science and Technology is provided. Lastly, I provide an overview of the STI landscape: the research and development performing institutions: higher education institutions, public research institutions and private research institutions.

Chapter 5: Research investment

This chapter focuses on research investment in Kenya. In the first section of the chapter, we present data on different research and development indicators of investment: gross expenditure on research and development (GERD), GERD by the source of funding, GERD by scientific field, GERD by sector of R&D performance and GERD by type of research activity. For comparison purposes, the chapter also presents the research investment for selected sub-Saharan African countries. This allows for a comparison of Kenya's investment in R&D with that of other sub-Saharan countries.

The second section of this chapter presents the results of a recent survey in Africa and specifically addresses one of the research questions in the study: What factors influence research performance, particularly research funding. A secondary analysis of survey data is used to address this question. First, I look at factors that influence research funding. Following the review of previous studies and the survey data, I examine how factors like age, gender, academic rank, and scientific field influence the research funding of researchers in Kenya. These factors are analysed against various research funding perspectives: receiving funding, amount of funding received, amounts of funding allocated to equipment and facilities and the funding sources. This chapter also present results on the reported research funding organisations for Kenyan science. Finally, the chapter presents, and analyses result on the barriers or challenges of accessing research funding and the possible consequences.

Chapter 6: Research Capacity

Chapter six is devoted to the research capacity in the Kenyan science system and is divided into two main sections. The first section of the chapter begins by discussing the research and development indicators of research capacity. In particular, I present data on human resources available in the population for research, the proportion of researchers according to the different scientific fields, sectors and occupation, as well as the proportion of female researchers.

In the second section of this chapter, I also present data on other aspects that are related to research capacity, particularly, the mobility of scientists or academics, mentoring and support received during careers and the career challenges of academics and scientists. In the survey with young African scientists, survey respondents were asked to report on their recent international mobility, mentoring and support during careers and other career challenges. I present and discuss results on how respondents' recent mobility varies by age, scientific field and receiving research funding. The chapter also discusses the interview data presented and expounds on the benefits of international mobility as identified by interviewees. In this chapter, I discuss how the lack of mobility opportunities negatively impacts the careers of scientists or academics, and how this varies by age and scientific field. In relation to mentoring and support, I present results on the mentoring and support received by scientists during their careers. Finally, I also present and discuss results on other career challenges such as the impact of a lack of training opportunities to develop professional skills. Similarly, I provide results of the impact of a lack of training opportunities disaggregated by age, gender and scientific field.

Chapter 7: Research output

Chapter seven is the first of three chapters that focus on research performance and specifically on research output. The chapter starts with a review of the literature on research production and specifically empirical (bibliometric) studies on research production. I subsequently present the results of a bibliometric analysis of the research output, the relative field strength and output by scientific field. In this chapter, I also present the survey results on reported research production. In part, the secondary analysis of the survey data addresses the question: What factors influence the research performance of researchers in Kenya, particularly research production.

Chapter 8: Research collaboration

The focus in Chapter 8 is on research collaboration. The chapter starts with a short review of the literature on this topic and specifically the importance of research collaboration, motives for collaboration, collaboration levels, collaboration types, collaboration strategies and the factors that enable or constraint research collaboration. Subsequently, I present and analyse the bibliometric data on research collaboration, including trends in different collaboration types and the collaboration by field and the collaboration intensity.

The chapter then discuss how age, gender, academic rank, scientific field, funding and publication output influence research collaboration. An analysis of the interview data is used in this chapter to investigate the factors that enable or constraint research collaboration. The interview data also addresses the question on the motives of collaboration, reasons for no collaboration, strategies that enhance collaboration and whom scientists collaborate with.

Chapter 9: Citation impact

This chapter presents and discusses the results of our bibliometric analysis of the citation visibility of Kenya's scientific output. I use bibliometric data on the citation impact of Kenya's science, as measured by the Field Normalised Citation Score of the overall scientific output, and also disaggregated by field.

Chapter 10: Conclusion

The thesis concludes with a summary of the main empirical findings of the research questions in the study. In this chapter, I also consider the theoretical and policy implications of this study.

Subsequently, I indicate the contributions of this study. Lastly, I look into possible future lines of research that arises from this study.

Chapter 2 Science in Kenya: The early history

2.1 Introduction

This chapter provides an account of the early history of agricultural and medical research in Kenya. I begin with agricultural research as it has the oldest history of research in Kenya, with some of the oldest scientific institutions. The history analysis shows that before the higher education institutions began their involvement in research, there were more than 30 years of basic research at public research institutes. The subsequent sections provide a discussion on the history of medical research, the early history of universities, the history of museums, the history of international research institutes and agencies.

2.2 Agricultural Research in Kenya

The history of agricultural research in Kenya is related to the overall history of Agricultural research in Sub- Saharan Africa (Beye, 2002) because the then colonial governments mostly established earlier agricultural research institutions. The history of agricultural research in Kenya dates back to the late 19th and early 20th century (Beye, 2002:12). Agricultural research during the early years of the twentieth century, till after World War I, was mainly focused on the "screening of the exotic raw materials" needed for the growing industries in the colonial nations (Beye, 2002:12). There was a need to enhance agricultural research and investigate the suitable crops and stocks for the different regions that would yield the needed produce for export (Tignor, 1976). Further, Beye (2002) notes that one of the important features of this period was the establishment of government farms and experimental stations.

The next sections discuss the developments of agricultural research from the early twentieth century, during the colonial period, the post-independence period and recent developments. The key features discussed include the establishment of different research units, their organisation and management as well as their research focus.

2.2.1 Agricultural Research: 1900 - 1945

The establishment of the Department of Agriculture (DOA) of British East Africa in 1903 was the "basis of a formal research service" in Kenya (Mbabu, Dagg, Curry & Kamau, 2004:97). In an effort to promote agricultural research, in 1903, the DOA established the first government experimental agricultural and stock-rearing farms in Nairobi and Naivasha respectively, marking the beginning of formal agricultural research in Kenya and in East Africa. Different authors describe the purposes of the experimental farms as follows: To test the crop varieties suitable for the different farming zones; ensure supply of planting materials; demonstrate the cultivation and manuring of crops; and for livestock improvement, by establishing pure breeds for the use and benefit of the settlers (Department of Agriculture [DOA], 1921; Mbabu *et al.,* 2004; O'shea, 1917; Tignor, 1976). These scholars also identify other experimental farms that offered educational training (DOA, 1914; O'Shea, 1917; Tignor, 1976).

In 1905, other experimental farms were established at Merihini site to study crops for the coastal region and Kibos farm for the development of agricultural resources and educational purposes in the lake region (DOA, 1914; O'Shea, 1917; Tignor, 1976). Some of the crops investigated at the Kibos farm included: beans, coffee, cotton, maize, groundnuts, rice, sugarcane, timber, tropical fruits, sim-sim and tobacco among others (DOA, 1914:28–37). By 1907, the Nairobi and Merihini sites were later closed and replaced by the Mazeras and Kabete Experimental farms. In 1908, an entomological laboratory was set up in Nairobi and later relocated to Kabete. In the same year, 1908, the government established the Kabete experimental farm to provide information and training for European settlers and agricultural instructors. Mbabu *et al.* (2004:98) referred to the Kabete farm as a "model agricultural farm" because all the research activities that occurred at this farm were later replicated at other farms established later on. In 1911, a Veterinary pathology laboratory was created at Kabete to investigate East Coast Fever, rinderpest Trypanosomiasis, and come up with vaccines for their control (Mbabu *et al.,* 2004).

The period between 1908 and 1922 revealed substantial growth in the research capacity involved in agricultural research as the government made several appointments to the Kabete farm. These appointments included an entomologist, a tobacco officer, and a coffee planting inspector, a horticulturist, a plant breeder, a mycologist and an agricultural chemist. These scientists later formed the research capacity for the Scott laboratories.

Mbabu *et al*. (2004) note that following the outbreak of World War I in 1918, interrupted agricultural research at the earlier established farms and experimental stations. These interruptions were because of the changes in the roles of researchers, as the research officers, the European farmers and African farm labourers joined the military service. These interruptions further resulted in a halt in agricultural exportation, as the excess products were consumed by the military troops. (Mbabu *et al.,* 2004:98). Mbabu *et al.* (2004) refer to the example of the veterinary department which from the beginning of the war became part of the military service (the East African military corps) that secured and maintained "draft and remounts for the army" (Mbabu *et al.,* 2004:98). This account shows that World War I had immeasurable effects on agricultural research during this period.

By 1922, the government closed the experimental farms at Kabete and Mazeras as an economy measure, while the Kibos farm continued its operations as it was essential for the African agriculture, especially in training the African native agricultural officer (Tignor, 2015:294). Following the closure of the Kabete farm after 1924, the Scott Agricultural Laboratories took-up Kabete's earlier research in entomology, ecology and plant breeding (Mbabu *et al*., 2004:98). The Scott Laboratories pioneered agricultural research in Kenya (Mbabu *et al*., 2004).

2.2.1.1 The Scott Agricultural Laboratories, Nairobi

The Scott Agricultural Laboratories (SAL) was the pioneer centre of agricultural research in Kenya whose history dates back to 1903 when the first experimental farm was acquired by the Department of Agriculture (Scott Agricultural Laboratories [SAL], 1936). The Scott Laboratories started research on crops such as wheat, coffee, tea, pyrethrum, tobacco and sisal that are currently grown in Kenya. The original buildings that later housed the Scott Agricultural Laboratories were first opened on 7th June 1913, by Mr C.C. Bowring, C.M.G (later Sir Charles Bowring – the Chief Secretary of the East African protectorate -Kenya) as the Scott Memorial Sanatorium (Scott Agricultural Laboratories [SAL], 1936:297). The Scott sanatorium, built for the European settlers, was named after Dr Henry Edwin Scott who was the head of the Church of Scotland Mission, Kikuyu (Kenya) and a medical missionary (SAL, 1936:297; McIntosh, 1969; Tignor, 1976). Scott headed the Scottish Mission from December 1907 until his death in 1911. During his three years stay in Kenya, Scott's intellectual contribution to the government and local community earned him the recognition and honour that resulted in the Sanatorium bearing his name: the Scott Memorial Sanatorium (The Glasgow Herald, 1939; McIntosh, 1969). The figure 2-1 below illustrates the original building, the Scott Sanatorium, that later housed the Scott Agricultural Laboratories.

Figure 2-1: The original building, the Scott sanatorium, that later housed the Scott Agricultural Laboratories.

Photo: Kind permission of the National Agricultural Research Laboratories [NARL], (2016).

After serving as a sanatorium during World War 1, the institution later received only limited support towards the running of the hospital. Given this lack of support, the Sir William Northrup McMillan, an American from a Scottish family and philanthropist, bequeathed it, together with its ten acres of land, to the Department of Agriculture to be used as an agricultural laboratory (SAL, 1936). In 1922, following the closure of the Kabete experimental farm, these buildings were converted from the sanatorium to laboratories and was then referred to as the Scott Agricultural Laboratories (SAL, 1936). These events were followed by a need for more researchers at the Scott Laboratories. In the late 1922 and early 1923, the entomologist, a plant breeder, and agricultural supervisor from Kabete and a mycologist from the laboratory in Ainsworth, Nairobi moved their headquarters to the Scott Agricultural Laboratories (SAL, 1936). In 1924, there was an increase in the number of researchers as a chemical agricultural officer was moved from the Department of Chemical Research to join the laboratories. In 1927, the headquarters of the plant breeding section was relocated to Njoro, while other substations remained at the laboratories. In 1934, the Coffee section moved its headquarters to the laboratories from the head office (SAL, 1936).

Following its establishment, SAL (1936:297) indicated that the main roles of the Scott Laboratories were stipulated as:

- the elucidation of agricultural problems by means of research and experiment;

- the provision of technical advice, and the demonstration of special agricultural methods; and,
- the training of natives in agriculture.

The Scott laboratories performed the above-mentioned functions through its several sections and substations, including the entomological section, the botanical section, and the chemical section, the plant breeding section, the coffee section and the native agricultural school. These sections were charged with the role of research in entomology, botany, agricultural chemistry and plant breeding SAL (1936: 299-301). The Native Agricultural School trained native agricultural officers needed for the settler and native farms. The observation here is that these research sections increased research output in agricultural research while more research capacity was also created for research SAL (1936).

After independence, The Scott Agricultural Laboratories later became the National Agricultural Laboratories (NAL) under the auspices of the Scientific Research Division in the Department of Agriculture (Kenya Agricultural Research Institute [KARI], 1990). When KARI was formed in July 1989, the National Agricultural Laboratories continued operations of agricultural research under KARI, but now as the National Agricultural Research Laboratories (Miruka, Okello, Kirigua & Murithi, 2012). Following the formation of KALRO in 2013, the National Agricultural Research Laboratories (NARL) is a research centre under KALRO. Currently, the centre has a national mandate and responsibility for agricultural-related research and services in Natural Resource Management (NRM), which comprise, land and water management and crop protection (CP), and socioeconomics and biometrics (KALRO, n.d.).

2.2.2 Other Research stations established during the late 1920s to the late 1940s

The period of the late 1920s and late 1940s experienced an increase in the economic value of animal and crop production, as well as the continued spread of the European settlers (Beye 2002). This necessitated the need to increase the establishment of research stations that will conduct research on crops, animals, soil and disease control (Mbabu *et al.,* 2004). In 1927, a plant breeding station was set up at Njoro and started its investigations on appropriate cereals in 1928 (Mbabu *et al.*, 2004). The sub-stations to the Njoro station included the Scott Agricultural Laboratories discussed above, and the Mau summit. The Mau Summit farm continued the research that had been started at the Lord Delamare's Njoro farm (Mbabu *et al.*, 2004).

Mbabu *et al.* (2004) indicate an increase in research on tea during this period, which had grown at Limuru, Kenya by 1904, following the increase in its cultivation and exports. Animal research husbandry research continued to be conducted at the Naivasha Stock Farm – in cooperation with the Rowett Research Institute in Scotland - and in Mariakani by 1932; whereas studies on livestock disease were investigated on at the Kabete Research Laboratory (see Beye 2002; Deaprtment of Agriculture [DOA], Colony and Protectorate of Kenya, 1928; Mbabu *et al.,* 2004). The increase in tea and coffee exports necessitated the need for increased research on coffee.

Following the demands for the Coffee Board to enhance research on coffee as recorded in the 1928 report, in 1937, the DOA set up a multidisciplinary Coffee Team to study the various concerns of coffee including disease and pest control. As recorded in the DOA, Colony and Protectorate of Kenya (1937) report and by Mbabu *et al.* (2004), the team comprised of an agricultural officer, a soil chemist, a plant pathologist, two entomologists, and an officer for white borer campaigns, an agricultural officer and an assistant from the Scott Laboratories. Similarly, other staff were an assistant vegetative propagator, and the officers who guided the research work at the Karimani and Nandi stations, and a biochemist from the Coffee Board (Mbabu et al., 2004:98-99; also see DOA, Colony and Protectorate of Kenya 1937). Later on, other stations designated with the task of investigating on coffee matters were created at Thika, Makuyu, Karimani, Nandi, Sotik and Mount Elgon (Mbabu *et al.,* 2004). In 1938, a sisal research station was established at Thika to support the studies conducted at the station in Tanganyika (now Tanzania) (Mbabu *et al.*, 2004).

According to Beye (2002:81), the establishment of other research stations during these early times in the colonial period was driven by the DOA's policy - "creation of research facility where the crops grow well". Consequent to this policy, other research stations were established between the periods of the mid-1940s to late 1950s. In 1944, a horticultural research station was created in Molo to investigate 'temperate' fruits and salads and later embarked Pyrethrum research, with a few occasional studies on the other products. In 1946, research facilities were set up at Kibarani (Coastal region) and later moved to Kikambala in 1960 after renovations, as a regional research station looking at tree crops such as coconuts, cashew nuts, and mangos, citrus among others (Beye, 2002). The diagram below illustrates the locations of the first government agricultural experimental farms and research stations in Kenya, as from 1900 to the late 1950s.

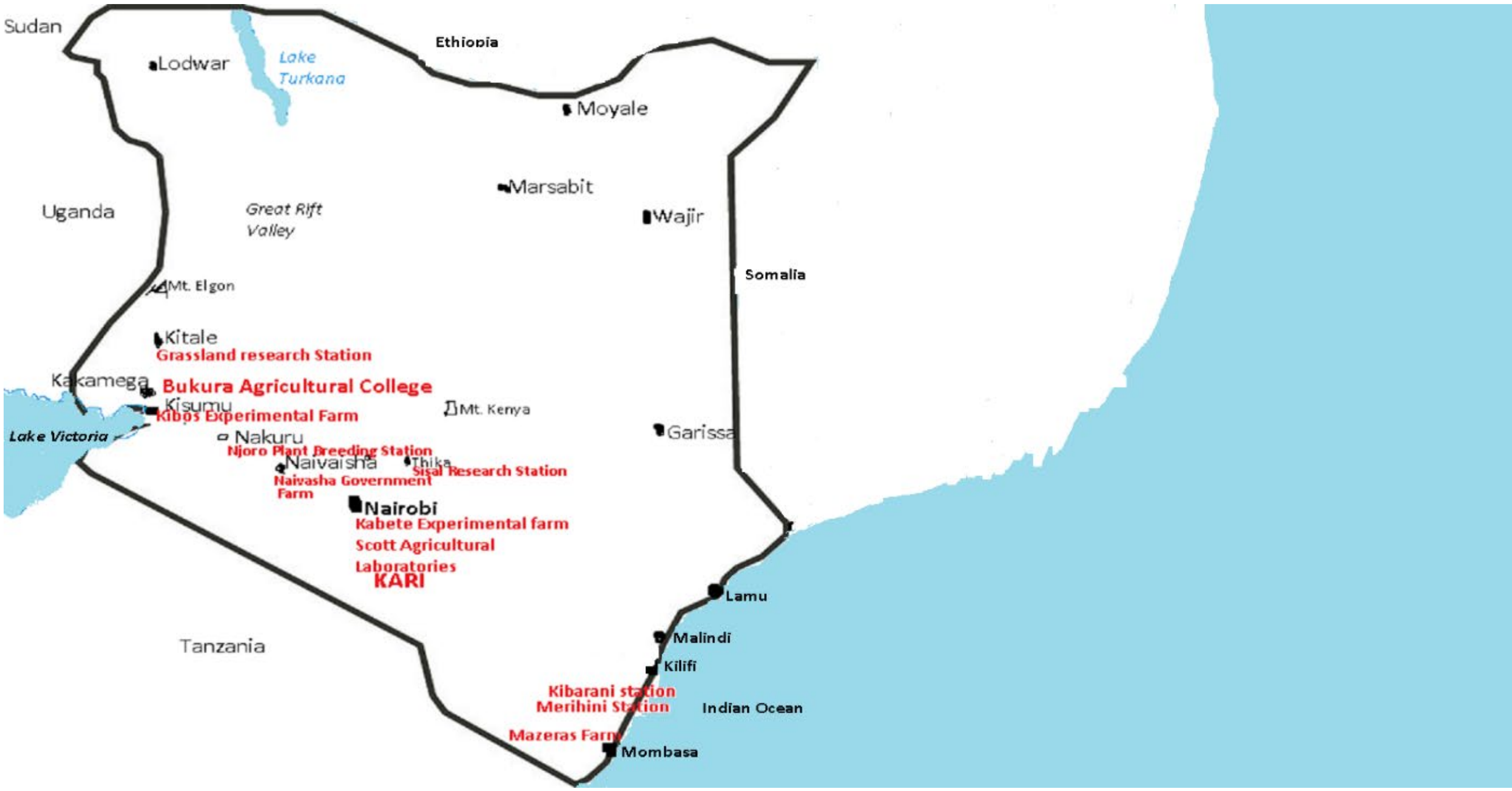

Figure 2-2: A map denoting the first agricultural government farms and research stations in Kenya

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In addition, in 1948, a sugar research sub-station was set up in Miwani in the Kano plains, to investigate sugarcane varieties and disease control (Beye, 2002:81). In the year 1949, coffee research that had been a section under the Scott Laboratories since 1924, was relocated to the Jacaranda and Rukera Estates in Ruiru (Beye, 2002:81). The pasture (grassland) research at the Scott Laboratories was transferred to Kitale in 1951; later renamed Grassland Research Station, Kitale. Through the efforts of the by the Empire Cotton Growing Corporation, cotton research facilities were set up at Kibos 1953 The maize trials conducted at Njoro were moved to Kitale in 1955 (Beye, 2002:81). The Figure 2-2 above is my diagrammatic representation of the location of the research stations discussed herein.

In summary, as outlined above, for the research stations put up over the years, Kenyan agricultural research was initially driven by the needs of the European settlers - crops for export and farm produce - and to a smaller extent for the native farmers. Much of the research on large-scale concentrated at the Scott Laboratories, although there was co-operation with the different sub-stations. Apart from the research on crops, training of agricultural instructors was one of the key features during this period.

2.2.3 Integration of Agricultural Research in East Africa

One of the key features of research during the period just before independence, in Kenya and in East Africa, was the efforts by the Colonial Office to integrate agricultural research in the East African region. These initiatives were not just unique to agricultural research; as seen earlier, on the evolution of higher education in the region, the Federal University of East Africa was also formed, to meet the higher education needs of the East African Region. This also applies to medical research in the region, with the formation of the East African Council for Medical Research (EACMR) to guide research, as discussed in the later sections of this project.

Clarke (2013:343) notes that in June 1945, the colonial government created a committee – Committee for Colonial Agricultural, Animal Health and Forestry Research (CCAAHFR) - to take charge of “the expansion of agriculture, veterinary science and forestry”. Following the establishment of the CCAAHFR, the Colonial Office recommended an approach to the organisation of agriculture research that will “reproduce” the setup of agriculture research in Britain to the colonies. The colonial Office recommended the need to create research institutions that were autonomous from the Departments of Agriculture already established in the colonies.

Thus, the new laboratories created were intended to be inter-territorial and meet the needs of an entire region and not just an “a small institution” for each country.

Following the recommendations during “a conference on agricultural and forestry research in Nairobi in July 1947”, there was an agreement to establish two new regional research organisations in Kenya (Clarke, 2013:345). The laboratories established were to be directed by senior researchers who were based in the Agricultural Research Council (ARC) units in Britain. The regional organisations created were to augment the national agricultural research systems of Kenya, Uganda and Tanganyika (Clarke, 2013; Mbabu *et al.,* 2004). Consequently, in 1949, the East African Agriculture and Forestry Research Organization (EAAFRO) was established at Muguga 17 miles from Nairobi, which absorbed the initial East African Agricultural Research Institute (EAARI) at Amani, Tanganyika, which began in 1927 (Clarke, 2013; Mbabu *et al.,* 2004). The EAAFRO was under the directorship of, Dr B.A. Keen of the ARC’s Rothamsted Experimental Station (Clarke, 2013). According to Clarke (2013:345), Dr A.G. Hill, the Director of EAARI at Amani, called for “a new site for his station”, arguing that after the World War 1, the station was unsuitable to continue with the agricultural research. The station had limited land for expansion, as well as given “its extreme isolation” (Clarke, 2013:345). This is because the station was no longer attractive to the researchers. The new EAAFRO station at Muguga replaced the EAARI at Amani.

Another key institution in the integration of agricultural research in East Africa was the East African Veterinary Research Organization (EAVRO) set up at Kabete. Dr E.G. White, a pathologist from the Rowett Research Institute, was the first director of EAVRO. The Rowett Research Institute often collaborated with the Naivasha stock farm to conduct research on the animal stock. Mbabu *et al.* (2004) and Clarke (2013) further note similar efforts by the Colonial Office were also made in West Africa, with little achievements in the creation of the ‘regional organisations’, except for research institutes that looked at Cocoa, Oil Palm and Rice (Clarke, 2013).

In cooperation with the CCAAHFR, Dr Keen and Dr White as the directors of these “regional laboratories” took on the responsibility of research in the two regional institutions conducting research on agriculture, forestry and veterinary (Clarke, 2013:346). It was on a few occasions that they involved the National Agricultural Research Systems in Kenya, Uganda and Tanganyika (now Tanzania) on their research plans (Clarke, 2013:346).

These regional laboratories were partly funded by the United Kingdom through The Overseas Development Ministry and the General Fund allocated by the East African Common Services Organization (EACSO). Equally, other funds for the research came from other organisations such as the Rockefeller Foundations, the American Agency for International Development, the Munitalp Foundation, the Coffee Boards and the Sugar Industry of East Africa. Other sources of the funds were the government taxes of the three countries (Mbabu *et al.,* 2004). From this account, it is apparent that agricultural research in East Africa was the responsibility of several funding organisations.

The Rockefeller Foundation and other USA Foundations were involved in the funding of agricultural research in Kenya and the East African region quite early on. Starting in 1943, the Rockefeller Foundation and the Mexican government laid the foundation for the Green Revolution when they established the Office of Special Studies, which resulted in the establishment of the International Rice Research Institute (IRRI), in 1960, the International Maize, and Wheat Improvement Centre (CIMMYT) in 1963 (Consultative Group on International Agricultural Research [CGIAR], n.d.). Following the support from the Rockefeller Foundation and Ford Foundation, developing high-yielding, disease-resistant varieties that dramatically increased the production of these staple cereals, and turned India, for example, from a country regularly facing starvation in the 1960s to a net exporter of cereals by the late 1970s. However, it was clear that these foundations alone could not fund all the agricultural research and development efforts needed to feed the world's population. In 1969, the Pearson Commission on International Development urged the international community to undertake "intensive international effort" to support "research specializing in food supplies and tropical agriculture" (CGIAR, n.d.).

The organisation of the EAAFRO and EAVRO was mainly based on disciplinary specialisations, as ‘specialist committees’ in East Africa facilitated on the various issues of concern such as “soils and plant nutrients, agricultural meteorology, pastures, forestry”. The recommendations from the specialist committees were taken up by the coordinating committees of the different sections such as agriculture, wildlife, animal industry and forestry, with cooperation with the Natural Resources Research Council, the Ministerial Committee for Social and Research Services. However, the regional organisations had their research facilities at the headquarters (Clarke, 2013; Mbabu *et al.,* 2004).

In summary, these inter-territorial organisations created during the early 1960s had a significant influence on agricultural research in Kenya and other East African countries. With the establishment of these organisations, we see a case of 'African Science' despite the influence of the colonial office. These organisations also had an influence on how the research was undertaken in the succeeding research institutions.

2.2.4 Agricultural research: Early 1960s - to early 1980s

After independence, from the 1960s, the Government of Kenya took up the responsibility of agricultural research. As was the case for the higher education system, the new government influenced the decisions in the agricultural system. Researchers at this time focused their research on commodities that were underrepresented in the colonial period. This then resulted in the establishment of more research stations on under-represented commodities like sugarcane, potato development, range management, seed quality and beef production (Beye, 2002:82). Beye notes that the research stations established during this period included the National Sugar Research station at Kibos (1968), the National Seed Inspection Services (NSQRC) (1969), the Beef Research Station (1969), the Range management Research Station (1971), the National Potato Research Station at Tigoni (1972), the Mwea Cotton Research Station at Wanguru (1972), the Garissa Regional Research Station (1981).

Apart from the research stations, the Government of Kenya through an Act of parliament made efforts to establish and Agricultural advisory body. In 1968, the Government Commission, Agricultural Research Survey Team, was tasked to review the research activities of the then Ministry of Agriculture. Given the shortcomings in research, the commission recommended the establishment of the Agricultural Research Advisory Council (ARAC), of which, "apart from its inaugural meeting in 1969, never became operational" (Beye, 2002:83). The National Council of Science and Technology that was later established, took the ARAC roles

Apart from research stations, institutions of higher learning participated in agricultural research. Some of the first institutions to engage in agricultural research was the University College, Nairobi (1962), later the University of Nairobi in 1970, Moi University (1984) which was established with a faculty of Forest Resources and Wildlife Management and the faculty of Agricultural Mechanization and Rural Engineering. Other universities that are involved in agricultural research include Jomo Kenyatta University of Agriculture and Technology (1988) and Egerton University (1994) which offered a diploma level training in Agriculture as the Egerton Agricultural College (see a detailed discussion at the individual universities).

Apart from the establishment of higher education institutions that took part in the agricultural research, the government took up the role of merging the research institutes that were initially under the East African Community (EAC) through the Agricultural Sciences Research Committee (ASRC), created under the Science and Technology Act of 1977. In addition, the STI Act of 1977 established the National Council of Science and Technology, an advisory and coordinating body that later took up the earlier intended advisory roles of the Agricultural Advisory Council. The amendment of the Science and Technology Act of 1977 in 1979 recommended the establishment of semi-autonomous research institutes. Beye (2002:83) identified the following are the semi-autonomous research:

i. Kenya Agricultural Research Institute (KARI), which comprised of the former EAAFRO and EAVRO under the same institute, and later in 1986, the Scientific Research Division of the Ministry of Agriculture became part of KARI;
ii. Kenya Forestry Research Institute (KEFRI), established I 1986, initially under EAAFRO;
iii. Kenya Trypanosomiasis Research Institute (KETRI), initially at Tororo in Uganda;
iv. Kenya Marine and Freshwater Fisheries Institute (KEMFRI), which was formerly part of EAMFRO based in Zanzibar;
v. Kenya Industrial Development Research Institute (KIRDI), initially part of EAIRO

Similarly, the tea and coffee research foundations mentioned earlier continued to make their important contribution to agricultural research in the National Research Agricultural Research System. From the above discussion, it is important to note that the independent governments in African countries took charge of agricultural research. This was especially seen in the formation of the STI Act in Kenya that resulted in the establishment of research institutes that continue to engage in agricultural research today. The next section provides a historical account of KALRO particularly; the section provides information on the establishment, structure and organisation, administration.

2.2.5 Kenya Agricultural and Livestock Research Organization

An Act of parliament founded the Kenya Agricultural and Livestock Research Organization (KALRO) in 2014 by merging KARI, Coffee Research Foundation, Tea Research Foundation and the Kenya Sugar Research Foundation. The history of KALRO dates back to the establishment of KARI in 1979. KARI became fully in operational in 1986 following the government's initiative to address food insecurity. The institute has the Ministry of Agriculture as its supervising agency. The institute took over research activities from the East African Agricultural and Forestry Research Organization (EAAFRO), the East African Veterinary Vaccines Organization (EAAVRO) and, later, the Ministries of Agriculture and Livestock Development. Before the merger to form KALRO, KARI had the mandate to conduct research, generate and disseminate knowledge and technology that meets the goals of the developmental policies of the country.

KALRO is the largest institute involved in agricultural research in Kenya given its national network of eighteen research centres and its extensive scope of work in agricultural research. KALRO records the highest number of agricultural researchers, about 3, 294 personnel distributed across the research centres, compared to those in higher education institutions. As of 2009 – 2016 (refer to figure 2-3 below), KALRO received funding from several sources.

KALRO funding sources: 2009 – 2016

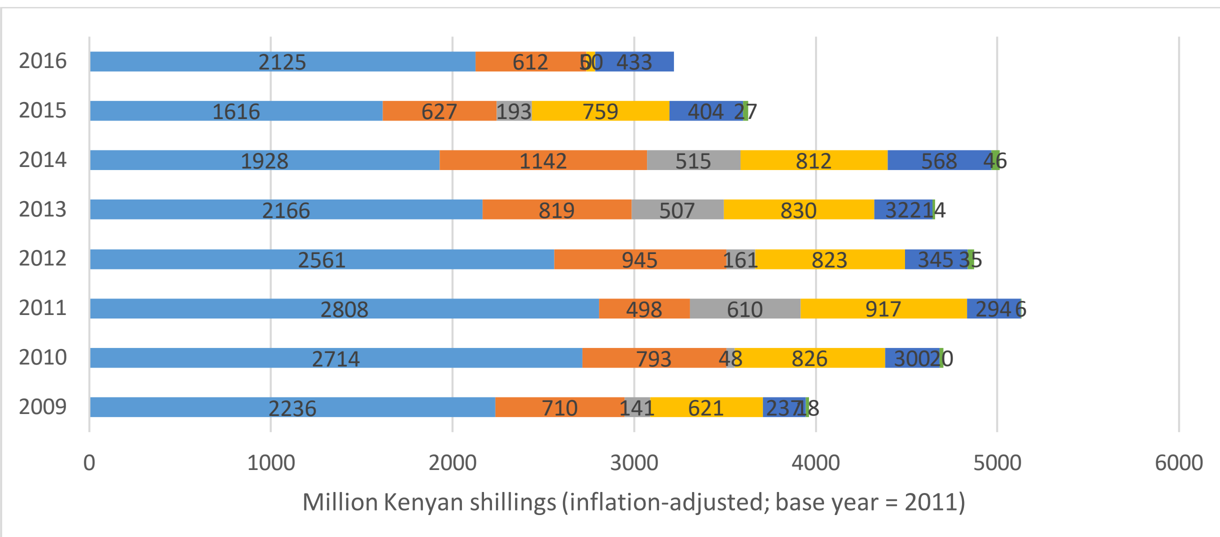

Figure 2-3 KALRO funding sources.

Data source: Calculated based on data from ASTI obtained from Beintema, Mose, Murithi, Emongor and Kibet (2016), Beintema, Mose, Kibet, Emongor, Murithi, Kimani, Ndungu and Mwangi (2018).

From the figure above, it is apparent that the government is the main source of funds for agricultural research at KALRO. However, this government support declined from 2,236 in 2009 to 1,616 in 2015 with a slight increase in 2016. Donor funding and World Bank loans almost doubled during 2009 – 2014 and later declined between 2015 and 2016. Several authors argue, that this contraction in donor funding could be attributed to the "completion of EAAPP and KAPAP" (Beintema *et al*., 2018: 3). Furthermore, another study that the funding declines in 2015 could be due to the overall restructuring of KALRO (Beintema *et al.,* 2016). Certainly, agricultural research at KALRO depends on government and donor funding.

Kenya's national science system also consists of international institutes and agencies that are involved are in agricultural research and natural sciences research. The next section discusses the establishment of these institutions in Kenya and the details of their research.

2.3 The history of research at International Research organisations

As signalled earlier, Kenya has a diverse science system with various international research organisations and intergovernmental organisations that undertake research and contribute to its science base. These research organisations are characterised by their research focus. The research organisations that focus on the natural, agricultural and applied sciences research include the International Centre for Insect Physiology and Ecology (ICIPE), the International Potato Centre, the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and the International Livestock Research Institute (ILRI). The other category of institutes focuses their research in social and economic sciences. These agencies include the African Economic Research Consortium (AERC), African Centre for Economic Growth (ACEG), and the Organization for Social Science Research in Eastern and Southern Africa (OSSREA). These institutes have a transnational and regional focus in their research (Jowi, Obamba, Mwema, &Oanda., 2014:8). The other international development agencies that also undertake research include the World Bank, UN Environment Program (UNEP), UN Development Program (UNDP), and the International Development and Research Centre (IDRC) (Jowi *et al.,* 2014:8). The next section elaborates on the international research centres that extensively contribute to Kenya's research performance in terms of the number of publications.

2.3.1 International Agricultural Research Centres

At the end of the 1960s, external donors continued to support International Agricultural Centres (IARC's) (Eisemon & Davis, 1997:111). Some of the international research centres created through these efforts included the International Council for Research in Agro-Forestry (ICRAF) established in 1977, and the International Livestock Research Institute (ILRI) initially established in Ethiopia and later expanded its operations to Kenya in 1980 (Eisemon & Davis, 1997). ILRI is a research institution aims at improving food security and reduction of poverty in developing countries through its research for better and more sustainable use of livestock. ILRI cooperates with the Consultative Group for International Agricultural Research (CGIAR) on its several research programmes, with aims to address key issues of global climate change, agriculture, food security and rural poverty. To achieve these aims, some of the research programmes at ILRI include Agriculture for Nutrition and Health, Animal science for sustainable productivity, food safety and Zoonoses, Livestock systems and environment among others.

The International Centre for Insect Physiology and Ecology (ICIPE), a research institute focussing its research in the natural and applied sciences also has a large contribution of publications to Kenya's science base. The next section provides an account of ICIPE's establishment and research trajectory over the years.

2.3.2 The International Centre for Insect Physiology and Ecology (ICIPE): Establishment and key developments

The International Centre for Insect Physiology and Ecology (ICIPE) was founded by a renowned Kenyan scientist, Thomas Risley Odhiambo. In support of Odhiambo, in 1967, Carl Djerassi (an organic chemist from Stanford University) argued that the mechanism to increase the speed of the scientific progress in the developing countries would be to establish 'centres of excellence' based on the participation of internationally recognised scientists. Djerassi was arguing based on the experiences and benefits of "international involvement" in the Mexican science system (Rabinowitch, 1985:1-2). He observed that the establishment of centres of excellence with the involvement of international scientists had resulted in the growth of the Mexican science system.

During this period, Thomas Odhiambo, then a senior lecturer at the University College of Nairobi, wrote an article, "East Africa: Science for Development" (Odhiambo, 1967:881) where he described the predicament of science in East Africa. In his article, he indicated that science in East Africa was faced with a weak science administration, inadequate trained human resources, specifically in disciplines in the science-based sectors of the economy, lack of coordination of research at the national and regional levels, less coherent science policies and minimal public understanding of science (Odhiambo, 1967). Based on these predicaments, Odhiambo emphasised the view that scientific research deserved high priority if significant economic and social development were to be achieved. In addition, he recognised the need for effective science-policy in Africa, as well as new approaches to science education (Odhiambo, 1967). Furthermore, echoing in parts the words of Djerassi, Odhiambo wrote, "it seems to me that Africa's best long-term solution to the problems of conducting effective research is to concentrate the research effort on a few very large centres (Odhiambo, 1967:881). Giving an example of research in insect biology, Odhiambo suggested the need to establish a major institute “in a locale where other ecological conditions are accessible”. Odhiambo was of the view that this institute would attract a great number of postgraduate students and postdoctoral researchers, international researchers with a representation of many science disciplines (Odhiambo, 1967).

Following the combined efforts of Thomas Odhiambo and Carl Djerassi, coupled with organisational support from the American Academy of Arts and Sciences, the International Centre of Insect Physiology and Ecology (ICIPE) was established in Nairobi, Kenya, in 1970. Quoting Odhiambo in part, Galun (2004:123) noted that one of the centre’s objectives was “to ensure that motivated, highly talented, ‘human capital’ in insect [research] and related areas of science is built up, so as to enable Africa to sustain herself and to lead the entire pan-tropical world in this area of endeavor”. Odhiambo was the first director of ICIPE and successfully headed the centre for 25 years (Bengtsson, 1994; Galun, 2004). Later on, 21 national academies offered sponsorship to ICIPE, also providing the ‘long-distance’ research directorship of the institute. In the early years of ICIPE, the visiting research directors were to help in nominating the postdoctoral researchers, actively participate in the activities of the centre by guiding research and, develop the capacity for the centre through advanced research methods training to qualified African scientists (Gulan, 2004; Rabinowitch, 1985).

Currently, ICIPE is guided by a ’4H(ealths) paradigm’ an approach that comprises of human, animal, plant and environmental health that determines the broad research themes at ICIPE. Since its founding to date, research projects at ICIPE are mainly funded by some core donors (Aid for Africa, USA; BMZ, Germany; SDC, Switzerland; SIDA and UK Aid); however, they also receive funding from the Kenyan government through the ministry of Higher Education, Science and Technology (ICIPE, 2016). Similarly, it has a wide range of research collaborations and partnerships with other scientific institutions, nationally, regionally and internationally. Through these collaborations, ICIPE aims to enhance the centres capacity and that of its partnership to improve the lives of Africans through accessing the relevant technologies and strategies in addressing their emerging problems.

Following its objective of creating ‘human capital’ in insect research, ICIPE under the leadership of Thomas Odhiambo founded the ‘African Regional Postgraduate Programme in Insect Science (ARPPIS) in 1983 (ICIPE, 2016). This is a partnership programme between [now 29] African Universities and ICIPE, for training MSc and PhD scientists. Since its inception of ARPPIS, a total of 297 PhD students and 311 Masters have completed their research training at ICIPE. These postgraduate students conduct research at ICIPE and offered degrees by 28 African Universities. For instance, in 2014, 118 students from 17 African countries, and 11 students from 5 non-African countries were at ICIPE conducting research. This programme has predominant support from international governments such as the Netherlands and Germany. One would argue that given the international nature of the programme, it would allow more interactions, networks and collaborations amongst the scientists, thus affecting their science productivity after training.

In summary, this section provided a historical account of agricultural research during the pre-colonial, colonial and independence periods. From this account, it will be made clear that the colonial government played a key role in establishing agricultural research institutions and funding of agricultural research. After independence, the government of Kenya took up the role of funding of agricultural research and the establishment of semi-autonomous agricultural research institutes. The government of Kenya was also involved with the formation of the coordinating and advisory body needed for agricultural research.

Apart from agricultural research that is discussed above, the national innovation system of Kenya consists of research institutions and institutes that are involved in medical research. In the next section of this project, I will provide a historical account of medical research in Kenya. I will start the section by providing the history of Foy and Kondi who set the foundations of medical research in Kenya (Hall & Bembridge, 1986). Secondly, I will discuss the involvement of the Wellcome Trust in medical research in Kenya from the late 1930s to date. Lastly, I will discuss the establishment of the Kenya Medical research institute in Kenya and its link to the Wellcome Trust.

2.4 The history of medical research in Kenya

The discussion in this section begins with a discussion of the developments of medical research during the early years of the colonial era (1895 -1940). In the second sub-section, I turn to a discussion on medical research and its development during the years after 1940. In particular, I focus on the contributions of two key individuals, Foy and Kondi who contributed to the founding and development of health research in Kenya. In the same section, I introduce and discuss the role of the Wellcome Trust in developing research in Kenya. In the last section, also discuss the establishment of KEMRI focussing on its research areas and collaborating partners.

2.4.1 Medical research during the colonial period: 1895-1940

As early as 1903, Sir Michael Foster, secretary of the Royal Society, called upon the Secretary of state to support colonial medical research (especially into malaria and Blackwater fever) financially and administratively" (Crozier, 2007: 84). A major challenge to the progress of research was the lack of basic research facilities within colonial East Africa. As the research started off, there was the recruitment of the first government bacteriologist, Philip Ross, to the East African Medical Service in 1903 (a specialist position with a higher remuneration in comparison to other medical officers) (Crozier, 2007). The medical officers worked under difficult conditions and discouragement. For a long period, the laboratory services were not of the same status as the clinical and sanitary branches of colonial medicine (Crozier, 2007). Kenya and Uganda, laboratory facilities belonged to a separate division of the Medical Department in 1915. Regardless of the previous efforts, research seemed not to be a key priority on colonial medical agenda, partly attributed to the interruptions of the World War I and the pressure on the colonial budget during the great depression of the 1930s. During this period, medical research was mainly distressed due to a lack of central funding and was only granted much attention after World War II (Crozier, 2007). According to Clarke (2013:341), "the period between World War I and 1950 saw scientific research move from an area that was said to be neglected in Britain to a field of intense state interest Clarke (2013:341).

Despite the challenges, the medical officers emphasised the need for improvement in colonial medical services, especially the research facilities. In 1919, through a departmental committee chaired by Sir Walter Egerton, requests made included, study leave for the medical officers, the establishment of research services and increase in the number of specialist recruitments. In 1920, the Medical Research Council (MRC) was formed, to promote biomedical research (Thomson, 1973). The creation of the MRC came after the development of the Department of Scientific and Industrial Research (DSIR) in 1916, which marked a phase of the state's commitment to research (Thomson, 1973; Clarke, 2013). The medical council, the agricultural council and the DSIR formed part of the research council system, through which the state allocated funds for medical research. The MRC claimed that, inasmuch as it received research funds from the state, “it was not subject to government control”. The ministers did not direct the MRC, but they reported to the parliament through a privy council. The premise was that the colonial government and/or administration did not have much control of the medical research (Thomson, 1973; Clarke, 2013). Quoted by Clarke, Edward Mellanby, Secretary 1933 indicated that “the independence of the MRC from direct departmental supervision and political influence was key to the council’s reputation as the purveyor of truth” (Clarke 2013:341). Similarly, the research priorities and decisions of the council were made by “an advisory council of scientists” (Clarke 2013:341) who directed each body.

From the 1920s, medical research formed part of parliamentary debates. In 1924, in Kenya, colonial research-oriented medical doctors through a formal memorandum requested the chairperson of a visiting Royal Commission to recognise the problems facing colonial medical research. These problems included negligence of scientific work, lack of cooperation, low recruitments of qualified medical researchers and lack of basic research facilities, which was a major hindrance to medical research work. In the second half of the 1920s, there were calls for the creation of a Colonial Medical Research Service. It was only until 1949 that the East African Bureau of Research in Medicine and Hygiene was established, being under the directorship of a former Medical officer, Kenneth Martin. Notably, this organisation marked the beginning of serious state-sponsored medical research in East Africa.

In the 1930s, there was a growth in specialist medical appointments. Amongst them was the appointment of Harley-Mason, the first ophthalmic specialist, in Kenya in 1937, and Braimbridge, the first surgical specialist in Kenya in 1934. The next section discusses the developments of medical research after the 1940s and onwards. The section will particularly introduce the works of Foy and Kondi in medical research. The next section will also discuss the establishment of the Wellcome Trust laboratories in Nairobi.

2.4.2 Medical research: after the 1940s

Medical research in Kenya in particular, and in Africa as a whole has highly been influenced by the initiatives and efforts of the Wellcome Trust’s “commitment to tropical medicine, the health of animals, clinical and related sciences, building and equipment, the stimulus given by the Trust to European and overseas studies and basic sciences and medicine” (Hall & Bembridge, 1986: 474). The influence of the Wellcome Trust on medical research in Kenya can trace its history back to Salonika in Greece, during the initial times of the Wellcome Trust, and the Trust’s first researcher Dr Henry Foy together with his long-time assistant Dr Athena Kondi, who later settled in Kenya for long-term research under the auspices of Wellcome Trust. The next section provides a brief introduction of Foy and Kondi. In the section, I also discuss in detail their contributions to medical research in Kenya.

2.4.2.1 Foy and Kondi

A brief introduction of Foy and Kondi will illustrate an important aspect of their research in medical sciences. Henry Foy was born in 1900. Foy went to Oxford University at the age of 18, where he studied physiology under Julian Huxley. Upon graduation, he taught biology at Gresham's School in Holt, Norfolk and at Malvern College, Worcestershire before immigrating to the West Indies to take up a teaching post at the Imperial College of Tropical Agriculture in Trinidad. From here, Foy became involved in a leper colony in Manaus on the Upper Amazon, which sparked his interest in tropical medicine.

Figure 2-4: Henry Foy and Athena Kondi, 1959.

Source: Hall and Bembridge (1986)

In 1932, when Foy moved to Greece, he moved construction of the laboratory, which was to be based in Athens, to Thessaloniki, following more incidences of malaria and other conditions. The upheavals in the region during World War I, the Graeco-Turkish War and the proximity to the malaria-infested Struma Valley guaranteed Foy a steady stream of interesting cases. In addition, with money provided by an American, Mrs David Simmons, Foy established a small laboratory in the grounds of Thessaloniki's Refugee Hospital, an institution that catered for Greeks displaced from Turkey following the breakup of the Ottoman Empire a decade earlier. According to the views of the renowned Australian physician Sir Neil Hamilton Fairley, who visited the laboratory during this early period, Foy had a perfect set-up, a judgement that influenced the Wellcome Trust's decision to support the laboratory. Looking at the history of Foy and Kondi and their involvement in medical research in Kenya, Hall and Bembridge (1986), the authors of Physic and Philanthropy note that it is essential to detail the history of the laboratory at Nairobi traced from Salonika in Greece. The next section discusses the scientific journey of Foy and Kondi from Greece to Kenya.

2.4.2.2 The Scientific journey from Greece to Kenya

When in Greece, Foy worked for the League of Nations Malaria Research Laboratory in 1932 (Wellcome Trust, 1957). After his funding ended in 1937, he got funding from Wellcome Trustees to support the research laboratory at Thessaloniki (Salonika) in Greece in 1938. This was followed by long-term funding of Foy and Kondi's research on malaria and nutritional disorders. Foy became the Trust's first medical research programme at the Salonika Laboratories. Initially, the Rockefeller Foundation, who intended to support the study for only seven years, funded the League of Nations Malaria Research Laboratory. The support from the Trust allowed Foy to continue with the research on malaria at Salonika until the end of 1940.

However, following the outbreak of World War II, Foy and Kondi's research on malaria and nutritional disorders at Thessaloniki Laboratory became difficult given the invasion of Greece by Germany in 1941. Foy and Kondi together with their lab equipment were attached to work temporarily (six months) with the British Military Mission in Istanbul, Turkey, carrying out "malaria surveys" on the airfields (Wellcome Trust, 1957:35). Later, Foy and Kondi moved to Johannesburg to work at the South African Institute for Medical Research for several years, with the full support of the Wellcome Trustees. In the years 1941-1944, while working with the South African research institute, they investigated malaria and blood dyscrasias in the neighbouring African countries of Swaziland, Basuto (now Lesotho), Bechuanaland (now Botswana) and Portuguese East Africa (now Mozambique) (Wellcome Trust, 1957; also see Wellcome Trust, 1991:9).

In 1944, Foy and Kondi opted to move to Cairo before returning to Greece. While at Salonika (1944-1948), the scientists worked on sickle cell anaemia, under the United Nations Reconstruction Relief Administration. However, their stay in Greece was short-term. Hall and Bembridge (1986:228) note that "political unrest, the wartime damage to the laboratory, population movement, and changes in the incidence of malaria" made the Thessaloniki Laboratory ineffective for their work. The drastic changes in the presence of malaria and other diseases that were of interest to Foy influenced his research ambitions. It was at this time that they identified sickle cell anaemia in Greece for the first time.

After leaving England and returning to Kenya, in 1949, Foy began research on malaria and sickle cell at Kenyatta Hospital (now Kenyatta National Hospital), citing the excellent opportunities and facilities for these investigations. Hall and Bembridge (1986:228) referring to the correspondence between Foy and Dale (Chairman of the Trust between 1936-1960) that:

> Nairobi was … just the place we needed … Malaria is abundant here … There is a widespread sickle-cell trait that varies in degree … an abundance of material for all kinds of work … we can do better here …

The above quote suggests that the abundance of the research material and facilities in Kenya were the contributing factors that interested Foy and Kondi. Hall and Bembridge note that the research interests of Foy and Kondi in Nairobi marked "the long association of the Wellcome Trust with research in Kenya" (Hall & Bembridge, 1986: 228). At this point, the Wellcome Trust Malaria Research Laboratory in Thessaloniki was then transferred to Kenya, leading to the Trust's Nairobi Laboratories. The sub-section below describes the establishment of the research unit in Nairobi.

2.4.2.3 The Establishment of the Research Unit, Nairobi

Upon establishing the laboratory at Kenyatta Hospital in Nairobi, Foy and Kondi's research resulted in publications and eminent findings such as the successful treatment of the blood disorders with penicillin (Hall & Bembridge, 1986). It is worth noting that Foy's publications and successful discoveries on malaria and blood disorders in Nairobi convinced the Trustees to fund the research in Kenya more.

In 1961, Foy and Kondi started research on hookworm infection and anaemia, research that continued until 1970 after Foy's formal retirement (Hall & Bembridge, 1986). In the same year, 1961, the Wellcome Trust and the Government of Kenya reached an agreement in relation to the Laboratory in Nairobi; a unit that was later named, The Wellcome Trust Research Laboratories, Nairobi. At this unit, the focus of the research was mostly on anaemias, marasmus and Kwashiorkor (Hall & Bembridge, 1986:231).

In the late 1960s and early 1970s, the research at the unit focused on the nutritional disorders and schistosomiasis. Later, in the mid-1970s and 1980s, the unit mainly worked on collaborative studies on hypertension and renal diseases (Hall & Bembridge, 1986:231; see also Wellcome Trust, 1965:30-31).

After Foy's retirement in 1965, the activities at the Nairobi unit were moved to the Zoological Society of London. However, the Wellcome Trust continued to fund studies on nutritional disorders (Wellcome Trust, 1965:32). During this period, the Nairobi unit worked on collaborative projects with other institutions from Britain, Europe and the USA and the Netherlands. (Wellcome Trust, 1967:32-35). In 1973, the association between the Nairobi unit and the Zoological Society of London ended following the end of the study of nutritional deficiencies in baboons (The Wellcome Trust, 1974:57; see also Hall & Bembridge, 1986:223, 231).

At the beginning of 1974, at the Wellcome Trust Research Laboratories, Nairobi, a new research project was started, to investigate immunology of schistosomiasis (Wellcome Trust, 1974). This study was under the direction of Dr Houba then Director of World Health Organization (WHO) Training and Research Centre in Immunology in Kenya and visiting professor of immunology in the Department of Pathology at the University of Nairobi. Other researchers involved in the project included, Dr AE Butterworth from Cambridge University researching on humoral immune responses, Dr RF Sturrock from the London School of Hygiene and Tropical Medicine investigating the parasitology of schistosomiasis and Professor Houba's investigating immunopathology in the infected baboons (Wellcome Trust, 1974:57-58; also see Wellcome Trust, 1976).

The study on schistosomiasis was mostly collaborative work, involving researchers from the University of Nairobi and the Ministry of Health Central Laboratories, Nairobi, as well as, international researchers from Europe and North America (Wellcome Trust, 1974; 1976). To ascertain this observation, it is recorded in the Trust's Eleventh Report (Wellcome Trust, 1976) that, the Nairobi Unit and its research then, continued due to the "interest and cooperation" (Wellcome Trust, 1976:88) of local researchers, such as, Dr J. Itotia, the (then) Director of Public Health Laboratories, and his colleagues, specifically Dr Siangok, Director of Division the Division of Vector-borne Diseases (Wellcome Trust, 1976:88). Similarly, the schistosomiasis programme attracted a number of funding organisations for support. Apart from the Wellcome Trust, funds for costs like, "the salaries and expenses of expatriate scientists" (Wellcome Trust, 1976:88) were drawn from funding organisations such as The Edna McConnell Clark Foundations, the Schistosomiasis section of W.H.O Special Programme for research and training in Tropical

Diseases and the Rockefeller Foundation (Wellcome Trust, 1983: 42). It is clear that the Wellcome Trust cooperates with other organisations in funding clinical research in Kenya.

Later in 1978, Dr Sturrock became director of the Nairobi Laboratory, Dr Butterworth moved to Harvard, whereas, Dr Cottrell from the Middlesex Hospital Medical School joined the Nairobi research group (Hall & Bembridge, 1986). What is clear from above is, in the late 1970s, the Nairobi Laboratory composed of scientists from different countries, especially the UK, USA and Geneva, working on different scientific disciplines.

In 1979, research at the Nairobi Unit transitioned from Schistosomiasis to clinical research (Wellcome Trust, 1981:81). Research on schistosomiasis was replaced by an investigation of "the epidemiology of hypertension in rural and urban communities [in Kenya] and of cardiovascular and renal disease" (Wellcome Trust, 1981:84). This research was endorsed by the Wellcome Trust in March 1979, following the visit of Professor W.S. Peart, Professor Sidney Cohen and Dr Williams to Nairobi Coincidentally, the Kenya Medical Research Institute (KEMRI) in Nairobi and the Medical School of the University of Nairobi (UON), were formed between 1979 and 1980 (Hall & Bembridge, 1986:233). In 1980, collaborative research ensured between KEMRI and UON.

Following Dr Sturrock's resignation, Dr BEC Hopwood, who had massive experience and knowledge, after guiding the Trust's Tropical Medicine Programme in London for long, was appointed as the "Programme Director" of the Nairobi unit (Wellcome Trust, 1981:82). The setting up of the new research programme in Nairobi involved other researchers like, Dr CH Edwards who guided the research at St. Mary's Hospital; whereas, Professor PS Sever developed the research proposal together with Professor Peart (The Wellcome Trust, 1981).

In 1983, on the clinical research on hypertension was concluded. The same year, KEMRI under the directorship of Professor Mugambi asked the Wellcome Trustees on the possibilities of establishing a research Unit at Kilifi, on the coast of Kenya, to investigate the "health problems" of the local people (Wellcome Trust, 1989:125). This suggestion was made to Dr CE Gordon and Dr PO Williams during their visit to Kenya in August 1983 (Wellcome Trust, 1985; 1987). The next section provides details on the establishment of this unit at Kilifi and KEMRI. I provide information on its establishment, research focus, research centres, the collaborative research programmes are discussed are delved in below.

2.4.3 The Kenya Medical Research Institute

The Kenya Medical Research Institute (KEMRI) is a clinical research institution founded through the Science and Technology (Amendment) Act of 1979, with the mandate to provide leadership and guidance on biomedical sciences in Kenya (Republic of Kenya, 1980). KEMRI is a semi-autonomous research institute that receives grants and allocations from the government through the relevant Ministry (Health), though other funds are derived from gifts, donations, subscriptions, fees and other amounts of money for the implementation of research programmes. A Board of Management designated by the government manages KEMRI, like other research institutes, or by the relevant Ministry. Practically, the board of management is responsible for the policy management, direction and guidance with regard to finances, property, programmes, appointments, personnel, programme varieties and the general development of the institute. The planning and management of the institute are under the auspices of the Director of the Institute, also the Chief Executive Officer (Republic of Kenya, 1980).

Furthermore, as recorded in the Science and Technology Act of 1979 (Republic of Kenya, 1980:9), at the time of establishment, like other government research institutes, KEMRI had its functions stipulated as:

- to carry out research in the field specified (biomedical sciences);
- to co-operate with other organisations and institutions of higher learning in training programmes and on matters of relevant research;
- to liaise with other research bodies within and outside Kenya carrying out biomedical research;
- to disseminate research findings; and
- to co-operate with the responsible Ministry, the Council and the relevant Research Committee, in matters pertaining to research policies and priorities.

The discussions hereunder illustrate how these functions of KEMRI have been executed and achieved, especially in relation to the collaborations of other research organisations such as the Wellcome Trust, the World Health Organizations, and higher education institutions in the UK, around African and in Kenya.

2.4.3.1 The KEMRI - Wellcome Trust Research Programme

As already mentioned, after its establishment, KEMRI continued cooperating with Wellcome Trust and being responsible for the Trust's activities in Kenya. The subsequent section discusses the studies have been conducted collaboratively between the Trust and KEMRI, and even interlinked their administrative roles.

In 1982, following the request to establish a research unit in Kilifi,[3] in 1989 the Wellcome Trustees accepted to fund a research Unit in Kilifi. This marked the beginning of the KEMRI-Wellcome Trust Research Programme, a collaborative research programme between the Kenya Medical Research Institute and the Department of Tropical Medicine at Oxford University, developed through the efforts of Professor David Warrell, who had initially directed the Trust's Unit in Bangkok. Mainly, the programme was to focus on studies on the "natural history of Malaria" especially in children. The scientists who started this research also included Dr K Marsh and Dr G Pasvol who were offered laboratory support for this research from their laboratories at Oxford University (Wellcome Trust, 1989; 1990). In addition, part of this research programme was the "epidemiological study" that received its funding from the World Health Organization (WHO) (Wellcome Trust, 1989:5, 110). This was the second study co-funded between the Wellcome Trust and the WHO, after the researches on the immunology of schistosomiasis, carried out in the mid-1970s and the early 1980s.

Furthermore, a research group was set up at the KEMRI Laboratories, Nairobi, to investigate the clinical aspects of AIDS in Kenya This was the first collaborative research on AIDs involved researchers such Dr CF Gilks from London, and Professor DA Warrell from Oxford (The Wellcome Trust, 1989:110). The second collaborative aspect of the study was on, AIDS affects other infectious diseases, in particular Tuberculosis. This study involved, Dr P Nunn, Dr RJ Brindle and Professors KPW McAdam investigated on the second study (Wellcome Trust, 1990:73). The studies conducted at this period were mostly collaborative between, KEMRI, the Wellcome Trust and scholars from the UK. Similarly, apart from the Trust's funding different institutions received funding from other funding organisations like WHO, as well as, the Kenyan government.

In 1985, following Hopwood's resignation, Dr WM Watkins assumed direction of the Research Laboratory at Nairobi, and administration of all the "Trust's research activities" in Kenya (Wellcome Trust, 1990:73). By 1990, Dr Watkins had integrated the research programmes in Nairobi and at Kilifi with those of KEMRI, Nairobi (Wellcome Trust, 1991). In addition, Watkins continued investigating "drug pharmacokinetics and parasite resistance in the chemotherapy" of

[3] Kilifi is in the South part of the Kenya coast.

malaria that was based at the Trust's Nairobi laboratories at KEMRI and used the facilities at Kilifi (Wellcome Trust, 1986:126). Watkins' research was conducted in collaboration with Professors A.M. Breckenridge (Department of Pharmacology and Therapeutics, University of Liverpool); and R.E Howells (then at Liverpool School of Tropical Medicine and P Winstakey, a research fellow based at Kilifi (Wellcome Trust, 1989; 1990; 1991:92).

Later in the 1990s, as the research at the Wellcome Trust - KEMRI Laboratories at Nairobi and Kilifi, became more established, the Trust sent more researchers on advanced training fellowships to these facilities. The scientists on the fellowships were either to work on independent projects or collaborative studies with the malaria research team in Kenya. In 1992, R. Snow on the Trust's International Senior Research Fellowship was at the Wellcome Trust-KEMRI laboratories, Nairobi, to conduct an "epidemiological study of severe malaria in children" a study closely related to the research by Dr Kevin Marsh on malaria (Wellcome Trust, 1992:53). Similarly, CRJC Newton of Nuffield Department of Clinical Biochemistry, the University of Oxford who for three years was to work on cerebral malaria and meningitis under D. K Marsh and Professor ER Moxon, Department of paediatrics, University of Oxford. Dr Robert Snow continued his research even later in 1999, but this time collaborating with Dr Mary Dobson from the Wellcome Unit for the History of Medicine in Oxford University, to "reconstruct the history of malaria and its control in the twentieth century in East Africa" (Wellcome Trust, 1999:56). In 2001 C Molyneux, received a senior research fellowship to work on malaria at the Trusts' unit in Kilifi. At this time, in 2001, Dr Kevin Marsh was the Director of the Trusts unit at Kilifi (Wellcome Trust, 2002:52). In addition, in 2001, D Bell, from the University of Liverpool was funded to investigate antimalarial drug resistance in Kenya, at the Kilifi unit (Wellcome Trust, 2002:45).

By 2004, the Wellcome Trust-KEMRI laboratories at Kilifi were under the directorship of Professor. Kevin Marsh (Wellcome Trust, 2004). At this time, the malaria collaborative research between the scientists at Oxford University, Edinburgh and Kenya continued. The same year, Mike English, a clinician based at KEMRI/Wellcome Trust, on a Senior Clinical Fellowship in Tropical Medicine, investigated the "research-to-policy-to-practice pathway". Exploring health care delivery to very ill children in Kenya (Wellcome Trust, 2004:45).

In 2005, James Berkley, Anthony Scott and colleagues at KEMRI-Wellcome Trust, Kilifi conducted an epidemiological study to assess the "prevalence of bacterial infections" in the children admitted at the Kilifi hospital. A study that was conducted for over five years of existing vaccinations for bacterial infections could reduce the deaths in children (Wellcome Trust, 2010).

The same year, 2005, new laboratories at Kilifi General Hospital had been completed and opened in 2006, to house the research of the KEMRI-Wellcome Trust Research Programme (Wellcome Trust, 2006). The malaria research by Professor Bob Snow and colleagues at the Trust's Laboratories in Kilifi believed that insecticide-treated nets they introduced in 2001 would reduce the spread of Malaria among children (Wellcome Trust, 2007).

In 2010, KEMRI and the Wellcome Trust Sanger Institute collaborated to look at a study of genomic sequencing of infectious disease. The researchers from Malawi-Liverpool Wellcome Trust Clinical Research Programme were also part of the study (The Wellcome Trust, 2010). Other researchers who collaborated in the study were from Gambia, Hong Kong, UK, and Vietnam. These kinds of collaborative studies give a large pool of scientists to establish networks with and, maybe, co-author research findings.

Another study investigating the impact of urbanisation and poverty on health received funding from the Wellcome Trust. The African Population and Health Research Centre (APHRC) conducts the Urbanization, Poverty, and Health Dynamics (UPHD) study since 2006 under the directorship of Dr Eliya Zulu. This study has informed the Kenyan government policy to develop means in support of safe childbirth, family planning services and handling of gender-based violence. In addition, it influenced advocacy and policies to enhance urban health in Kenya and in other Sub-Saharan countries (Wellcome Trust, 2011).

The directorship of medical science also experienced shifts. In September 2014, Dr Bejon became the Director of the KEMRI-Wellcome Trust Research programme at Kilifi. Dr Bejon, a clinical epidemiologist, who worked with the programme since 2002, and focuses on vaccine development succeeded Professor Kevin Marsh who directed the programme for 25 years (Wellcome Trust, 2014).

2.4.3.2 A shift towards African Science: New Funding Initiatives and Directorship

As highlighted earlier, since August 2014, there has been a shift in the management and funding of medical science in sub-Sahara Africa, and in Kenya in particular. As discussed, the Wellcome Trust has a long history of supporting the development of medical science in Kenya. Over the years, research support was underpinned by different research themes, although Malaria research has been their focus for over 75 years. However, in August 2014, the Wellcome Trust made a "significant shift to support the African-led development of world-class researchers in Africa" (Wellcome Trust, 2014:31). The new scientists created are expected to participate "in shaping and driving a locally relevant health research agenda in Africa, contributing to improved health and development in the continent" (Wellcome Trust, 2014:31). To achieve this aim, The Trust launched a new programme, The Developing Excellence in Leadership, Training and Science (DELTAS) Africa initiative, which would "focus on developing scientific excellence, research leadership and scientific citizenship in sub-Saharan Africa" (Wellcome Trust, 2014:31). The DELTAS Africa programme aims to train African scientists; and develop the leaders and managers of African science, from Africa and for Africa (Wellcome Trust, 2014, 2015). Looking at the trends of medical research discussed above, these initiatives are quite a huge shift, for medical science in Kenya and Sub-Sahara Africa.

The UK's Department for International Development co-funds the DELTAS Africa initiative. In the year 2016, the DELTAS Africa budget, a total of €46 million received from seven grants which were supposed to be managed by the newly launched Alliance for Accelerating Excellence in Science in Africa (AESA). The African Academy of Sciences and the New Partnership for African Development affiliated to the African Union formed AESA. AESA was formed with the aim to cooperate with the individual African governments to support and fund science. To produce, "internationally competitive researchers to lead and conduct the most locally relevant research to improve health across Africa" (Wellcome Trust, 2015:15).

In summary, in the above sections, I provide a historical account of medical research carried out by public research institutes in Kenya from the times of the Wellcome Trust Research Laboratories in Thessaloniki in 1938 to its transfer to Nairobi in 1949. The Wellcome Trust Nairobi unit provided a framework for the works of the Wellcome Trust overseas and in the Kenyan research (Wellcome Trust, 2015). The section also highlights the key works of Foy and Athena, the first researchers of Wellcome Trust, who formed a foundation for medical research in Kenya. This analysis highlighted the key research areas of the Wellcome Trust units. These research areas included malaria, nutritional disorders, sickle cell anaemia and other blood disorders. This research also included schistosomiasis, hypertension and renal diseases. We see the establishment of KEMRI and the Medical School at the University of Nairobi in 1979 and 1980 respectively. The establishment of KEMRI then resulted in the establishment of the KEMRI-Wellcome Trust Research Programme based in Kilifi Kenya, which has continued to investigate malaria and its control to date (Wellcome Trust, 2015). There were also focuses on policy and social science studies conducted at the Kilifi unit. The discussions outline the support to the individual researchers either locally or internationally by Wellcome Trust. One of the key aspects noted in this discussion is the recent shift of the Wellcome Trust and other funders who have the aim to develop excellent local researchers, leaders and managers of science ‘from Africa and for Africa’ through AESA. From the discussion, The Wellcome Trust remained the key funder of medical Science in Kenya. However, there are cases of other funders such as W.H.O, the Rockefeller Foundation among other organisations and to some extent the Kenyan government. The funding of medical science in Kenya differed with the case in Agricultural research, where over 62 per cent of the funding is from the Kenyan government to its National Agricultural Research Institute, KARI. Above all, funding of malaria research in Kenya and other tropics remains the Wellcome Trust funding scheme to date (Wellcome Trust, 2015).

In the next section, I provide a historical account of higher education in Kenya. It is important to note here that apart from public research institutes, Kenya’s national science system comprises of higher education institutions that conduct research and train personnel. I begin the analysis with a general historical overview of higher education in Kenya. In this analysis, I also provide information on the different research centres and institutes and their research focus. I also look at the research investment in higher education and the human capacity available in these institutions.

2.5 The early history of universities in Kenya

The early history of higher education in Kenya can be traced back to the establishment of the first university in Kenya, the University of Nairobi. The establishment of the University of Nairobi dates back to the colonial period when the British colonial government established the Royal Technical College in 1949[4] as one of the Asquith colleges. The British colonial government and the government of Kenya had aimed to a technical and commercial college serve the East African students from Kenya, Uganda, Tanganyika and Zanzibar (now Tanzania) (Ajayi, Goma & Johnson, 1996; Mngomezulu, 2012; Mwiria, Ng’ethe, Ngome, Ouma-Odero, Wawire & Wesonga, 2007). The British colonial government tasked the Asquith Commission (1943-1944) headed by Justice Cyril Asquith with the goal of promoting “higher education, learning and research and the development of universities in the Colonies” (Lulat, 2005:227). The above quote suggests that the Asquith commission recommended the creation of university colleges mainly affiliated to the University of London in all the British colonies. The university colleges established in the colonies played both political and educational roles (Lulat, 2005). These initiatives resulted in the establishment of the University College of Ibadan (1947), the University

[4] It is important to note here that the Royal technical college dates back to the establishment of the Makerere College in Uganda in 1922.

College of Ghana (1948) and the Royal Technical College at Nairobi (1949) among other colleges.

In 1952, the Royal Technical College, Nairobi became the Royal Technical College of East Africa. Following its establishment, the Royal Technical College played the role of higher technological training, professional training, research and, vocational training through its schools or institutes. These schools and institutes included engineering, science, laboratory technology, sanitary science, pharmacy, domestic science, industry, commerce, accountancy economics, arts, art and artistic crafts (Mngomezulu, 2012). During the early 1950s, the Asian community of East Africa had plans to establish a college of Arts, Sciences and Commerce in memory of Mahatma Gandhi. In order not to duplicate efforts, the Gandhi memorial society merged its interests with those of the East African government(s). In 1954, the Gandhi Memorial Academy was incorporated to the Royal Technical College. In 1956, that the Royal Technical College (RTC) admitted its first intake of students and offered degrees in the following fields: Architecture, Arts, and Domestic science, Commerce, Engineering and Science (Mwiria *et al., 2007).*

After the arrival of the first students at the Royal College, higher education in East Africa needed improvement within higher education. This improvement had two sides to it: (1) it was necessary due to the inaccessibility of the College to potential students from other East African countries. (2) There was also a need to promote institutional autonomy by becoming a university college. Replacing the Royal College, the university college was established in 1961 commonly referred to as Royal University College, and the third University College at Dar es Salaam was established in the same year (Mngomezulu, 2012; Mwiria *et al.,* 2007). Ashby (1964) notes that these University colleges were seen to be 'autonomous institutions' though they were previously modelled against and affiliated to the British Universities. The established university colleges in 1961 trained students in bachelor's degrees that were awarded by the University of London.

In 1963, the three university colleges of Makerere, Royal College and Dar es Salaam formed the Federal University of East Africa, independently awarding its degrees at the University of East of Africa. The establishment of the Federal University of East Africa formed a key foundation of higher education in East Africa (Mngomezulu, 2012; Mwiria *et al*., 2007). However, even with the establishment of the University of East Africa, only a small number of East African students pursued postgraduate training and an insignificant amount of the institutional budget was reserved for research expenditure (Odhiambo, 1967:877). Odhiambo illustrates that "during the

1965-66 academic year at the University College of Nairobi only about €3000 of the budget was invested in research" (Odhiambo, 1967:881). This shows that university education in East Africa has had funding challenges since its genesis.

In 1964, immediately after Kenya's independence, the Royal College of Nairobi was renamed, the University College, Nairobi, a constituent college of the Federal University of East Africa. After attaining the "University College" status, the University trained students for bachelor's degrees awarded by the University of London as well as continued offering college diplomas courses. Later in 1966, the University College Nairobi started preparing students solely for degrees of the University of East Africa (Mwiria *et al.,* 2007).

In 1970, following the collapse of the East African Community, the Federal University of East Africa was dissolved. Post-independence nationalism amongst the three East African countries, Kenya, Uganda and Tanzania resulted in the dissolution of the Federal University, in preference to public national universities for the countries. Mngomezulu (2012:9) argues that the development of higher education in East Africa was a "contested process; it was a process filled with political disputes, negotiations, suspicions, compromises and differing interests". For instance, the varying national interests resulted in the need of these countries to establish national universities that will be useful in the pursuance of national needs. Notably, independence resulted in shifts in the history of higher education by ushering in the "era of national universities" (Lulat, 2005:228). Lulat further expounds that, in the early years of independence, a national university just like the national currency, the national bank, the national anthem and an international airport denoted a symbol of sovereignty (Lulat (2005:228). As a national public institution, the University was responsible for training workforce, "undertook responsibility for political socialisation, an ideological endeavour to reconstruct the political thinking of Africans to support the ideals of African socialism as a foundation for nation-building" (Oanda, Chege & Wesonga, 2008:19). There was a conflict of interest between the colonial government and the nationalist/post-colonial government. On the one hand, the colonialists saw the need to establish higher education institutions that will produce the elite needed to play the political and administration roles in the colonies. On the other hand, the nationalist/post-colonial government saw higher education as a means to produce manpower that will replace the colonial administrators and meet local needs.

In light of the nationalist interests, Kenya, Uganda and Tanzania later established independent national universities through their respective individual Acts of Parliament. Therefore, in 1971, the Individual Act of Parliament resulted in the establishment of the University of Nairobi (UoN) being the first fully-fledged university in Kenya. This Act has since been repealed following the Enactment of Universities Act No.42 of 2012; that resulted in UoN being re-accredited and awarded a charter in 2013 (Commission for University Education [CUE], 2012).

In the 1980s, there was an increased demand for higher education, hence the Kenyan government made efforts to expand the public university system. A presidential working party headed by Colin Mackay (Republic of Kenya, 1981) was mandated to prepare detailed plans and recommendations on the establishment of the second university in Kenya. Among other policy recommendations, the Mackay report proposed the establishment of a second university. The proposed institution was to be located in a rural area and was to focus on science and technology courses that merged academic programmes with the realities of Kenya's social and cultural life.

Consequent to these suggestions, Moi University was established in Eldoret in 1984, being the only university in Kenya that began with full university status. Moi University emphasised in establishing academic programmes in technological fields in agriculture, science, forestry, medicine and veterinary. Construction work started on the site near Eldoret in the following year. The University administration later moved its temporary offices in Eldoret to the present Main campus in (Kesses), Uasin Gishu County on July 29, 1986. The University was officially inaugurated on December 6, 1985, by the then Chancellor, His Excellency the Second President of Kenya, Hon. Daniel Toroitich Arap Moi. Similarly, the report recommended the University should have an emphasis on technology. Over time, the University has experienced tremendous growth from the initial one faculty in 1984, to a total of 15 schools, 9 directorates, and 2 institutes currently (Moi University, n.d.; also see Mwiria *et al.*, 2007).

Kenyatta University College, a constituent college of the University of Nairobi since 1972, was upgraded to an autonomous university status in 1985, and renamed Kenyatta University, becoming the third University in Kenya. The history of Kenyatta University dates back to 1965 when the British Government handed over the Templar Barracks to the newly formed government of Kenya. The Barracks were later was converted into a middle-level institution named Kenyatta College. In 1970, Kenyatta College became a constituent college of the University of Nairobi through an Act of Parliament and would be renamed Kenyatta University College. The University College admitted first of its own students, 200 in number, in 1972 to pursue a Bachelor of Education Degree. In 1985, Kenyatta University College became a fully-fledged university through a Kenyatta University Act and renamed Kenyatta University.

Egerton University became a fully-fledged university in 1987. However, the history of Egerton dates its history dates back to 1939 when Egerton was founded as a farm school aimed at training white European youth for careers in agriculture, originally known as the Egerton Farm School. The establishment of the school followed the generosity of Lord Maurice Egerton, the 4th and last Baron Egerton of Tatton - a British national who settled in Kenya in the 1920s - who donated 300 hectares (740 acres) of his estate. In 1950, the farm school became an Agricultural College offering a one-year certificate course and a two-year Diploma programmes. The Egerton Agricultural College Ordinance was enacted in 1955. In 1979, the Government of Kenya and the United States Agency for International Development (USAID) provided funds for a major expansion of the college. In 1986, Egerton Agricultural College was gazetted as a constituent college of the University of Nairobi. In 1987, Egerton University became a fully-fledged University through an Act of Parliament (Egerton, n.d.).

Jomo Kenyatta University of Agriculture and Technology (JKUAT) was established in 1994. The history of JKUAT dates back to 1981 when Jomo Kenyatta University of Science and Technology was founded as a middle-Level College – Jomo Kenyatta College of Agriculture and Technology (JKCAT) – by the Government of Kenya with the generous assistance from the Japanese Government. However, plans for establishing JKCAT started in 1977. In 1978, the first president, Jomo Kenyatta donated 200 hectares of farmland for the establishment of the college. The first admission of students happened in May 1981. The then-president H.E Daniel Arap Moi officially opened JKCAT in March 1982. The JKCAT started by offering diploma courses in Agricultural Engineering, Food Technology and Horticulture. The university held its first graduation ceremony on April 1984. In 1988, JKCAT became a constituent college of Kenyatta University. The JKCAT became Jomo Kenyatta University College of Agriculture and Technology (JKUCAT). In 1994, JKUCAT became a fully-fledged university known as the Jomo Kenyatta University Agriculture and Technology through an Act of parliament (JKUAT, n.d.[5]).

Maseno University became a fully-fledged university in 2001. The history of Maseno University dates back 1991 following the merging of Maseno Government Training Institute (GTI) with Siriba Teacher's Training College to form Maseno University College as a constituent college of

[5] www.jkuat.ac.ke

Moi University. Rev. J.J Willis coined the name 'Maseno' out of the name of a tree known in local dialects as 'Oseno' or 'Oluseno' that stood next to the spot where the first missionaries in the region put up their base. Subsequently, the gazettement of the two institutions happened in 1990. Maseno University became a fully-fledged university in 2001.

Masinde Muliro University of Science and Technology became a university with full accreditation in 2007. Masinde Muliro University of Science and Technology was founded through the Harambee spirit in 1972 as Western College of Arts and Applied Sciences (WECO) under the stewardship of former Member of Parliament, Masinde Muliro. Muliro was the chairperson of the project executive committee, together with Prof. Reuben Olembo (then Head of the Department of Botany, University of Nairobi) as secretary. The establishment of the college was intended to meet the needs of the people of Western Province, to have a college that will provide training for technical manpower for the province and the nation. In December 2002, WECO became Western University College of Science and Technology (WUCST) after being elevated to a constituent college of Moi University. In 2007, President Kibaki assented to a bill making WUCST a fully-fledged university and change of its name to Masinde Muliro University of Science and Technology (MMUST) (MMUST, n.d.). The table below illustrates the details of the establishment of these universities and others.

By 2012, higher education in Kenya witnessed a number of important developments. As earlier noted, the Enactment of Universities Act No. 42 of 2012 resulted in the expansion of the higher education systems, with the establishment of more public universities and private universities. The Universities Act No. 42 entailed upgrading most of the national polytechnics and the existing university constituent colleges to fully-fledged universities. The massive expansion aimed at increasing access to higher education, as well as, meeting the high demand for university education in Kenya. By 2017, Kenya had 38 public universities of which 31 had full accreditation and6 public university constituent colleges (see table 2-1 and 2-2).

Table 2-1 Kenya's Fully-Fledged Public Universities

No	Public Universities	Year of Establishment	Year of Award of Charter
1	University of Nairobi	1970	2013
2	Moi University	1984	2013
3	Kenyatta University	1985	2013
4	Egerton University	1987	2013

5	Jomo Kenyatta University of Agriculture and Technology	1994	2013
6	Maseno University	2001	2013
7	Chuka University	2007	2013
8	Dedan Kimathi University	2007	2013
9	Kisii University	2007	2013
10	Masinde Muliro University of Science and Technology	2007	2013
11	Pwani University	2007	2013
12	Technical University of Kenya	2007	2013
13	Technical University of Mombasa	2007	2013
14	Maasai Mara University	2008	2013
15	Meru University of Science and Technology	2008	2013
16	Multimedia University of Kenya	2008	2013
17	South Eastern Kenya University	2008	2013
18	Jaramogi Oginga Odinga University of Science and Technology	2009	2013
19	Laikipia University	2009	2013
20	University of Kabianga	2009	2013
21	Karatina University	2011	2013
22	University of Eldoret	2011	2013
23	Kibabii University	2011	2015
24	Kirinyaga University	2011	2016
25	Machakos University	2011	2016
26	Murang'a University of Technology	2011	2016
27	Rongo University	2011	2016
28	Taita Taveta University	2011	2016
29	The Co-operative University of Kenya	2011	2016
30	University of Embu	2011	2016
31	Garissa University	2011	2017

Source: CUE (n.d.).

Table 2-2 Kenya's Public Constituent Colleges

No	University	Year of Establishment	Year of Award
1	Alupe University College	2015	

2	Kaimosi Friends University College	2015	
3	Tom Mboya University College	2016	
4	Turkana University College	2017	
5	Bomet University College	2017	
6	Tharaka University College	2017	

Source: CUE (n.d.).

In summary, I observe that both the colonial and independent governments defined the history and key developments of the higher education system in East Africa in general, and Kenya in particular. On the one hand, East African countries made their demand for higher education part of their struggle for freedom and the push for nationalism. On the other hand, the British colonial government and missionaries saw the need for higher education as means for evangelism, colonial control, and as the colonial rule ended production of the elites who will take up the political and administrative roles from the colonial government. Thus, by establishing higher education institutions, Britain aimed at producing an educated workforce that could utilise modern science and technology for African societies. This illustrates the colonial legacy of science as discussed in the section above.

The role of both the colonial and post-independent governments is illustrated in different periods. One sees that the 1920s was characterised by the establishment of university colleges that were linked to British universities. The 1960s witnessed the creation of the Federal University of East Africa and its influence and role on higher education in the region. The 1970s was a period when national universities were established through the different Acts of Parliament in East Africa. The 1980s saw the expansion of the university system in Kenya, resulting in the establishment of a second fully-fledged public university and other constituent colleges. These institutional establishments consequently resulted in the growth of student numbers in the universities, constrained budgets from the state and introduction of the cost sharing and increase in the number of private universities in the 1990s. From 2000 till date, the key features deliberated on include establishment of more public universities, increase in the number of universities through the Enactment of Universities Act of 2012, soaring student enrolments, decreased state funding, the introduction of full-fee paying programmes and the increase in the number of degree programmes. The next section discusses research on the history of the National Museum of Kenya and the key developments in research at the museum.

2.6 Government Parastatals: The National Museums of Kenya

The National Museums of Kenya (NMK) is a state corporation established by an Act of Parliament, the National Museums Heritage Act No. 6 of 2006 (Republic of Kenya, 2006). NMK is a multidisciplinary institution mandated to collect, preserve, study, document and present Kenya's past and present cultural and natural heritage. As a parastatal, the NMK is under the auspices of the Ministry of State for Heritage. By 2017, the NMK comprised of nine museums countrywide. However, the history of the origin of the NMK dates back to 106 years ago (NMK, 2010).

The East Africa and Uganda Natural History Society (now East African Natural History Society (EANHS) founded the National Museums of Kenya in 1910. This society comprised of two canons of the Church Missionary Society, Rev. Harry Leakey (father of Louis Leakey) and Rev. Kenneth St. Aubyn Rogers as well as some government officials notably, John Ainsworth and C.W Hobley, doctors, big-game hunters and plantation owners. These nature enthusiasts needed a place to store and preserve their huge collections of cultural and natural specimens. Consequently, Mr Aladin Visram, an Indian merchant, opened the first museum where Nyayo house is currently located, aimed to display a natural history collection. An honorary curator, TJ Anderson, originally managed the museum and Library. In 1914, Mr Arthur Loveridge, a herpetologist, was appointed as the first full-time and paid curator. Considering the increase in the museum collection, the sight was seen to be small (Kiereini, 2016a; NMK, n.d.).

In 1922, a larger building was set up where the current Nairobi Serena Hotel is situated, under A.F.J. Gedye as curator. In 1929, the colonial government set aside land on Ainsworth Hill (today's Museum Hill), and the construction of the museum started at the current site. The Museum hill site was officially opened on 22nd September 1930, and it was named Coryndon Museum in honour of Sir Robert Thorne Coryndon. Sir Coryndon was a British Colonial administrator born in the Cape Colony, South Africa, once a governor of Kenya (1922-1925) and a great supporter of the Uganda Natural History Society. During his governorship, Sir Coryndon established an annual government grant for museums. Following the opening of the Coryndon Museum, the society relocated its expansive library into the museum complex. This collection in part forms the collection of the current NMK Herbarium. Today the Coryndon Museum forms part of the old section of NMK (NMK, n.d.; Kiereini, 2016).

Following the completion of the Coryndon Museum, Dr Van Someren who had served in an honorary capacity in a number of years became the curator. A fulltime Librarian was employed to take care of the growing collections of books and journals. Through a donation by Ernest Carr, a botanist was also employed for three years (Kiereini, 2016a).

In 1941, Louis Leakey joined the Coryndon Museum as an honorary curator, after the resignation of Van Someren. In 1945, Louis Leakey was appointed as a paid curator, building up exhibitions and opened them up for Africans and Asians through lower admission fees. Around the same period of the early forties and early fifties, the late Dr Louis Leakey appealed to the public for a fund to expand the museum galleries, which was granted. The funds enabled the construction of the current galleries next to the NMK main entrance. The galleries were named in honour of the community members who made funds available for the construction: the Mahatma Gandhi Hall, the Agakhan and the Churchill Galleries, among others.

In 1958, Louis Leakey founded the Primate Research[6] Centre in Tigoni together with Cynthia Booth, the today's Institute of Primate Research (IPR), located in Ololua natural tropical forest near, Karen (NMK, 2010). IPR mainly focuses its research on biomedical/animal welfare and conservation aspects using East African primates. Currently, IPR focuses on breeding and use of non- human primate study, prevention and or treatment of diseases with the support of Animal Welfare. The housing facilities of IPR allows breeding colonies of about 270 primates (National Museums of Kenya, 2016b). The institute is recognised as a World Health Organization (WHO) collaborating centre in Human Reproduction and Tropical Disease Research (NMK, 2016b).

In 1960, Kamoya Kimeu, Kenyan's renowned fossil hunter joined the museum, during this time to work under Mary Leakey at Olduvai Gorge. In 1961, Louis Leakey founded the Centre for Prehistory and Paleontology[7] on the same grounds as the Coryndon Museum and moved together with his collections to it, making himself the director. In the same year, Leakey resigned and Robert Carcasson, an English Entomologist specialising in butterflies, became director of the museums from 1961-1968 (NMK, 2010; Kiereini, 2016b).

[6] Primate Research involves primates to provide data on cognitive processes

[7] Paleontology is the branch of science concerned with fossil animals and plants

In the early sixties (1961), the Nairobi Snake Park was started with an aim of it being an attraction and offer a research facility on snakes and the reptiles of Kenya. To date, the snake park continues to be a huge attraction in the museum.

Until 1964, the museum was entirely for the members of the East African Natural History Society. The curators and the visitors were largely Europeans. Mirara notes that the museum was seen as “a forum for dialogue and a colonial agent” (Mirara, 2006:3). The development and collection of exhibitions were under a few individuals. Mirara (2006) claims that, before Kenya’s independence, the curators were not interested in Kenya’s history. Mirara further argues that personal interests drove the curators as they aimed at collecting exhibitions for themselves and other members of the East African Natural History Society. Considering changes in the audience base of the museum base and the interests of the curators, it is argued that, the period after independence, the 1980s and 1990s witnessed changes in the operations of the museums of Kenya. (Mirara, 2006). The next section discusses the developments at the museum after independence.

2.6.1 The National Museum of Kenya: The Independence Years

After independence, in 1964, the Coryndon Museum was renamed the National Museums of Kenya (NMK), thus becoming a national institution. In 1967, Richard Leakey together with other influential Kenyans like Joel Ojal (the government official in charge of the museums then) started the Kenya Museum Associates (now the Kenya Museum Society). The association was intended to ’kenyanise’ and improve the National Museums of Kenya. In 1968, after the resignation of Carcasson, Richard Leakey became the director of the museum, a position that Leakey held for 30 years until 1989 (Kiereini, 2016a).

As a national institution, NMK formed the nucleus of the establishment of museums in Kenya leading to the establishment of new museums at the regional level (Mirara, 2006; NMK, 2010). Since the beginning of 1969, the museum expanded its services and assets beyond Nairobi, including the creation of regional museums in Kitale, Meru, Kisumu, Lamu and Fort Jesus in Mombasa. In addition, the museum took charge of other sites and monuments that had been considered by the government as locations of national heritage. These include, among others, the Kariandusi and Orlorgesailie prehistoric sites, the Hyrax Hill site in Nakuru, the Kobi Fora archaeological site in Turkana district, Thimlich site in Nyanza, the Karen Blixen Museum and the Ololua Forest Environmental and Research Station.

After 1969, the museums have experienced massive growth and diversification. In 1977, Dr Mwangi Mwaniki, then Minister of Foreign Affairs opened the International Louis Leakey Memorial Institute for African Prehistory that currently hosts the archaeology and palaeontology department, under the museum. Similarly, between late 1970 and early 1980s, the museums established collaborations and research and developments programmes. These research programmes have seen cooperation with the University of Nairobi and the Institute of African Studies, focusing on ethnography and cultural anthropology. The Institute of Primate Research and the Research Institute of Swahili Studies of East Africa were established during the early 1980s.

In 1989, Dr Mohamed Isahakia, became the first African director of the National Museums of Kenya and subsequently Director-General, initiating a period of scientific expansion into biodiversity and institutional reorganisation. Mohamed held the position for 10 years until 1999. Dr George Abungu took over as Director-General of National Museums a position he held for two years. In the late 1990s, NMK was funded by the European Union, 8 million Euros, within the framework of National Museums of Kenya Support Programme (NMKSP), to support the museum's expansion. It was until the mid-2000's that the project was started. The "Museum in Change Programme", as is popularly referred to, was aimed at making NMK "an outward-looking institution that responds to visitors needs while providing quality products and services" (NMK, 2016, n.p). Similarly, the museum was expected to participate in development through its research programmes and ensure that the research findings are incorporated in development projects. The programme comprised of four components including, infrastructure, NMK's legal reform (preparation of the heritage bill), organisation review and public programmes (NMK, n.d.).

In 2005, the Nairobi Museums was closed to allow for the major expansion and modernisation, as well as the development of exhibitions. In 2006, the then president of the Republic of Kenya, Hon. Mwai Kibaki re-opened the new Nairobi National Museum (NMK, n.d, n.p). In 2008, Nairobi Museums was re-opened to the public after the two-year closure. In 2010, The NMK Endowment Fund (NMKEF) was launched by the then Minister of State for National Heritage and Culture, William Ole Ntimama, with an inaugural art auction. The NMK board of directors established the NMKEF to create a revolving fund that will support heritage research and activities in Kenya (NMK, n.d.). The next section highlights some of the key researches conducted at the museum over the years.

2.6.2 National Museum of Kenya: Key Research over the years

Since its establishment, in 1910, the National Museum of Kenya has become a treasure for East African. The National Museum of Kenya houses some of the significant discoveries in palaeontology, including some of the oldest hominid fossils. In 1919, John Walker, a British Geologist discovered Olorgesailie a lower Paleothilic archaeological site. Currently, the excavations at Olorgesailie continue under Dr Rick Potts in collaboration with the Smithsonian Institution, USA (Lagat, 2017). In 1928, Louis Leakey discovered the Acheulian site of Kariandusi and began excavations. Later in 1932, Louis Leakey started work in Kanam and Kanjera on the North-Eastern side of Lake Turkana in and made his first discovery of human origins. This discovery marked the beginning of Leakey's and NMK's legacy in paleoanthropological studies. In 1947, an excavation team in Rusinga Island found Miocene mammals dated 18 million years. In 1948, Mary Leakey found a complete skull of proconsul Africanus. The Excavation was done by Heselson Mukiri, Mary's field assistant (Leakey, 1974; Lagat, 2017).

For research continuity, in 1968, Louis Leakey created the Louis Leakey Foundation in the US, to support Louis and Mary Leakey's fieldwork and the research of young scientists in palaeontology. Today, the Leakey's foundation continues to fund human origins research in the US and Kenya (Leakey, 1974; Lagat, 2017).

In 1972, during a research expedition led by Richard Leakey, there a spectacular discovery by Richard Ngeneo of ER 1470 a Homo Habilis skull. The skull is estimated to be 1.9 million years, said to be the most complete skull of Homo Habilis. In 1984, Kamoya Kimeu on a research expedition led by Richard Leakey discovered a 1.6-million-year-old almost complete skull of a 9-12-year-old Turkana boy. This is the oldest known specimen of Homo erectus in human history. In 1994, Peter Nzube discovered Australopithecus Anamensis in a research team led by a paleoanthropologist Meave Leakey at Kanapoi on the shows of Lake Turkana; estimated to be 4 million years old. Justus Erus discovered Kenyanthropus platyops in a research team led by Kyalo Manthi at Lomweki in 1999. Estimated to 3.5 million years; this is NMK's latest additions to human origins craniums (Leakey, 1974; Lagat, 2017).

The researches discussed above support and safeguard the heritage that has been conducted in collaboration with other researchers locally and internationally. These development and collaborating partners include Birdlife International, Cambridge University (Prof. John Cooper), European Commission, Flemish Association for Development Cooperation & Technical

Assistance (VVOBO), Missouri Botanic Gardens, Nature Kenya (East African Natural History Society), Rutgers University, School of Oriental Studies, London University (SOAS), Swedish International Development Agency (SIDA), The American Embassy in Nairobi (Ambassadors Fund). Others include The British Museum, The Germany Embassy, The French Embassy, The Japanese International Co-operation Agency (JICA), The Kenya Museum Society, The Louis Leakey Foundation, and The paleontological Scientific Trust (PAST) of South Africa, The Royal Botanic Gardens Kew, The Royal Netherlands Embassy, and The Smithsonian Institution. The other partners included The Wenner-Gren Foundation for Anthropology, The World Health Organization, United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the University of Leuven – Belgium (NMK, n.d).

In summary, we see that since its establishment, the National Museum of Kenya has had key contributions in the following researches: archaeology, primate research, palaeontology and biodiversity. Over the years, I observe that these researches have received funding support from individuals, the Government of Kenya, international donors and other developmental partners. Given the collaborative nature of funding of research at the NMK, research at NMK has involved collaborating researchers at the international level from the United States, the Netherlands, the United Kingdom, Belgium and Japan among other countries.

2.7 Conclusion

The discussion above provides a historical account of the science system and scientific institutions in Kenya. This chapter discusses the history of research institute, especially those involved in agricultural and medical research, and the higher education institutions and international research institutes. The discussion of the history and development of science in Kenya raises a number of perspectives in the science system. I observe the existence of 'colonial legacies in science' as seen in collaborations of the universities and research institutes in Kenya/other East African countries and their colonies. In addition, I noted that the research institutes established during the colonial period still exist and are some of the high performers in terms of publications in Kenya. Apart from the colonial efforts in establishing research institutions in Kenya, I show that the nationalists/post-independent governments also made efforts in establishing universities, research institutes, and advisory bodies needed to support science and technology. I also observe that both the colonial government and post-independent governments supported research production and training of human resources needed for research and society. The discussion also shows that, since the beginning of formal research in Kenya, research support has come from different sources, including the government, external donors and sale of goods and services. This chapter also points to the fact that individuals, organisations or other countries involved in the establishment of research institutions also shaped the later collaborations of these institutions. These observations point to the fact that several actors, which have ensured the performance of this system, have influenced Kenya's research system.

In the next chapter, I provide a discussion of the science technology and innovation landscape for Kenya. The next chapter focuses on science technology and innovation policies and how they have evolved. The next chapter will also look at the governing institutions of science and technology.

Chapter 3 The Kenyan science system: Governance and institutional landscape

3.1 Introduction

The Science, Technology and Innovation system of a country is often defined as a set of functioning institutions, organisations and policies, which relate and “interact in the production, diffusion and use of new, and economically useful, knowledge” that ensures the pursuit of a common set of socio-economic goals and objectives (Godin, 2007:7). According to Godin (2007), the National Innovation System emphasises “the relationships between the components or sectors as the ’cause' that would explain the performance of the system. This study follows the National Innovation System (NIS) framework as espoused by Kuhlmann and Arnold in various writings (Arnold, 2004; 2012; Kuhlmann, 2003, 2014; Kuhlmann & Arnold, 2001). The National Innovation System (NIS) framework (Figure 3-1) illustrates several dimensions that are at the centre of science, technology and innovation in a country: demand, framework conditions, industrial system, intermediaries, education and research, political system and infrastructure. Most of the dimensions on this framework are applicable to the STI systems, and subsystems, in high-income countries. Developing countries such as Kenya often lack a strong industrial system that performs and funds research. Inasmuch as some dimensions of the NIS are weak in the developing countries, the historical analysis (see chapter 2) shows that other components – such as the presence of international research performing institutions – play a stronger role in developing countries. We return to this later in our discussion of the STI landscape in Kenya.

This chapter is divided into two main sections. The first section focuses on the political system, which involves a discussion of the governance of the system, the roles of government and government ministries in STI and the education and research and intermediaries of Kenya’s science system. The second section of the chapter discusses the science landscape of the system following the framework below: the education and research system that comprises of higher education and research, public sector research, professional education and training. This section also discusses the intermediaries (research institutes) and the international research organisations which also form part of Kenya’s science landscape. Although Kenya has a weak industrial system that supports and contributes to the STI in the country, the analysis of research output (see chapter 7) show that almost negligible publication output is produced by private companies or SMEs, thus this chapter discusses some of these companies and SMEs.

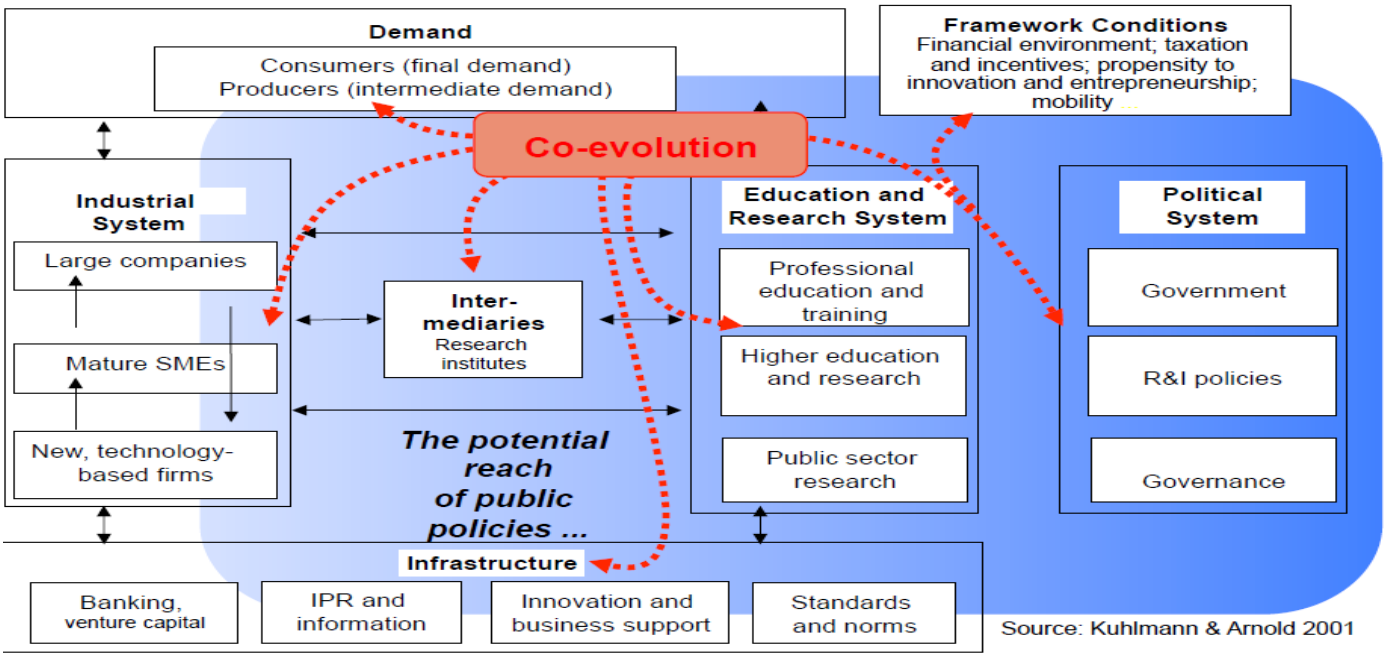

Figure 3-1: A national innovation Systems model

Source: Arnold (2004), Kuhlmann and Arnold (2001)

3.1.1 Political System

The political system as a dimension of the NIS includes both government, science, technology and innovation policies, on the one hand, and the governance structures, on the other. In the context of the evaluation of the science system, Arnold (2004) identified the following key institutional blocks of the political system:

- effectiveness of the policy intelligence and analysis function(s);
- research and innovation policies; policy mix
- effectiveness of the institutional structures and the division of labour in devising and implementing R&D and innovation policies.

Studies have shown a positive relationship between effective governance and scientific productivity (Kraemer-Mbula & Scerri, 2015). Based on this background, the next sections of this chapter discuss the role of Kenya's government in STI (e.g. role of different ministries), the science technology and innovation policies and the governance of the system.

3.1.2 The Education and Research System

The education and research dimensions comprise of several elements or actors: professional education and training, higher education institutions and research and public sector research organisations. The actors in the education, research system and intermediary structures (knowledge infrastructure – higher education institutions) play a key role in the performance of the system (Arnold, 2004; Kuhlmann & Arnold, 2001). The strategic decisions made by the different institutions (universities, research institutes and centres) in a system influence the performance of the larger NIS system. The interactions between research institutions are important for the performance of the institutions. Godin (2009) notes that, what is important to the overall performance of the system is not largely dependent on how the individual institutions perform or contribute to the science base, but rather the interactions with each other. Apart from the interactions between institutions, Arnold (2004:6) states that the "historical path dependence" of the institutions in the system are a key aspect to consider in the performance and when evaluating a system. In relation to "historical path dependence", Arnold elaborates that the decisions made earlier and how the institutions could perform previously and the learning processes that have happened influence the current and future performance of the system. In the context of the evaluation of a research system, Arnold (2004:5) provided a listing of the "institutional blocks" of the actors in the education, research and intermediary structures. These are:

- the capacity and quality in research education;
- participation in higher education and research training;
- strategic/managerial performance;
- effectiveness of interacting and interfacing with other parts of the science system

According to Arnold, research institutions and their environments are inter-dependent. In essence, the different actors in the system do not work autonomously, that is, "the performance of the individual firm or institution and the system as a whole are inter-related" (Arnold, 2004:5). The inter-relationship between the institutions in the education and research system has an influence on the performance of the system.

3.1.3 Framework conditions

Arnold (2004) further argues that the framework conditions (financial environment, taxation and incentives) within which the institutions operate and interact shape the performance of a system. These elements include consistency of the regulatory and facilitative environments and their implementation with R&D, innovation and change. Among others, these environments provide rules that govern research collaboration, research financing, and researcher mobility and policy direction.

3.1.4 STI Infrastructure

Science infrastructure is key in the evaluation of a research system. Arnold argued that the provision of infrastructure must be adequate; as well as, effective and efficient in its operation. Infrastructure includes banking, standards and norms, among others, which may shape the performance in a STI system. The authors also show that demand and supply drive research and innovation. This is determined by elements like the receptivity of the consumers/buyers of products from R&D and innovation. Therefore, the demand for enhanced skills and knowledge from the research system may also shape its performance (Arnold, 2012).

3.1.5 Kenya's National Science and Innovation System

In this section, I present an overview of Kenya's national science and innovation system, modelled against the above framework. Figure 3-2 below is a diagrammatic representation of the different components and institutions that form the Kenya's National Science and Innovation System.

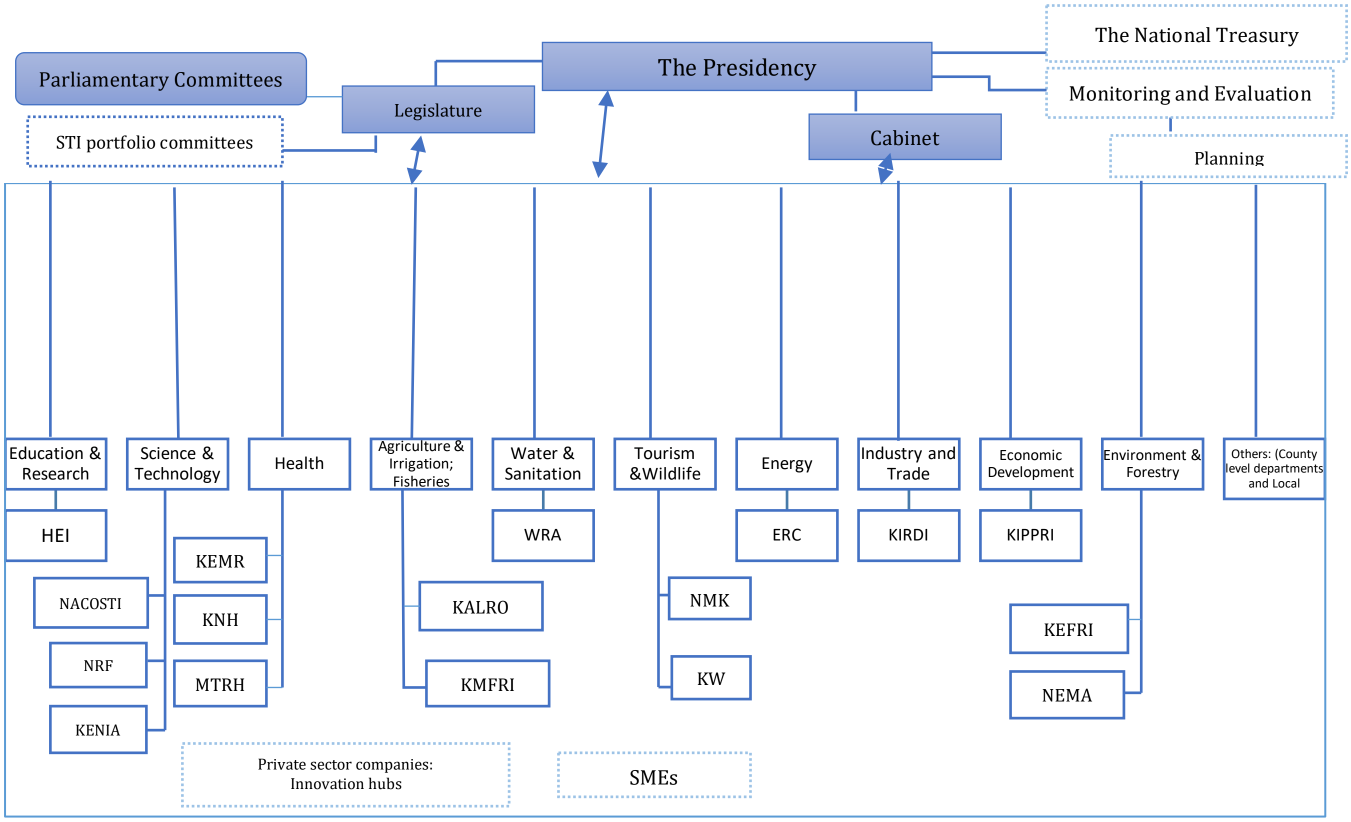

Figure 3-2: Kenya's National Science and Innovation System.

Kenya's national science and innovation system comprises of the following key elements and stakeholders: the presidency composed of the national treasury and the cabinet, the legislature, the National Council for Science and Technology; Research Institutes; universities; Kenya Industrial Property Institute (KIPI); micro, small and medium enterprises (SMEs); passionate innovation stakeholders; and innovation hubs, among others" (Republic of Kenya, 2012:13). The different institutions interact and interrelate to ensure the functioning and performance of Kenya's national science and innovation system. The structures and responsibilities of these institutions, especially in science, technology and innovation are discussed in the next sections.

Section one: Science Technology and Innovation Governance and Science Policies

3.2 Governance of science, technology and innovation

In order to enhance "on the development, acquisition, utilisation and dissemination of STI" the policies and strategies directing science sought to create key institutions that will compose the governance system. These institutions provide "a governance framework to support autonomy, coordination, gender parity and partnership-based applications of STI" (Republic of Kenya, 2012:20). These institutions include: the ministry directing Science, Technology and Innovation, the Department in charge of Science Technology and Innovation, the National Commission for Science, Technology and Innovation, the Kenya National Innovation Agency (KENIA) and the National Research Fund. These institutions play different roles, as discussed below, to ensure governance of the science system.

3.2.1 Government Ministries and Parliament

The government plays a central role in the science, technology and innovation system as it ensures that the different dimensions of the NIS, that is, the demand, the framework conditions, the political system, the education and research system, the intermediary organisations, the industrial system and the business system interact effectively to ensure the performance of the system. The government has central coordinating ministries that are involved in the STI matters and have cross-cutting functions. These ministries include The Office of the President, concerned with the appointment of managers to research and development institutions. The Ministry of Planning and National Development has the mandate of integrating STI into national development plans. Lastly, the Ministry of Finance plays a key role in providing funds for STI (Gacuhi, 2000).

In addition, line ministries are those ministries involved in the management of the specific STI portfolios in the government. They include the ministry of health, water development, industry, agriculture, education, energy, research and technology, environment and natural resources. These ministries are responsible for identifying needs in specific areas of STI and formulation and implementation of sectoral strategies and plans. Apart from the government sector, the private sector, business associations and corporations consisting of private firms, businesses and consultants are also responsible for the STI outputs are key for their competitiveness in the economy. Figure 3-3 below provides an illustration of the governance system of Kenya.

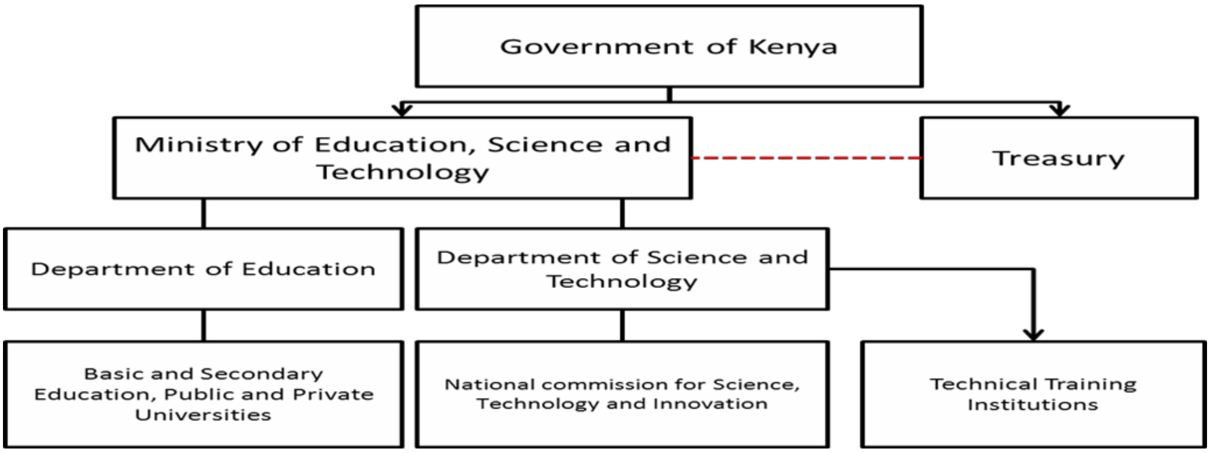

Figure 3-3: Governance of Kenya's science system

Source: Swanepoel (2015)

3.2.1.1 The Ministry of Education, Science and Technology

Over the years, the Kenyan government has created and mandated various ministries to oversee science and technology in the country. The ministries were responsible for promoting science and technology in the country, create the financial, human and infrastructural resources for science and technology and enhance the country's efforts to create, apply and adopt suitable science and technology for socio-economic growth. The governance of science was first under the Ministry of Regional Development, Science and Technology first established in 1982, which later became the Ministry of Research, Science and Technology in 1987. The Ministry of Research, Science and Technology oversaw science and technology in the country, underwent disbandment in 1999 and its functions integrated into the current Ministry of Education, Science and Technology. The current Ministry of Education Science and Technology formed after the integration of the Ministry of Education and the Ministry of Higher Education Science and Technology.

The Ministry of Education, Science and Technology (MoEST) is charged with the overall role of overseeing science and technology in Kenya. In addition, the Ministry of Education, Science and Technology play the coordination role of STI at the systemic level together with the

National Commission of Science Technology and Innovation. The Ministry is responsible for Science Technology and Innovation Policy, University Education, public and private universities and tertiary institutions, management of institutes of science and technology, and the National Council for Science and Technology (Republic of Kenya, no date).

The Department of Science and Technology (DST) housed by the Ministry of Education, Science and Technology is responsible for policy formulation and implementation of science, technology and innovation. The objective of creating the department was to enhance competitiveness in the fields of Research, Science, Technology and Innovation (RST&I) through creation, dissemination and use of knowledge for sustainable development and implementation of RST&I policies" (Ministry of Higher Education Science and Technology [MHEST], 2012:25). Additionally, the Department of Science and Technology ensures promotion and coordination of the interaction between the industry and trade, centres of research and education, and strengthening the industry and research policies. The DST performs several functions: First, formulation, review, coordination and implementation of policy on national research, science, technology and innovation. Secondly, promote strategic regional and international linkages, collaboration and cooperation in STI. Further, the DST has to ensure management of the nation's RSTI investment and ensure that the investment adds value to the economy (MHEST, 2012). The Department of Science and Technology hosts the National Commission for Science and Technology (NACOSTI), the Kenya National Innovation Agency (KENIA) and the National Research Fund (NRF).

3.2.1.2 The Ministry of National Treasury and Planning

The Ministry of National Treasury and Planning is committed to the implementation of the policy goals adopted from the government's economic transformation agenda, with attention to the prioritisation that it has given to improving affordable housing for all, food security, providing affordable healthcare, improving the manufacturing industries and moving the country forward under the three pillars of national cohesion and unity ("Umoja"), economic transformation ("Uchumi"), and transparency and accountability ("Uwazi") (GOK, n.d.)[8]

The Ministry's core objectives include:

- To strengthen planning and policy formulation at all levels
- To strengthen linkages between planning, policy formulation and budgeting at all levels

[8] http://planning.go.ke/

- To Contribute to National Competitiveness through Regional and International Economic Cooperation
- To improve tracking of implementation of development policies, strategies and programmes
- To enhance co-operation between Kenya and regional and international economic institutions.
- To provide policy guidance, capacity building and support as well as oversight, management and development support for the RDAs
- To coordinate the implementation, monitoring and evaluation of the SDGs

3.2.1.3 The Ministry of Agriculture, Livestock, Fisheries and Irrigation

The mission of the Ministry of Agriculture, Livestock, Fisheries and Irrigation "to improve the livelihood of Kenyans and ensures food security through the creation of an enabling environment and ensuring sustainable natural resource management" (GOK, n.d.)[9].

The ministry's core functions include:

- Formulation, implementation and monitoring of agricultural legislation, regulations and policies
- Supporting agricultural research and promoting technology delivery
- Facilitating and representing agricultural state corporations in the government
- Development, implementation and coordination of programmes in the agricultural sector
- Regulating and quality control of inputs, produce and products from the agricultural sector
- Management and control of pests and diseases
- Collecting, maintaining and managing information on the agricultural sector

3.2.1.4 The Ministry of Health

The mission of the Ministry of Health is "to build a progressive, responsive and sustainable health care system for accelerated attainment of the highest standard of health to all Kenyans" (GOK, n.d.).

The ministry has the following key mandates

- health policy
- health regulation

[9] http://www.kilimo.go.ke/?page_id=90

- National referral health facilities
- Capacity building and
- Technical Assistance to counties

3.2.1.5 Ministry of Industry, Trade and Cooperatives

The mission of the Ministry of Industry, Trade and Cooperatives, is to create an enabling environment for a globally competitive, sustainable industrial, enterprise and co-operative sector through appropriate policy, legal and regulatory framework, among others, have the following core functions:

- Industrialisation Policy
- Kenya Property Rights Policy (Patents, Trade Marks, Service Marks, and innovation)
- Private Sector Development Strategy
- Quality Control including Industrial Standards
- Co-operative Policy and Implementation
- Co-operative Financing Policy
- Micro and Small Enterprise Development
- Co-operative Education and training

The above ministries interact with the regulatory and advisory bodies discussed below to ensure the governance of the system. The discussion focusses on the formation of the bodies as well as their major functions.

3.2.2 STI regulatory and advisory bodies

This section discusses the regulatory and advisory bodies in the Kenya's science system.

3.2.2.1 The National Commission for Science Technology and Innovation (NACOSTI)

In 1977, the Science and Technology Act (Chapter 250) was enacted following the need to institutionalise mechanisms of coordinating and promoting science and technology in the country (NCST, 1984). The Science and Technology Act established the National Council for Science and Technology (NCST). NCST was mandated to formulate science and technology policy advice for the government on all matters related to science and technology, particularly, planning and coordinating research. Apart from these broad mandates, NCST had inter alia the following key functions:

- to determine priorities for scientific and technological activities in Kenya in relation to the economic and social policies of the Government and its international commitments;

- to advise the government on national science policy, including general planning and the assessment of the requisite financial resources;
- to ensure the application of the results of scientific activities to the development of agriculture, industry, and social welfare in Kenya;
- to advise the Government on the scientific and technological activities requirements for the conservation of the natural and social environment in Kenya;
- to ensure co-operation and co-ordination between the various agencies involved in the machinery for making the national science policy; and
- to promote public confidence in scientific expenditure and an atmosphere conducive to scientific activities.

In 2013, the Kenyan government created and implemented the Science Technology and Innovation Act of 2013 (No. 28 of 2013) (Republic of Kenya, 2013). The enactment of the STI act of 2013 Act established the National Commission for Science, Technology and Innovation (NACSTI) replacing the National Council of Science and Technology (NCST) (MHEST, 2012; Ministry of state for planning National Development and Vision 2030, 2012). NACOSTI is a semi-autonomous body, with its own legal entity, housed under the Ministry of Education Science and Technology. NACOSTI has a board of management comprising of representatives from the MEST and Ministry of Finance, the Directors of NRF and KENIA, together with three STI experts and a representative from the (MHEST, 2012; Republic of Kenya, 2013).

NACSTI has the mandate "to regulate and assure quality in the STI sector and advise governments on all matters of science, technology and innovation" (MHEST, 2012:26). NACSTI is also in charge of the coordination of the sector, that is, ensure co-operation between the various agencies involved in STI. Together with the Kenya National Innovation Agency (KENIA) and the National Research Fund (NRF), NACOSTI is supposed to ensure funding and implementation of prioritised research programmes. Lastly, NACOSTI is also tasked with the regulation of the sector, that is, conduct regular quality audits of the public research institutes in Kenya and approve of the research activities performed in Kenya.

3.2.2.2 Kenya National Innovation Agency (KENIA)

The STI Act of 2013 also established the Kenya National Innovation Agency (KENIA), which is a 'body corporate', tasked to develop and manage the Kenya National innovation system. The agency needs to institutionalise linkages between universities, research universities, private industry, government and other actors in the national innovation system. KENIA is tasked with the creation of specialised innovation centres of excellence in priority sectors. The agency needs to promote and nurture innovative ideas from individuals, training institutions, private sector and other STI Institutions through funding innovation prizes and any other assistance. The agency also has the role of promoting knowledge on intellectual property rights (MHEST, 2012; Republic of Kenya, 2013).

KENIA was formally created in 2016, starting with an Acting CEO and a secretariat of two other staff. KENIA has a board of management constituting of representatives from the MEST, a representative from a body linking academia and industry, director of NACOSTI and four STI experts. As stipulated in the STI Act, the National Innovation Agency will establish offices in the counties to perform its core functions, including promoting innovation, scouting for innovations, protecting IP and facilitating incubation and commercialisation (MHEST, 2012).

3.2.2.3 National Research Fund (NRF)

The STI Act of 2013 also established a National Research Fund (NRF. The NRF through its board of trustees has the mandate “to mobilize and manage financial resources for the Kenya National Information System” needed for the creation of knowledge, innovations and development in all fields of STI. The NRF is managed by a board of trustees who play the following key functions, among others:

- ensure proper management and investment of the funds from the government, international funders or donors, private sector and industry;
- Support development of human resources through grants, scholarships or bursaries to individual scientists or research institutions;
- Provide financial support for the development of STI infrastructure in universities, research institutions or universities; and
- Support the development of research capacities in the national priority areas of science and technology innovation.

The NRF has developed funding schemes or absorbing previous schemes from NACSTI, which include grants, scholarships or bursaries as well as support for conferences, workshops, seminars and meetings among others (MHEST, 2012; Republic of Kenya, 2013).

According to the STI Act of 2013 in section 32(2), the initial fund of the NRF will be from the government, not less than 1% of the Gross Domestic Product from the treasury every financial year. The other sums of the money may include donations, endowments, grants and gifts from different sources and designated for the Fund. The establishment of the NRF formally commenced in November 2014, as provided in the STI Act of 2013. This resulted in the appointment of the independent NRF Board of Trustees, formally gazetted on 24th of July

2015, and inaugurated on November 2015. In early 2016, there have been calls for the disbandment of the NRF by the minister of science and education, citing a replication of functions performed by existing institutions, such as NACSTI. Since its establishment, it is only in October 2016 that the NRF launched its first call worth Kshs. 130 million (US$ 1.2m). Its claimed, the NRF executed their mandate immediately by making their first call, to avoid the disbandment of the NRF board (Waruru, 2016). However, this has resulted in increased concerns on how the country will increase its Gross Domestic Expenditure on Research and Development (GERD).

3.2.3 Science, technology and Innovation Policies

Since its independence from the British colonial administration in 1963, Kenya has adopted several strategies and policies for its economic development. The initiatives to promote and support science, technology and innovation were mostly instilled in the country's developmental plans for the periods of 1970-1974 and 1974 to 1978 (Republic of Kenya, 1974; 1978) and later the current Vision 2030 (Republic of Kenya, 2008). The different governments during these different periods believed in the key role of science and technology plays in economic development, hence the need for continuous efforts to look for machinery for policy-making in science and technology.

In Kenya, the recognition of science, technology and innovation was first evidenced in the establishment of the Science and Technology Act, 1977. The Science and Technology Act, 1977, Chapter 232, that led to the establishment of the National Council of Science and Technology (NCST). In the next section, I provide a historical account of the initiatives of the Government of Kenya towards the enactment of the Science and Technology Act, 1977. These initiatives comprised of two main phases: the enactment and amendment of the Science and Technology Act. I also present the reasons the government preferred the NCST secretariat for science policy. The section also highlights the challenges the government faced in the formulation and implementation of the Science and Technology, Act 1977.

3.2.3.1 Enactment of the Science and Technology, Act 1977

This section provides a discussion on the implementation of a policy of science and technology. This entails a discussion on the establishment of National Council of Science and Technology and later the enactment of the Science and Technology Act.

3.2.3.1.1 The establishment of the National Council of Science and Technology: 1964 to 1970

It is not clear as to when the government of Kenya began thinking of a formal mechanism to make and implement a policy for science and technology and research in Kenya (NCST, 1984, n.p.). Based on the available information, the preliminary moves seem to have been initiated in January 1964, when, the Ministry of Economic Planning and Development in a letter to the Office of the President indicated that there was "no centralised responsibility for the formulation of science policy in this country" (NCST, 1984, n.p.). This followed suggestions that this responsibility, formerly under the Treasury on an ad hoc basis, should be taken by the Ministry of Economic Planning. This stage only involved the Ministries of Finance, Education and Natural Resources and Wildlife (NCST, 1984).

The following years involved an interchange of ideas within the government and later engaging the ministries of agriculture and health, followed by interventions by the University of Nairobi and the East African Academy. At this stage, the deliberations mostly involved the need for a council or a commission for science policy-making. An agreement was reached on the need for inter-ministerial decision-making and the formulation of an advisory body. However, major problems emerged in relation to its scope and membership (Martin, 1977; NCST, 1984).

In 1966, the East African Academy (EAA) suggested the creation of a research council with issues stemming from its relations with the East African community and its research councils: the EA Natural Resources Research Council and the EA Medical Research Council. At this stage, differences emerged about the nature of the body, manifested in the suggested titles such as “National Science Council”, or, “National Research Council”. In 1968, a fourth draft of the Act of Parliament was drafted, emphasising on “science policy than research coordination” (NCST, 1984: n.p).

During this same period, the Ministry of Agriculture proposed the establishment of an 'Agricultural Advisory Research Council'. However, following the uncertainty regarding the research coordination role of the 'National Science Council', the Ministry of Agriculture withheld the implementation of its proposals on the basis that there was no need for two research councils. There were deliberations with the Attorney General’s office of the National Research Council being made a statutory organisation (Martin, 1977; NCST, 1984).

In 1969, the Ministry of Economic Planning and Development prepared the fifth draft for a “National Science and Research Council” for the cabinet, while several ministries suggested amendments. In 1970, the Ministry of Agriculture prepared a sixth draft regarding its

'Agricultural Advisory Research Council' as ‘complementary’ to the national council. Several of these issues were unresolved by the end of 1970; thus, there is no acceptable memorandum and bill to the cabinet for approval.

The government’s initiatives in relation to science and technology in the country remained clear as its stipulated in the country’s developmental plan of 1971/1974 (section 3.21 to 3.22:79, 80) (Republic of Kenya, 1974). According to the Government, based on “historical reasons” there was no close integration of scientific research into national developmental goals. Thus, the government suggested that to ensure integration of research in national development, the establishment of a national research and the scientific council is important. As signalled earlier, the council’s mandate was to advise the government on all matter science and technology (Republic of Kenya, 1974). This council was to represent both the government and non-government interests. The council was also meant to have sub-committees that deal with specific fields. The council would make recommendations to the government annually of a harmonised research budget and finally, the council was also required to have “evaluation machinery” to measure the benefits of research.

3.2.3.1.2 The initiative towards the Science and Technology Act: 1971 – 1977

From the start, in January 1964, the government contacted UNESCO/UNDP for advisory services in establishing the “necessary machinery for science policy-making”. However, the mission with UNESCO was postponed following lack of a decision on the part of the ministry or office where the council would be affiliated. The government renewed the request with UNESCO/UNDP in early 1971 following the stalemate reached in 1970, and it was agreed on the council was attached to the Planning Division of the Ministry of Finance and Planning (NCST, 1984:n.p).

In the latter half of 1971, the status of science and technology in Kenya was assessed which resulted in several “new discussions” in relation to issues involved. The evaluation was important in determining the government’s expenditure on Science and Technology and “their organizational complexity”. These discussions also involved incorporation of the government, higher education and private sectors as well as the clarification on the “scope of science policy-making and research coordination” as a key role of the council and ensure the involvement of all those concerned.

During this period, the study conducted on science and technology activities and expenditure on R&D in the country and the organisation of science revealed, “there was a vacuum in government organisation at the policy and management level” (Martin, 1977:4). This process in the government sector involved all the technical ministries as well as the office of the president. The Ministries of Finance and Planning, Education, Health, Commerce and Industry, Cooperative and Social Services, Housing, Works, Power and Communications, Agriculture, Natural Resources, Tourism and Wildlife and Lands and Settlement. Others involved were the higher education and the private sector. All these sectors unanimously declared support for the establishment of a mechanism for making science policy (Martin, 1977:5).

Following the discussions in the later 1971, the Ministry of Finance and Planning sought approval for the establishment of the policy-making machinery through a 'Science and Technology Bill' to the Cabinet and National Assembly. Inter-ministerial meetings of February 1972 and April 1972 resulted in a consensus in relation to the proposal. The proposal was later also approved by scientists in higher education institutions and research institutes (NCST, 1984).

The efforts of the government in establishing a science and technology policy-making machinery were again resumed and restated in the 1974/1978 Developmental plan, in the chapter on "Science Technology for Development". The Development plan restated the functions of this body, including determining scientific priorities, advisory role on national science policy, ensuring scientific application to development and ensuring coordination between the agencies involved in science policy making, among others.

In November 1974, the Science and Technology Bill was re-introduced to the Cabinet following some terminological amendments especially on the title and responsibility of the National Environment Secretariat. Others include the addition of the Ministry of Water and Development and the Ministry of Foreign Affairs to the membership of the NCST. In December 1975, the Science and Technology Bill was gazetted following the Cabinet's approval.

Earlier on before the gazettement of the Bill, with the assistance of the Science Advisor from UNESCO, in April 1975, there was a recruitment of a "nucleus secretariat" consisting of the Secretary and two Science Assistant Secretaries (initially referred to as Scientific Assistants (NCST, 1984:n.p). The Government established the secretariat for it to gather data and prepare working papers for NCST. The Secretary to the council also conducted studies of science policy in other nations (Martin, 1977:44).

In March 1976, the Bill underwent its first reading in the National Assembly. In December 1976, the Bill passed its second reading, committee stage and the third reading followed at the same time without any amendments. On 1st March 1977, the President assented to the Science and Technology Act No. 3 of 1977. The Science and Technology Act:

> An Act of Parliament to establish machinery for making available to the Government advice upon all matters relating to the scientific and technological activities and research necessary for the proper development of the Republic; and for the co-ordination of research and experimental development; and for matters incidental thereto and connected therewith (Republic of Kenya, 1980:3).

The Science and Technology Act established the NCST and it commenced its functions in July 1977. However, as indicated earlier, prior to this period in 1975, the council's secretariat was already operational. In October 1977, the then Minister of Finance and Planning inaugurated the council. In addition, the Science and Technology Act established four advisory research committees in the fields of agriculture, medical and natural sciences. Among other roles, the advisory research committees had to advise on the details of the research programmes and projects required to implement the research priorities arising from the national science policy.

3.2.3.2 The amendment of the Science and Technology Act, 1977

In 1979, the Science and Technology Act was amended resulting in the establishment of five semi-autonomous research institutes, including: Kenya Agricultural Research Institute (KARI), Kenya Medical Research Institute (KEMRI), Kenya Trypanosomiasis Research Institute (KETRI), Kenya Industrial Research and Development Institute (KIRDI) and Kenya Marine and Fisheries Research Institute (KEMFRI). In 1986, the Kenya Forestry Research Institute (KEFRI) was created, resulting in the forestry research activities of KARI being transferred to KEFRI through a legal notice (see table 3.1 for the details on the research institute). According to the Science and Technology Act No. 7 of 1979, the functions of the research institutes include:

a. "to carry out research in agricultural sciences, natural sciences, industrial sciences and medical sciences;
b. to co-operate with organisations and institutions of higher learning in training programmes and on matters of relevant research;
c. to liaise with other research bodies within and outside Kenya carrying out similar research;
d. to disseminate research findings; and
e. to co-operate with the responsible Ministry, the Council and the relevant Research Committee, in matters pertaining to research policies and priorities" (Republic of Kenya, 1980:9).

The research institutes have a Board of Management established for each of them, comprising:

- the Permanent Secretary of the responsible Ministry or his representative;
- the secretary of the council or his representative;
- the secretary of the relevant Research Committee;
- the Director of the Research Institute, who shall be the secretary of the Board; the Permanent Secretaries of the participating ministries and or their representatives; and
- at most seven members, appointed by the responsible Minister, who shall be qualified persons in the research institutes' research activities (Republic of Kenya, 1980).

The relevant government ministry (line ministry) supervises the operations (salaries, operational costs and some amount of development funds) of each institute and finances it through parliamentary grants. The Act also allowed the transfer of research resources and programs from the relevant government ministries to the specific research institutes. The NCST was responsible for the assessment of the programs and financing of each research institute and advise the government on the budgets needed to start-up research programs.

Before the enactment of the Science, Technology and Innovation Act of 2013, line management and decision-making between the relevant Ministry, NCST and the public research institutes were as follows: firstly, the government comprised of several Ministries including the Ministry of Education Science and Technology (MEST). Second, MEST hosted the National Council of Science and Technology however several other ministries were involved since STI components exist in the different ministries or sectors. Public research institutes were under the line management of respective parent Ministries e.g., KEMRI was line managed by the Ministry of Health. However, there were changes depending on whether science and technology were under the Ministry of Science and Technology or whether S&T was under the Ministry of Education. For instance, during the period of 1987 to 1999, there was a separate Ministry of Science and Technology in Kenya. During this period, public research institutes were under the line management of this Ministry. In 1999, the Ministry of Science and Technology was disbanded, and the relevant ministries took charge of the public research institutes, for instance, KARI was under the line management of the Ministry of Agriculture. As of 2019, matters of science and technology fall under the Ministry of Education, therefore, the line management of research institutes falls under the respective parent ministries.

Studies have shown that the hosting of science and technology activities under different ministries over time has resulted in difficulties in addressing and considering science and technology issues fully (Hanlin, 2017:12). This is a challenge Kenya's STI continue to face to date.

3.3.2.3 Recent priorities in science and technology policy

This section discusses the recent priorities in Science and Technology in Kenya. The discussion focusses on the STI initiatives embedded within vision 2030 and the enactment of the recent STI 2013 Act. 3.3.3.3.1 The launch of Kenya's Vision 2030 initiative

As signalled earlier, the Government of Kenya has had its initiatives in science, technology and innovation clearly stipulated in its development plans (e.g. development plans 1970/74; 1974/78); thus, they have influenced the implementation of STI policy and promotion of STI in Kenya. In 2008, the Government of Kenya launched the Development Plan, Vision 2030, which acknowledges the application of science, technology and innovation for national development and economic growth.

Kenya's Vision 2030 and the Millennium Developmental Goals are strategies adopted by Kenya to ensure reduced poverty and access to basic needs by most of the Kenyan populace. The Vision 2030 "aims to transform Kenya into a newly industrializing, middle-income country providing a high-quality life to all its citizens by 2030"(Government of the Republic of Kenya, 2007:1). Research, Science, Technology and Innovation (RSTI), is recognised both nationally and globally to be important for the economic transformation, wealth creation, global competitiveness of Kenya and enhance the quality of life for its people. Also, STI is essential components for social integration, sustainable development and poverty reduction (MHEST, 2012:3). To facilitate the achievement of the Vision 2030, it is essential for the Government of Kenya to harness and apply STI and R&D to increase productivity and efficiency levels across the key pillars of the vision 2030, economic, social and political. Essentially, the key pillars of the vision 2030, economic, social and political, are anchored on several factors including science, technology and innovation, human resource development and wealth creation opportunities (Republic of Kenya, 2007).

Science, technology and innovation is considered a key foundation for the vision 2030, enables the production of new knowledge, which has a "critical role in wealth creation, social welfare and international competitiveness of the country". From an economic front, research and innovation enhance the prosperity of Kenya through economic development. Universities and research institutions play a critical role in national research and innovation systems, particularly, in the creation, dissemination and application of useful knowledge needed for the key sectors in the economy. On the social development front, research, technology and innovation provides useful solutions that will improve "natural resource management for public safety, food security and poverty alleviation as well as resolving human and animal health conflicts and developing a sustainable tourism industry" (Republic of Kenya, 2007; Republic of Kenya, 2012:v).

The vision 2030 document put forth flagship projects seen to be key in promoting STI in Kenya. They include (a) progression and enactment of the STI and (b) increasing the numbers of STI capacities and capabilities in Kenya across all the sectors of the economy. Hanlin (2017) observes that the recent update, (by March 2016), of these projects, show that the following have been achieved:

- Draft STI and information bill presented to the cabinet;
- Research Fund established under the National Council for Science, Technology and Innovation;
- University of Nairobi students undertook an exchange programme in nuclear science in Japan; and
- The Ministry of Education, Science and Technology developed a technology development, transfer and diffusion programme

In addition, Vision 2030 also has other flagship projects linked to the creation of STI capacities in the countries. These include:

- Konza city, a 'technopolis' which will host the National Physical Science Research Laboratory, a Science Park together with the Kenya Electronics Telecommunications and Computing Research Institute (GoK, 2013) and the Kenya Advanced Institute of Science and Technology, a post-graduate university (Kenyatta, 2017).
- Development of the Nairobi Industrial Technology Park in partnership with Jomo Kenya University of Agricultural and Technology
- Establishment of technology innovation hubs in different counties.

3.3.3.3.2 The enactment of the Science Technology and Innovation Act of 2013

Given the importance of STI and Research and Development in national development, the Kenyan government created and implemented the Science, Technology and Innovation Act, 2013 (No. 28 of 2013) and a policy framework for STI to support the Vision 2030 and other developmental goals. The Act and policy framework denote the government's recognition of the role of STI in national development.

The STI sector intends to utilise the knowledge and integrate STI into all the national production systems that drive Kenya's Vision 2030 and the economy. Mainly, the aim is ensuring an enhanced and efficient environment for the operation of research, science, technology and innovation. The objectives of the STI policy includes to: strengthen the technical capacities and capabilities of STI, university education, TVET institutions and systems; intensify the use of innovation in priority sectors as well as create a functional National Innovation System; create awareness on the application of knowledge to improve productivity among the policymakers, implementers and users.

Although the Kenyan Government recognises the importance of STI in national development, the Kenyan National Innovation Systems has a number of gaps and challenges. The STI policy is underpinned by four major strategic thrusts. Firstly, the “institutional re-engineering” that focuses on the formulation and implementation of policies and addressing the gaps in the Kenya National Innovation System. Secondly, strategising on resource mobilisation by harnessing the resources required in supporting STI. Thirdly, formulating strategies on knowledge and technology governance that focuses on the creation and utilisation of innovations and lastly, address the strategies that will enhance STI linkages and collaboration. Lastly, establishing lower commercialisation rate of the innovations and insufficient funding and support for R&D and innovations (Republic of Kenya, 2012:v).

The Kenyan government has set out policy measures, in order to address the different gaps in the National Innovation System. First, the government, through the STI Act, has established institutional and regulatory frameworks to ensure promotion, coordination and mobilisation of resources and management of STI. The next section discusses in detail the functions of the institutions that support STI. Secondly, the government through relevant institutions has aimed to utilise STI to transform the economy through several national priority areas. They include Telecommunications, Electronics and Computers (TEC) manufacturing technologies, software development technologies, renewable and green energy, food and nutritional security technologies, among others. The government has aimed at allocating at least 1% of its GDP annually in R&D and liaise with other stakeholders to fund STI. In implementing this policy, the government aims to increase public investment for universities, government laboratories, and research institutes. However, to date, the investment in R&D below the targeted 1% (NPCA, 2014).

The STI policy is based on the “guiding principles of relevance, realism, cost-effectiveness, multi-disciplinarily, good leadership and governance” among others (Republic of Kenya, 2012:v). These guiding principles provide the key dimensions for benchmarking the science system. Consequently, there are aspirations through the STI policy to “strengthen governance and management of the STI sector and institutions to make them more efficient and effective and accountable for performance” (Republic of Kenya, 2012:8). The ‘new’ management system has a number of roles to play, among them, ensure the "restructuring and rationalization of the existing STI & R&D institutions to make them more effective in addressing national priority needs" (Republic of Kenya, 2012:8).

In efforts to seek for a solution to the weak performance management framework, some of the major strategies have included, developing and implementing a robust system for identifying, evaluating, recognising, protecting intellectual property rights and rewarding excellence in ST&I activities. Equally, this includes developing, implementing, continuously reviewing and globally benchmarking a comprehensive performance management framework (Republic of Kenya, 2012:21). The performance framework is assumed to ensure regular science and technology monitoring and forecasting in all areas relevant to national development. The STI Act of 2013 established three key institutions, discussed above, for the promotion and coordination of STI in Kenya: National Commission for Science, Technology and Innovation (NACOSTI), the Kenyan National Innovation Agency (KENIA) and the National Research Fund (NRF). The next section discusses the functions of these institutions and clearly stipulates its support and coordination of STI in Kenya.

3.3 Science, Technology and Innovation Institutional Landscape

In this section I provided an overview of research and development performing institutions in Kenya. This includes institutions higher education institutions, government research institutes, Non-governmental research organizations, international research organizations and private organizations.

3.3.1 An overview of research and development performing institutions in Kenya

Research and development in Kenya has traditionally been located at higher education institutions/universities, Government research institutes and parastatals, Non-government organisations/civil society/Community-based organisations, private sector and companies and international research organisations. An analysis of the research performing institutions in Kenya shows that universities, public research institutes and government parastatals dominate the research production in Kenya. Equally, international research organisations (especially those focusing on agricultural, livestock, and food security research) contribute substantially to Kenya's science base. The figure below provides an overview of Kenya's main research performing institutions. The subsequent figure elaborates on the research centres at public universities that undertake research in Kenya. In the Figure 3-4 below I diagrammatical illustrate an overview of the main research performing research institutions in Kenya.

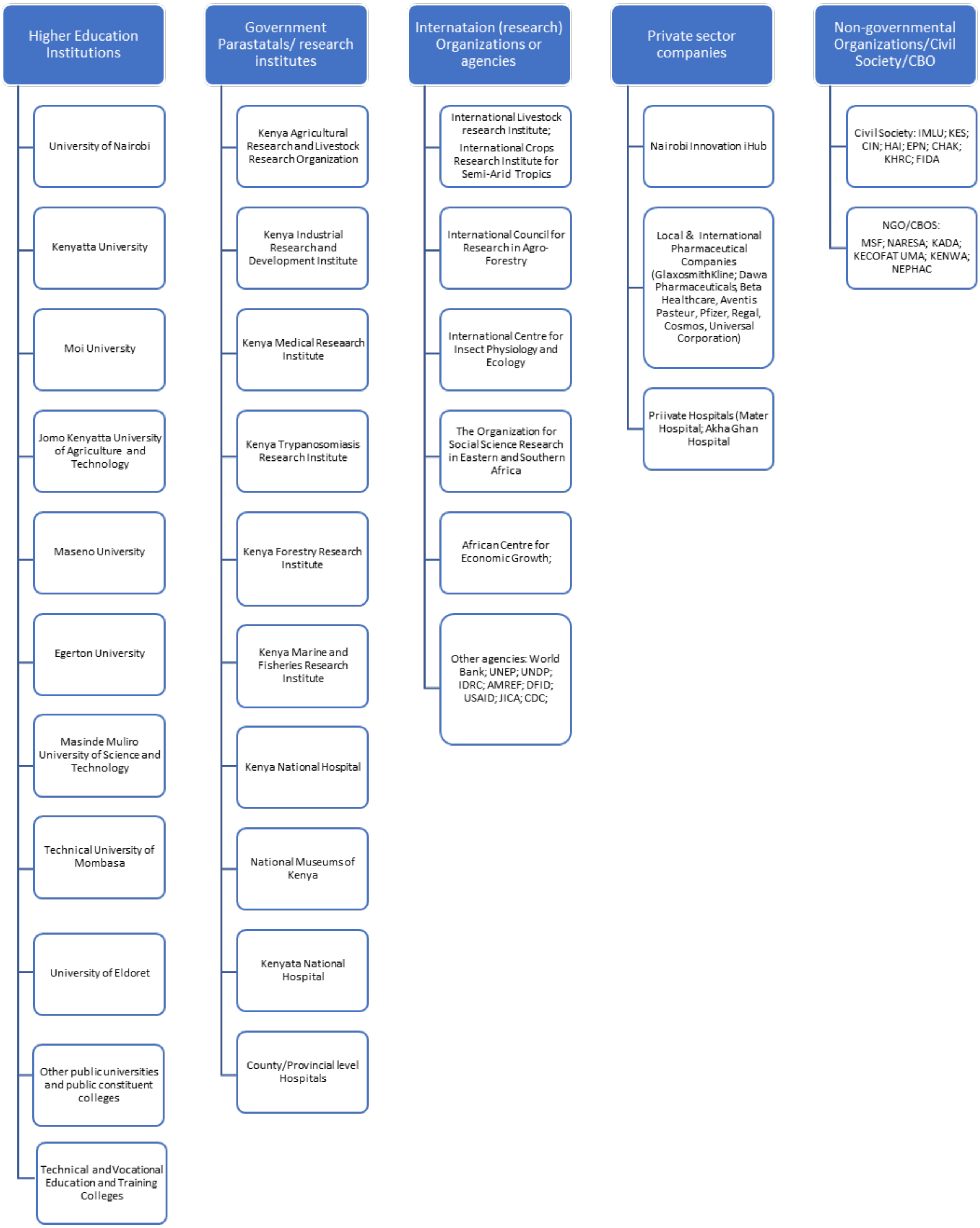

Figure 3-4: Kenya's main research performing institutions

In the subsequent sections, I discuss each of these research performing institutions in detail. I discuss their organisation in their research centres, institutes, faculties or schools. I begin the discussion with the higher education institutions, followed by the public research institutes and government parastatals and lastly the international research organisations.

Since Kenya' public research institutes are organised in four broad research thematic areas (agriculture, health, social and industrial technologies research) I provide the institutional landscape of research in these research areas.

3.3.1.1 Higher Education Institutions in Kenya

Recent years have seen the expansion of the higher education sector in Kenya. Kenya currently has 74 higher education institutions (universities and constituent colleges). In 2005, Kenya had just 5 public universities, whereas today Kenya has 31 Public Chartered Universities, 6 Public Constituent Colleges, 18 Private Chartered Universities, 5 private constituent colleges, 14 institutions with Letters of Interim Authority (CUE, 2017). The growth in the university sector has coincided with the upgrade of already existing colleges to universities. Although, these numbers are equally distributed across the public and private institutions, given their capacity and size, public universities enrol the highest number of students and has the highest number of academic staffs. In this section, I describe in more detail those public universities in Kenya who are the main contributors to science in Kenya.

The University of Nairobi (UON) was established in 1971 as the first fully-fledged university in Kenya. The history of UON can be traced back to 1949 with the establishment of the Royal Technical College in 1949. It was one of the Asquith colleges that later became a constituent college of the University of East Africa. UON has its emphasis in research programmes in agriculture, health, social sciences and engineering. The university is currently organised in the following major six colleges and schools:

- College of Agriculture and Veterinary Sciences (agricultural research and veterinary medicine research);
- College of Biological and Physical Sciences (biotechnology, biological sciences, mathematics, physical sciences, computing and informatics);
- College of Architecture and Engineering (engineering, built-environment, nuclear science and technology);
- College of Education and External Studies (educational research and training)

- College of Health Sciences (HIV prevention & research, tropical & infectious diseases, dental sciences, medicine, nursing, pharmacy and public health); and
- College of Humanities and Social Sciences (women studies, African studies, development studies, arts, law, population studies, international studies, journalism, economics, business).

These colleges are host to several research centres and institutes that engage in research. These research centres/institutes include, among others, Institute of Development Studies, The Institute of Tropical and Infectious Diseases (UNITID), Centre for HIV Prevention and Research (CHIVRI), The Centre for Biotechnology and Bio-informatics (CEBIB) (see figure below for details).

Moi University was established in 1984 as the second University in Kenya. Moi University was established to meet the increasing demands of higher education in Kenya in the 1980s. Moi University has its emphasis in technical programmes such as Agriculture, Forestry, wildlife and medical sciences. Moi University is organised in the following major schools and departments, among others:

- School of Agriculture and Natural Resources (animal science, agriculture research and biotechnology, natural resources, agricultural economics;
- School of Arts and Social Sciences;
- School of Biological and Physical Sciences (biological, physical and chemical sciences, mathematics and computer science);
- Schools of: Nursing, Dentistry, Medicine, Public Health;
- School of Education (Educational research and training); and
- School of Engineering (chemical, mechanical, energy, civil, electrical and Manufacturing engineering sciences).

Apart from these key schools and institutes, Moi University also has two centres of excellence that contribute to its research base: Centre of Excellence in Phytochemical, Textile & Renewable Energy (ACEII – PTRE). ACEII-PTRE is one of the 24 African Centers of Excellence funded by the World Bank ACE II Project that aims to provide high quality training and research within the African Region. The main objective of the centre is to train highly skilled manpower in Phytochemicals, Textile, and Renewable Energy through research, innovation and technology transfer for enhancement of the manufacturing sector.

East and South African-German Centre of Excellence for Educational Research Methodologies and Management (CERM-ESA) partners with Germany (University of Oldenburg), South Africa (Nelson Mandela University), Tanzania (University of Dar es

Salaam) and Uganda (Uganda Management Institute). CERM-ESA among other objectives aims to advance and expand excellent and innovative educational research on methodologies, instruction and management strategies for African contexts.

Kenyatta University became a fully-fledged university in 1985 admitting students in the Bachelor of Education degree programme. The history of Kenyatta University dates back to 1965 when the British Government handed over the Templar Barracks to the newly formed GoK. The Barracks were later converted into a middle-level institution named Kenyatta College, mainly offering training in education. Kenyatta University admitted its first 200 students in 1972. In 2017/18, Kenyatta University had a total enrolment of 72, 033 students. Kenyatta University is organised in the following major schools, among others:

- School of Agriculture and Enterprise Development (Agricultural sciences and animal health);
- School of Architecture and the Built Environment;
- Schools of: Business, Economics;
- School of Engineering and Technology (mechanical, energy, civil, electrical and agricultural engineering sciences);
- School of Education (Educational research);
- School of Environmental Studies (environmental research);
- Schools of: Medicine, Nursing, Medicine, public health and applied human sciences ;
- School of pure and applied sciences (Biotechnology, biological sciences, physical sciences, chemical sciences); and
- School of humanities and social sciences

Egerton University became a fully-fledged university in 1987 through the Act of Parliament. However, its history dates to 1939, first founded as Egerton Farm School, offering training white European youth for careers in agriculture. Egerton University mainly specialises in agricultural sciences research among others. Egerton University is organised in the following major faculties:

- Faculty of Agriculture;
- Faculty of Arts and Social Sciences (Anthropology, Community Development, Criminology, Economics, History, Literature, Linguistics, Kiswahili);
- Faculty of Education (Educational research);
- Faculty of Engineering and Technology (agricultural, civil, energy, environmental, industrial and electrical engineering);
- Faculty of Education and Community Studies;

- Faculty of Environment and Resource Development (Environmental science, geography and natural resources);
- Faculty of Science (Botany, Zoology, Computer Science, Mathematics, Physics and Chemistry);
- Faculty of Health Sciences (clinical sciences, nursing);
- Faculty of Veterinary Medicine and Surgery (biomedical sciences, clinical studies and population medicine).

Egerton University created Tegemeo Institute of Agricultural Policy and Development[10], a policy research institute under the Division of Research and Extension of Egerton University (Egerton University, n.d.). Tegemeo research institute, among other objectives, has the mandate to conduct research and analysis on policy in the domains of agriculture, rural development, natural resources and environment.

In addition, Egerton University hosts the Centre of Excellence in Sustainable Agriculture and Agribusiness Management (CESAAM[11]) (one of the 24 World Bank Funded Centres of excellence). CESAAM has the mandate of addressing food security and poverty through agricultural research (biotechnology, climate change) and agricultural training (Egerton University, n.d.).

Jomo Kenyatta University of Agriculture and Technology was established as a fully-fledged university in 1994. The University is organised in the following major colleges and schools:

- College of Health Sciences (medicine, nursing, public health, pharmacy and biomedical sciences)
- College of Engineering and Technology (architecture, mechanical, manufacturing, material, civil, electrical, electronic, information, biosystems and environmental engineering).
- College of pure and applied sciences (biological, physical, chemical, mathematical and computing sciences)
- College of Agriculture and Natural Resources (Agriculture, food and nutrition, natural resources, animal science and environmental sciences).

JKUAT has a research centre involved in sustainable materials, research and technology research. Maseno University became a fully-fledged university in 2001. The history of Maseno University dates to the merging of the Maseno Government Training Institute (GTI) with Siriba

[10] www.tegemeo.org
[11] http://www.cesaamegerton.org/background-information/

Teacher's Training College to form Maseno University College as a constituent college of Moi University. Currently, the university is organised in the following main schools, among others:

- Schools of: medicine, public health, nursing,
- School of environment and earth sciences
- School of Agriculture and food security (plant science, animal science, fisheries and natural resources)
- School of Biological and Physical sciences (chemistry, physics & material sciences, zoology and botany)
- School of Agriculture Mathematics, Statistics and Actuarial Sciences
- School of Environment and Earth Sciences (environmental research)
- School of Arts and Social Sciences
- School of Education
- School of Development and Strategic studies.

Apart from the above major public universities that were established earlier in Kenya and are the top performers in research (see table below), the enactment of the Universities Act No. 42 of 2012 established a further 23 public universities with full accreditation and 10 public university constituent colleges. Some of these universities include Masinde Muliro University of Science and Technology, Jaramogi Oginga Odinga University of Science and Technology; the University of Eldoret, South Eastern Kenya University among others (Chapter 2 provides a list of all the universities in Kenya). The next figure illustrates an overview of the research centres at the Kenyan public universities. In the subsequent table, I will provide information on the top performing universities in Kenya as compared to other institutions.

3.3.1.1.1 Research Centres at Public Universities

This section presents an overview of some of the main research centres at Kenya's public universities. The University of Nairobi records the largest number of research centres in the health sciences and natural sciences. Jomo Kenyatta University of Agriculture and Technology also records several health centres in the natural sciences and applied technology. Figure 3-5 below illustrates the research centres at public universities in Kenya.

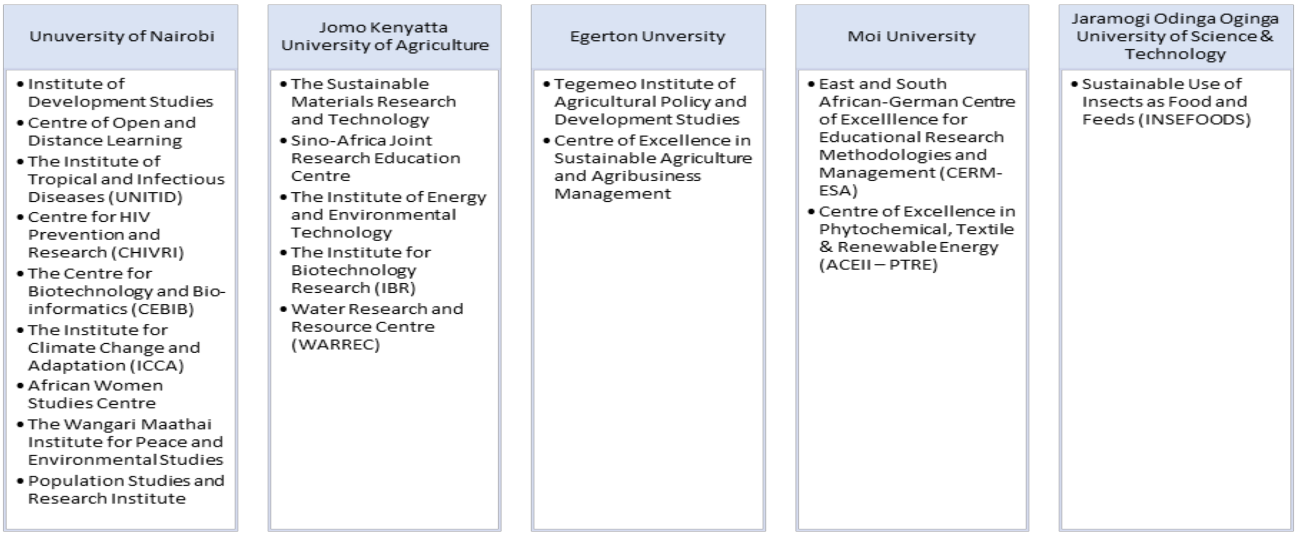

Figure 3-5: Research Centres at Public Universities

Data Sources: Listing from Universities (webpages) Accessed 15 August 2019.

3.3.1.1.2 A comparison of publication output by universities versus other scientific institutions

A comparison of the publication by university versus other scientific institutions for the period of 2012-2014 (Table 3-1) shows that public universities produces nearly half of Kenya's scientific output.

Table 3-1: Publication by University vs other institutes in Kenya's research: WOS (2012 -2014)

Local higher education institutions	Count	Other institutions	Count
University of Nairobi	830 (19.2%)	Kenya Medical Research Institute	955 (22.2%)
Jomo Kenyatta University of Agriculture and Technology	309 (7.2) %	National Museums of Kenya	183 (4.2%)
Moi University	264 (6.1%)	Ministry of Health	167 (3.7%)
Kenyatta University	206 (4.8%)	Centre for Geographic Medical Research - Coast	155 (2.8%)
Egerton University	138 (3.2)	Kenya Agricultural Research Institute	112(2.6%)
Maseno University	130(3.0%)	Kenyatta National Hospital	108(2.5%)
Masinde Muliro University of Science and Technology	37 (0.9%)	Ministry of Public Health and Sanitation	98 (2.3%)
University of Eldoret	36 (0.8%)	KEMRI/CDC Research and Public Health Collaboration	79 (1.8%)
Moi Teaching and Referral Hospital	35 (0.8%)	Ministry of Environment, Water and Natural Resources	61 (1.4%)

Technical University of Mombasa	31 (0.7%)	Aga Khan University Hospital, Nairobi	60 (1.4%)
South Eastern Kenya University	28 (0.7%)	Kenya Marine and Fisheries Research Institutes	60 (1.4%)
TOTAL			

Source: Web of Science, CREST (2016)

3.3.1.2 Public Research Institutes and Government Parastatals

Kenya has several government-based research institutes and parastatals that contribute to its science base. The amendment of the Science and Technology (Amendment) Act (Chapter 250) in 1979, which has since been amended Science and Technology Act 2013, resulted in the establishment of six semi-autonomous government research institutes: Kenya Medical Research Institute (KEMRI), Kenya Agricultural and Livestock Research Organization (KALRO), previously the Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI), Kenya Trypanosomiasis Research Institute (KETRI), Kenya Marine and Freshwater Fisheries Institute (KEMFRI), Kenya Industrial Development Research Institute (KIRDI) (Republic of Kenya, 1980; 2013). These research institutes are categorised into several groups according to their areas of research focus as discussed below.

The main performers of research in the fields of health are mainly located in the local universities or in KEMRI. In relation to the university sector, research is still predominantly hosted in the colleges of medicine and health sciences (University of Nairobi, University, Moi University, Jomo Kenyatta University of Agriculture and Technology, Moi University, Maseno University) and faculties of science or natural science at other universities. Teaching hospitals and the Kenyatta National Hospital also contribute a good proportion of output to the health research in Kenya. The subsequent table illustrates the share of output produced by these public research institutions in health research.

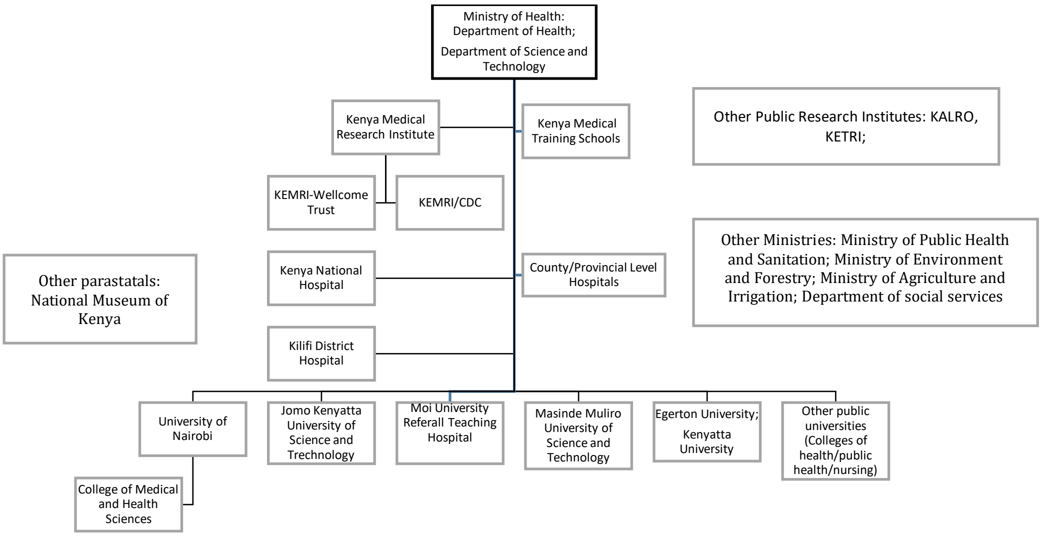

Figure 3-6: A sector map of public research institutions in health research.

Data Sources: Listing from research institutions' (webpages) Accessed 15 August 2019.

3.3.1.2.1.2 Top performers in health research

The table below shows that, among others, the topmost producers of health research are the Kenya Medical Research Institute and the University of Nairobi followed by Moi University and Jomo Kenyatta University of Agriculture and Technology.

Table 3-2: Top Performers in health research: WOS publication output (2012 -2014)

Higher Education institutions	Public research institutes	Non-governmental research agencies or organisations
University of Nairobi 511 (18.8%)	Kenya Medical Research Institute 744 (27.4%)	Centres for Disease Control and Prevention, Kenya 57 (2.1%)
Moi University 181 (6.6%)	Ministry of Health 134 (4.9%)	Impact Research and Development Organization 22 (0.8%)
Jomo Kenyatta University of Agriculture and Technology 180 (6.6%)	Kenyatta National Hospital 100 (3.7%)	
Kenyatta University 91 (3.4%)	Centre for Geographic Medical Research – Coast 94 (3.4%)	
Maseno University	Ministry of Public Health and Sanitation 78 (2.9%)	
Egerton University 38 (1.1%)	National Museums of Kenya 59 (2.1%)	
Moi Teaching and Referral Hospital 32 (1.1%)	Kenya Agricultural Research Institute 31 (1.1%)	
Great Lakes University of Kisumu 19 (0.6)	Coast Province General Hospital 20 (0.7%	

Source: Web of Science, CREST, 2016).

3.3.1.2.1Health Research

The Kenya Medical Research Institute (KEMRI) was established in 1979 as a national body responsible for carrying out health research in Kenya. KEMRI has several mandates:

- To carry out research in human health.
- To cooperate with other research organisations and institutions of higher learning on matters of relevant research and training.
- To liaise with other relevant bodies within and outside Kenya carrying out research and related activities. To disseminate and translate research findings for evidence-based policy formulation and implementation.
- To cooperate with the Ministry of Health, the National Commission for Science, Technology & Innovation (NACOSTI) and the Medical Sciences Advisory Research Committee on matters pertaining to research policies and priorities. To do all things as appear to be necessary, desirable or expedient to carry out its functions.

The figure below provides an overview of the research centres at KEMRI. These centres include those in global health research, respiratory diseases research, parasite control, public health, microbiology, parasitic diseases, geographic medicine, biotechnology research, traditional medicine and drug research, among others.

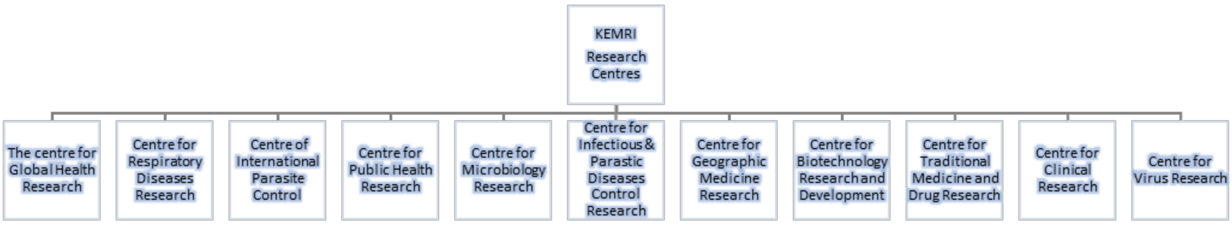

Figure 3-7: KEMRI research centres. Source: Listing from KEMRI webpage Accessed 15 August 2019

The figure below (Figure 3-7) illustrates other main research performing institutions and institutes including KEMRI that are involved in health research in Kenya. As signalled, most of the research is conducted at the Kenya Medical Research Institutes followed by Kenyatta National Hospitals, teaching referral hospitals, as well as other government ministries or departments. The next section illustrates the institutional landscape of health research in Kenya, including the other public research institutions involved in health research.

3.3.1.2.2 Agricultural Research

The main performers of research in the fields of agriculture are mainly located in the local universities or in KALRO. In relation to the university sector, research is still predominantly hosted in the Faculties of Agriculture (University of Nairobi, Egerton University, Moi University, Jomo Kenyatta University of Agriculture and Technology, Maseno University) and Faculties of Science or Natural Science at other universities.

The figure below illustrates public sector institutions performing agricultural research: Universities, public research institutes and government departments. The subsequent table below provides a list of the main research performers in agriculture obtained by looking at those universities and research organisations (public and private) who produce publications in the agricultural field. The publication data (Table below) is organised in three sections: higher education institutions (universities), public research institutes and departments, and private and industry-based research institutes and organisations.

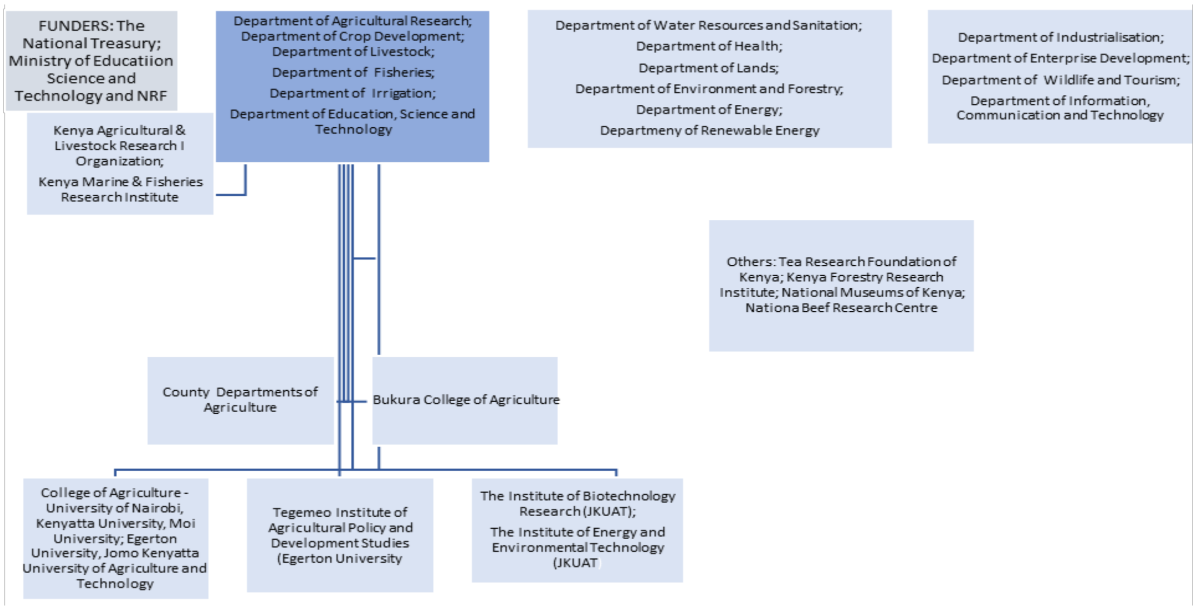

Figure 3-8: Sector map of public research institutions involved in agricultural research.

Source: Listing from Agricultural research institutions' (webpages) Accessed 15 August 2019.

The table below shows that the University produces the largest number of papers in agricultural research followed by the Kenya Agricultural Research Institute, Egerton University, and Jomo Kenyatta University of Agriculture and Technology.

Table 3-3: Top performers in agricultural research

Higher Education	Public research institutes	Non-governmental research agencies or organisations
University of Nairobi 139 (23.0%)	Kenya Agricultural Research Institute 63 (10.4%)	International Center for Tropical Agriculture, Kenya 27 (4.4%)
Egerton University 53 (8.7%)	Kenya Medical Research Institute 28 (4.6%)	International Crops Research Institute for the Semi-Arid Tropics, Kenya 13 (2.1%)
Jomo Kenyatta University of Agriculture and Technology 39 (6.4%)	National Museums of Kenya 21 (3.5%)	International Maize and Wheat Improvement Center, Nairobi 8 (1.3%)
Kenyatta University 38 (6.2%)	Ministry of Agriculture Livestock and Fisheries Development 16 (2.6%)	International Maize Wheat Improvement Centre (CIMMYT) 64 (10.9%)
Maseno University 19 (3.1%)	Kenya Marine and Fisheries Research Institutes 12 (1.5%)	World Agroforestry Centre, Kenya 7 (1.1%)
Moi University 16 (2.6%)	Ministry of Environment, Water and Natural Resources 10 (1.7%)	Forum for Organic Resource Management and Agricultural Technology 7 (1.1%)
University of Eldoret 12 (2.0%)	Tea Research Foundation of Kenya (1.0%)	Food and Agriculture Organization of the United Nations, Kenya 6 (1.0%)
South Eastern Kenya University 8 (1.3%)	Kenya Forestry Research Institute 6 (1.0%)	Research Program on Climate Change, Agriculture and Food Security, Kenya 6 (1.0%)
		International Potato Center, Kenya 6 (1.1%)
		International Institute of Tropical Agriculture, Kenya 6 (1.0%)

Source: WoS, CREST, 2016

The Kenya Agricultural Research Institute (KARI) (now Kenya Agricultural and Livestock Research Organization) was established in 1979 and started its operations fully in 1986, following the need to address food insecurity in the country. The institute has the Ministry of Agriculture as its supervising agency. The institute took over research activities from the East African Agricultural and Forestry Research Organization (EAAFRO), the East African Veterinary Vaccines Organization (EAAVRO) and, later, the Ministries of Agriculture and Livestock Development. Before the merger, KARI was mandated to conduct research, generate and disseminate knowledge and technology that meets the goals of the developmental policies of the country.

In 2014, the Kenya Agricultural and Livestock Research Organization (KALRO) was formed following a merger of four state parastatals involved in agricultural research - the Coffee

Research Foundation (CRF), the Tea Research Foundation (TRF) and the Kenya Sugar Research Foundation (KESREF) – replacing KARI. The research focus of KALRO is on crops, livestock, agricultural engineering, and natural resources.

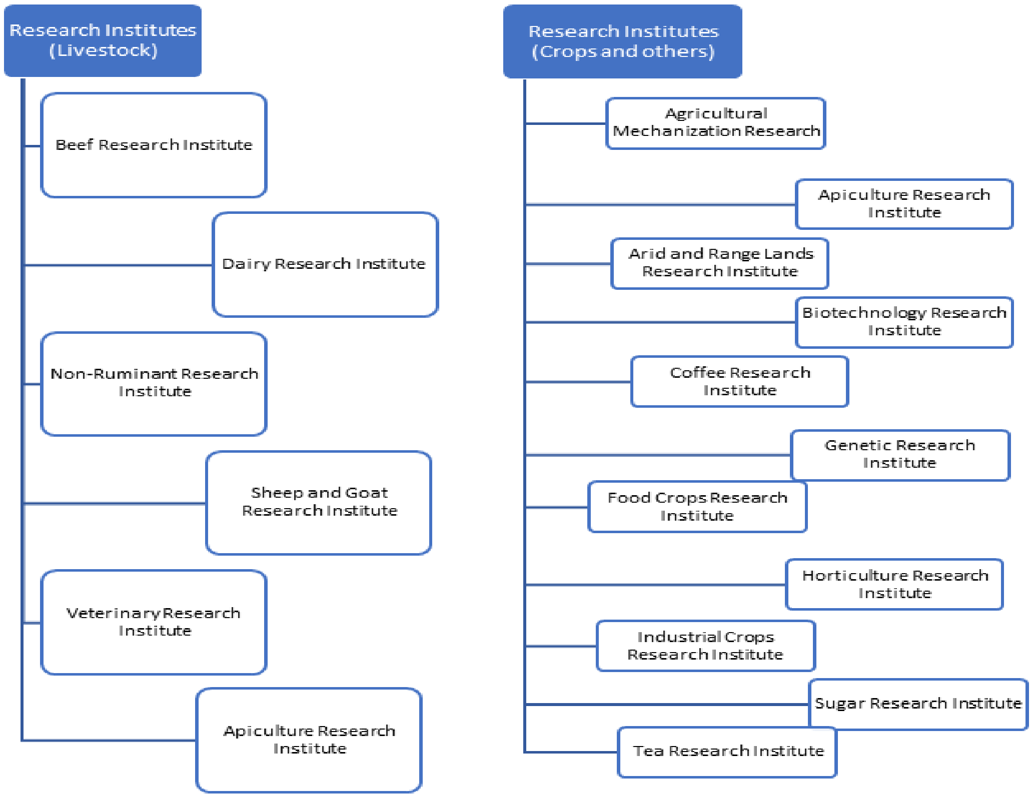

Figure 3-9: Kenya Agricultural and Livestock Research Organization Research Institutes.

Source: Based on information from KALRO webpage

KALRO is a corporate body created under the Kenya Agricultural and Livestock Research Act of 2013 to establish a suitable legal and institutional framework for the coordination of agricultural research in Kenya with the following goals:

- Promote, streamline, co-ordinate and regulate research in crops, livestock, genetic resources and biotechnology in Kenya.
- Expedite equitable access to research information, resources and technology and promote the application of research findings and technology in the field of agriculture.

The Kenya Trypanosomiasis Research Institute focuses on human and animal trypanosomiasis (KETRI) is also involved in agricultural research. In 2003, following the governments re-organisation of research institutions, KETRI was merged the government merged with the Kenya Agricultural Institute (KARI) and renamed the Trypanosomiasis Research Centre -KARI (currently Trypanosomiasis Research Centre – KALRO). The Trypanosomiasis Research Centre continues to focus on human and animal trypanosomiasis research. The figure above illustrates an overview of research centres/institutes at Kenya Agricultural and Livestock Research Organization.

The Kenya Forestry Research Institute was established in 1986 and is mandated to undertake research in forestry and allied natural resources. Currently, KEFRI focuses on the following four research thematic areas:

- forest productivity and improvement (forest resource assessment, biotechnology, forest health tree improvement and silviculture);
- biodiversity and environment management (forest rehabilitation and restoration, forest hydrology, climate change research, sustainable management of natural forests and woodlands and soil and water management);
- forest products development (forest harvesting, logging and handling; forest product processing and efficient utilisation; development and promotion of efficient technologies for bio-energy processing and utilisation); and
- socio-economics, policy and governance (forest and land tenure, gender and forestry, forest conflict resolution; policy and governance, research forest extensions; participatory forestry management and marketing in forest products).

The figure below illustrates the KEFRI's research programmes and the different areas of their research focus.

KEFRI's Eco-regional research programmes

Central Highlands Eco-region Research Programme (CHERP)	**Drylands Eco-region Research Programme** (DERP)	**Rift Valley Eco-Region Research Programme** (RVERP)	**Coast Eco-Region Research Programme** (CERRP)	**Lake Victoria Basin Eco-region Research Programme** (LVBERP)	**Forest Products Research Programme** (FPRP)
• Forest Productivity and Improvement • Biodiversity and Environment Management • Socio-economics, Policy and Governance	• Forest Biodiversity and Environment Management • Forest Productivity and Improvement • Forest Product Development • Socio-economics, Policy and Governance	• Forest Productivity and Improvement • Biodiversity and Environment Management • Forest Products Development • Socio-economics, Policy and Governance	• Forest Productivity and Improvement • Biodiversity and Environment Management • Socio-economics, Policy and Governance	• Forest Productivity and Improvement • Biodiversity and Environment Management • Socio-economics, Policy and Governance	• Forest Productivity and Improvement • Forest Products Development

Figure 3-10: Eco-regional research programmes.

Source: KEFRI (webpage) accessed 16 August 2019

The Kenya Marine and Fisheries Research Institute (KMFRI) was established in 1979 mandated to conduct research on marine and freshwater fisheries and provide management recommendations important for the national exploitation of living and non-living aquatic resources in the ocean waters, including the freshwater in the hinterland. KMFRI focuses on the following research areas: freshwater fisheries, aquaculture, fisheries and post-harvest development, environment research, dee-sea research, oceanography and hydrography and socio-economic research. The figure below illustrates an overview of research centres/institutes at the Kenya Marine and Fisheries Research Institute.

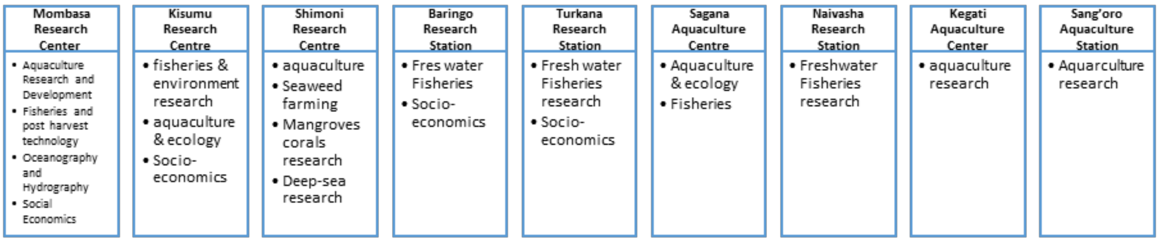

Figure 3-11: KMFRI's research centres.

Source: KMFRI (webpage) accessed 16 August 2019

3.3.1.3 International and non-governmental organisations based in Kenya

Kenya has several international and non-governmental research organisations in Kenya which undertake research in several fields (e.g. agriculture, forestry and ecology), thus contributing to its science base. Most of these international research organisations form part of the CGIAR (Consortium of International Agricultural Research Centres) research centres/institutes, a global research partnership involved in agricultural and food security research to ensure a food-secure future.

The International Council for Research in Agro-Forestry (ICRAF) also known as World Agroforestry is a centre of science and development excellence that harnesses the benefits of trees for people and the environment. ICRAF aims to leverage the world's largest repository of agroforestry science and information, in order to create knowledge practices, to ensure food security and environmental sustainability. ICRAF is guided by the broad development challenges pursued by CGIAR which include poverty reduction, increasing food and nutritional security, and improved natural resource systems and environmental services. ICRAF's research also addresses most of the aspects of Sustainable Development Goals (SDGs) particularly those that aim to eradicate hunger, reduce poverty, provide affordable and clean energy, protect life on land, and combat climate change.

ICRAF receives its funding from several sources including governments, private foundations, international organisations, regional development banks and the private sector. ICRAF collaborates with several scientific and development institutions around the globe.

International Livestock Research Institute (ILRI), established in Ethiopia and later expanded its operations to Kenya in 1980 (Eisemon &Davis, 1997). ILRI is a research institution aims at improving food security and reduction of poverty in developing countries through its research for better and more sustainable through enhanced livestock value chains and increased productivity. Also has an aim of improving human health through improved access to animal-source foods and reduction in the burden of zoonotic and food-borne diseases, and management of adaptation of livestock systems to climate change. ILRI cooperates with the Consultative Group for International Agricultural Research (CGIAR) on its several research programmes, with aims to address key issues of global climate change, agriculture, food security, environment, gender, health and rural poverty. To achieve these aims, some of the research programmes at ILRI include Agriculture for Nutrition and Health, Animal science for sustainable productivity, food safety and Zoonoses, Livestock systems and environment among others.

International Centre for Insect Physiology and Ecology (ICIPE) was established in 1970 with a mandate "to ensure that motivated, highly talented, 'human capital' in insect [research] and related areas of science is built up, so as to enable Africa to sustain herself and to lead the entire pan-tropical world in this area of endeavor" (Galun, 2004:123). ICIPE is guided by a "4H(ealths) paradigm" an approach that comprises of human, animal, plant and environmental health that determines the broad research themes at ICIPE.

The International Potato Center (CIP) was founded in 1971 as a research-for-development organisation with a focus on potato, sweet potato and Andean roots and tubers. Through its research work, it provides science-based solutions to address food security. Other International research organisations that engage in agricultural and food security-related research (form part of CGIAR) are The International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and the Centre for International Maize and Wheat Improvement (CIMMYT). The African Medical and Research Foundations (AMREF) is concerned with medical research.

Other organisations and agencies include the African Economic Research Consortium (AERC), the African Centre for Economic Growth (ACEG), and the Organization for Social Science Research in Eastern and Southern Africa (OSSREA). The other international development agencies with offices in Kenya and participate in research include the World Bank, UN Environment Program (UNEP), UN Development Program (UNDP), and the International Development and Research Centre (IDRC). The next section elaborates on the international research centres that extensively contribute to Kenya's research performance in terms of the number of publications.

3.3.1.2.3 Social, Economic an industrial and Allied technologies research

The third category consists of institutions that undertake Social, economic and industrial and allied technologies research. The Kenya Industrial Research and Development Institute (KIRDI) is a research institute under the Ministry of Industry, Trade and Cooperatives established in 1979 with a mandate to undertake multidisciplinary Research and Development in industrial and allied technologies including: Mechanical, Electrical & Electronics, Chemical, Ceramics and Building Materials, Food, Leather, Textile, ICT, Environment and Energy. The technologies developed are transferred to both Micro, Small and Medium Enterprises and Large Industries to enhance their competitiveness and productivity.

The history of KIRDI dates back to 1942 when the then colonial government set a Central Laboratory at Kabete, Nairobi. The laboratory was aimed to initiate and develop industries to relieve the industrial goods shortages occasioned by the Second World War. The laboratory was administered by the Kenya Industrial Management Board (KIMBO). Following the expansion of the laboratory, it was renamed the East African Industrial Research Organization (EAIRO) and later managed by the East African Community (EAC). EAIRO, the predecessor of the current KIRDI has Centres in; Kenya, Uganda, Tanzania which ceased its operations in 1977, following the collapse of the then East African Community. In 1979, the Science and Technology (Amendment) Act established the current KIRDI.

Other organisations and/or networks in this category include the Kenya Institute of Public Policy Research and Analysis (KIPPRA), a semi-autonomous Government Agency (SAGA) that focuses on development, economic and natural resources research, the National Crime Research Centre (NCRC), and the National Economic and Social Council (NESC). The National Museums of Kenya (NMK) focuses its research in botany, zoology, biodiversity, and earth sciences.

3.3.1.4 Private sector companies and institutions

Several private companies also contribute to Kenya's science base. These private companies and institutions include the Nairobi Innovation iHub, local and international pharmaceutical companies such as GlaxoSmithKline, Dawa and Beta healthcare among others. Private hospital such as Aga Khan Hospital and Mater Hospital. The results on research output show that these institutions produce a considerable number of papers to Kenya's science base.

3.4 Summary and Conclusion

The chapter shows that Kenya recognises the importance of STI, illustrated by its integration to the national development plans: from the first national development plan of 1974 to the recent vision 2030 (2008). The recognition of STI for national development by Kenya has resulted in the creation of legal and institutional frameworks such as NACOSTI that play a key role in the coordination, advisory and planning on matters of STI. Similarly, Kenya has established institutions such as the NRF and KENIA that are responsible for the funding of science and innovation in Kenya.

The chapter shows that Kenya recognizes the importance of STI, illustrated by its integration of science and technology imperative into the national development plans: from the first national development plan of 1974 to the recent developmental plan, vision 2030 (Republic of Kenya, 2007). STI falls under the auspices of the government, different government ministries (e.g. the ministries of health, agriculture, trade and industry, among others) which ensures that the institutions in the national innovation system interact to ensure optimal research performance. The recognition of STI for national development by Kenya has resulted in the creation of legal and institutional frameworks such as NACOSTI that plays a key role in the coordination, advisory and planning on matters of STI. Similarly, Kenya has established institutions such as the NRF and KENIA that are responsible for the funding of science and innovation in Kenya. However, at the same time we have seen that the establishment of NACOSTI (initially NCST), that the history of institutionalizing a proper governance framework for science and technology in Kenya since the early 1970's has been a very chequered and protracted process. One could conclude that there has been a lack of political will to take the required actions to establish the necessary framework in an efficient manner. The establishment of the NCST was faced with problems of the membership and scope of the NCST. There were also challenges with the relationship of the new council with the East African Community together with its existing research councils (i.e. the EA Natural Resources Council and the EA Medical Research Council). Given that there were other research councils in existence, the establishment of the NCST faced other challenges such as the nature of the body to be established, also manifested in the names of the body that were suggested such as the "National Science Council" or "National Research Council" whereas there was an emphasis on the science policy and research coordination.

Following the establishment of NCST (now NACOSTI), it took the GoK about four decades to create the National Research Fund (NRF) in 2013. Several reasons can explain the reasons why it took the government so long to establish the NRF. This include lack of a political will to establish the NRF needed for the management and investment of research funds from the government or international partners. The establishment of the NRF was also faced with the challenges of funding and personnel needed to set up a board of members for the NRF. Given these challenges, the roles of management and investment of research funds were under NACOSTI until the establishment of the NRF in 2016.

In this chapter, we also discussed Kenya's recent priorities and initiatives that support science technology. These are typically linked to the national development plans. The vision 2030, as recent Kenya's development plan, acknowledges the importance of science, technology and innovation. The vision 2030 has established several flagship projects to support STI such as the STI and information bill, the National Research Fund, exchange programmes and establishment of technology and innovation hubs. These projects have attempted to support and implement STI in Kenya, with the aim of creating the knowledge base needed for economic growth.

The second part of the chapter was devoted to a discussion of Kenya's STI landscape. This discussion shows that research and development are predominantly located in higher education institutions/universities, public research institutes, civic organizations, Non-governmental organizations and international research organizations. Higher education institutions play a crucial role in scientific production in Kenya, as they contribute the highest proportion of Kenya's publication output (produces about 50% of all output) based on the papers published in the WoS. The universities have several centres of excellence, institutes, colleges and schools, especially in the fields of agriculture, health sciences and biotechnology that produce the universities' scientific output.

There is a specific configuration that is evident in the STI landscape is that viz. the fact that a fairly well-articulated institutional spread (universities, research institutes and international research organizations). A comparison of the performance of the university sector and other research institutes show that the university sector tends to dominate knowledge in Kenya. Several factors could explain this scenario. First, the conclusions from my historical review (chapter 2) could perhaps explain this. The historical overview showed that universities in Kenya have a long history dating back to the establishment of the Royal Technical College in 1939, that later became a fully-fledged university in 1979. Since the establishment of the first university, many other universities, private and public have been established (about 74). When compared to the research institutes that were established as from 1979, the university sector has a larger number of research personnel who engage in knowledge production. In addition, knowledge production at universities is linked to the incentive structures, therefore, academic staff are required to publish so as to be promoted to the next academic ranks. The demand to ‘publish or perish’ at the universities could also explain why researchers will publish more thus the dominance of universities in the knowledge production.

In addition, public research institutes (i.e. KARI, KEMRI, KEFRI and KIRDI) particularly those involved in agricultural research (i.e. KALRO, KEFRI) and health research (i.e. KEMRI) also contribute a considerable proportion (about 30% of all output) of Kenya’s scientific output. Kenya’s health research institutional landscape comprises of the main research institutes involved in health research (KEMRI) other research institutes (KALRO, KETRI), government parastatals (NMK), ministries (health, agriculture), universities, public and private hospitals are the main producers of scientific output in health research. In relation to agriculture research, the institutional landscape comprises of the main research institute involved in agricultural research (KALRO), other research institutes (KEFRI), government parastatals (NMK) and government ministries or departments (livestock, agriculture, fisheries, irrigation and land), universities and agricultural colleges are the main ins institutions that contribute to agricultural research. Most of these institutions receive funding from the government and other international funding to support research.

The overview of the STI landscape shows that Kenya has become a ‘magnet’ to many international research organizations, especially in the agricultural and health sciences. Clearly as discussed in the funding chapter, this international organizations clearly come with higher amounts of international funding. The historical review conclusions in chapter 2 show that, prior to independence, many international organizations such as Wellcome Trust were already working with Kenya. This was explained by the interests of the colonial government to fight diseases such as Malaria allowing a conducive environment for settlement. This historical path dependence has allowed the continuous attraction of international research institutions to Kenya. This is a similar scenario for the international organizations in agricultural sciences, as the colonial government set-up stronger agricultural institutions and stronger agricultural research culture. This was possible given the availability of research materials needed for research.

Private companies, especially the pharmaceutical companies and the Nairobi innovation iHub, have produced small but notable numbers of research papers. Apart from the public research institutes and universities, private companies (pharmaceutical companies, the Nairobi Innovation iHub) and few SMEs contribute to Kenya’s science base, though in negligible numbers. The minimal output from the private companies can be attributed to a weak industrial system in Kenya, thus minimal funding from the industries as well as research output.

Chapter 4 Conceptual Framework, Research Design and Methodology

Section One

4.1 Introduction

For the evaluation of research in Kenya, this study adopted the research and innovation evaluation framework (Mouton, 2015) as the conceptual framework for the study. The research and innovation performance framework is based on our understanding of the National Science and Innovation system as discussed in detail below. The second section of this chapter discusses the research design and methodology of this study. This study adopted a case study design for the evaluation of research in Kenya. Following the features of the case study design, the study uses evidence from multiples sources, that is, bibliometric data, survey data, interview data and document reviews. Apart from the discussion on research design and methodologies, the section also discusses the data analysis approaches used in the study.

4.2 Evaluation Context: Research and Innovation policy imperatives for Kenya

Investment in research and innovation is deemed important for economic growth and in addressing social problems. The Kenya Vision 2030, a developmental plan, acknowledges the important role research and innovation plays in enhancing economic development, particularly in newly industrialising economies around the world. Essentially, the key pillars of the vision 2030, economic, social and political, are anchored in several factors including science, technology and innovation, human resource development and wealth creation opportunities (GoK, 2007). Given the critical role of research and innovation in socio-economic transformation of Kenya, as stipulated in the vision 2030, the science and innovation policy framework has been created to augment the Kenya Vision 2030 (MHEST, 2012).

Research and innovation as a foundation for the vision 2030, enables the production of new knowledge, which has a "critical role in wealth creation, social welfare and international competitiveness of the country". From an economic front, research and innovation enhance the prosperity of Kenya through economic development. Universities and research institutions play a critical role in national research and innovation systems, particularly, in the creation, dissemination and application of useful knowledge needed for the key sectors in the economy. As far as social development is concerned research and innovation provides useful solutions that will improve "natural resource management for public safety, food security and poverty alleviation as well as resolving human and animal health conflicts and developing a sustainable tourism industry" (GoK, 2007; Republic of Kenya, 2012:v).

According to the policy framework for STI, the Kenyan national research and innovation system has several challenges. Despite the system's critical role in the country's prosperity, there is weak coordination between key actors in the system. Additionally, the research and innovation system "lacks a national research agenda and does not have a strong institutional framework". Another key challenge in the system is the "weak performance management framework" (Republic of Kenya, 2012: v). The Kenyan national research system is argued to have weak mechanisms for implementation, evaluation and review of STI initiatives (Republic of Kenya, 2012: 7). Thus, one of the initiatives of the policy is improving the management of scientific performance.

As will be expounded on in the next sections, the STI policy is based on the "guiding principles of relevance, realism, cost-effectiveness, multi-disciplinarily, good leadership and governance" among others (Republic of Kenya, 2012: v). These guiding principles provide the key dimensions that the science system can be measured against. Consequently, there are aspirations through the STI policy to "strengthen governance and management of the STI sector and institutions to make them more efficient and effective and accountable for performance" (Republic of Kenya, 2012: 8). The 'new' management system has a number of roles to play, among them, ensure the "restructuring and rationalisation of the existing STI & R&D institutions to make them more effective in addressing national priority needs" (Republic of Kenya, 2012:8).

In an effort to seek for a solution to the weak performance management framework, some of the major strategies have included, developing and implementing a robust system for identifying, evaluating, recognising, protecting intellectual property rights and rewarding excellence in ST&I activities. Equally, this includes developing, implementing, continuously reviewing and globally benchmarking a comprehensive performance management framework (Republic of Kenya, 2012: 21). The performance framework is intended to ensure regular science and technology monitoring and forecasting in all areas relevant to national development. The STI policy proposed the formation of the National Research Foundation (NRF) in 2014 through which amongst other major roles will strengthen the research performance management (Republic of Kenya, 2012: 29). Another proposed role of the NRF is compiling and maintaining a national database of research and innovations funded by the Fund (Republic of Kenya, 2012:29). These efforts through the formulation of the national science policy, the formation of the NRF and the need to strengthen the performance management framework of the national research system, show that the Kenyan government is committed to the regular assessment of the national science system.

4.3 Understanding the science system

This study adopts the research and innovation framework proposed by Mouton (2015). Several authors have outlined various conceptual frameworks of the national innovation systems. According to Mouton (2015), any proposed research and innovation performance framework should be embedded in the conceptualisations of the national research and innovation system. The next subsections discuss the concept of the national and innovation system.

The National Research and Innovation System framework proposes that the main aim objective of a research system is "[research] and innovation and that the system is part of a larger system composed of sectors like government, university and industry and their environment" (Godin, 2007:16). According to Lundvall (1992:2), the National research and innovation system comprises of "elements and relationships which interact" in the creation, dissemination and application of new knowledge useful to the economy. Apart from the institutions involved in scientific research, the system also includes institutions that train and educate the country's population, the institutions involved in the development of technology, production of innovative products as well its distribution to the economy (Godin, 2007; Nelson, 1993). Further, Godin emphasises that the interactions of the set of institutions in the national research and innovation system are the key determinants of the [research] and innovative performance of the national system. These institutions include universities, government/public research laboratories (science and education system), and industrial enterprises firms (economy system); but also the intermediary bodies and government regulatory bodies (political system), and others such as formal and informal networks that form part of the interaction to ensure performance in the system (Godin, 2007:7, 15).

According to Kuhlmann and Arnold (2001), in other systems that they refer to as "hybrid", these elements comprise of a section of the society which plays other roles in other societal areas, for instance, through innovation and education activities. Research and innovation systems have a significant effect on the modernisation processes of a society (Kuhlmann, 2003:354). Given the importance of research and research and innovation systems, there are different views about how the performance of the systems has to be evaluated and monitored.

Science is not an "autonomous" activity in isolation from the social demands such as national security, health, food security, improved living standards more leisure for the populations, as well as economic growth (Godin, 2007). Given the different roles of science and the science system, researchers, economists, educators and political leaders have to cooperate and interact in the decision making for the enhancement of science, and ensure that the nation and its population can tap the benefits of science (also see OECD, 1963:15). Furthermore, Godin (2007:7) states that, in essence, “science, in a word, has become a public concern”.

In summary, the National research and innovation framework emphasises that the institutions’ behaviour and relationships to each other, which could be the “causal” explanation of the performance of the system. “The overall innovation performance of an economy depends not so much on how specific formal institutions (firms, research institutes, universities, etc.) perform, but on how they interact with each other” (Godin 2007: 8).

4.3.1 The relationships essential for the performance of a science system

The first major interactions in the research system are between the public sectors: government, university and industry. The industrial sector is specifically targeted as far as innovation and economic growth is concerned. Given the importance of industrial research, there is a need for government to invest more funds for science, technology and innovation. The emphasis on university-industry relationships or interactions is to ensure that research produced at universities and industries is cross-fertilised. Similarly, the relationships and interactions between the university, industry and market are to ensure the commercialisation of products and inventions.

Secondly, the other type of relationship in the national research and innovation system is between “basic and applied research”. The interaction between basic and applied research speaks to the argument against the idea that research and innovation is a linear process that begins with basic research and ends with commercialisation. According to the OECD reports of 1963, it is argued that there are no clear boundaries between basic and applied research (OECD, 1963). However, according to Godin, the problem is in how to link basic and applied research (Godin, 2007:18). For most of the research that is conducted a “system approach” has been adopted with an emphasis on creating institutions which are not only limited to the research environment. This is a result because of the link between science and technology.

Thirdly, the other relationship and interactions in the research and innovation system pertain to policy. There are continuous calls for an established relationship and interaction between science and policy. There is an emphasis on a continuous working relationship between the officials charged with the responsibility of science and the national policymakers. According to OECD reports, the national policies in other spheres such as economic, social, military, foreign and aid policies, should take into consideration the expectations and achievements of research, technology and innovation (OECD, 1963: 26). Accordingly, this involves the use of science policy together with other national policy policies to address the economic and societal needs (Godin 2007:19). Therefore, one of the key recommendations for each country has been to create a national research office that is charged with the responsibility to formulate national policies, co-ordinate scientific research and innovation and ensure integration of the national policy and the science-policy (OECD, 1963:24).

The fourth type of relationship and interaction emphasised in the research and innovation system involves the economic environment. Therefore, the need for a relationship between a national policy for economic development and policy for scientific research and development. Importantly, there should be a relationship between those charged with the responsibility to develop the economic policy and those responsible for the science and innovation policy.

Lastly, the relationship and interactions stressed in the research and innovation system is that of international cooperation. International cooperation between scientists has increased in the recent past despite the boundaries. However, Godin and others stress the importance of international collaborations between governments on matters that concern science, innovation and technology (Godin, 2007). The elements, sectors, relationships and interactions of the research and innovation system form a broader context of understanding some of the dimensions of the science system that are assessed.

4.4 The purposes of the research and innovation performance assessment framework

Recent times have seen an increased interest in the functioning of national research and innovation systems with a concomitant increase in interest in system-level evaluations (Rip, 2003:34). System-level approaches adopt the standard evaluation approaches discussed in the literature in the evaluation of the performance of a science system. Ex-post evaluation is rooted in "accountability and punitive evaluation (when an evaluation is called for to justify a decision to close down something" (Rip, 2003:34). Accountability pressures have their links with the advent of new public management (NPM) and the related emphasis on evaluation of performance (Arnold, 2004; Rip, 2003, OECD, 2011; Lewis, 2014). According to Rip (2003:35), accountability often involves the question "what did you do with the money?" In this case, "audit type methods" are used in assessment, where public research institutions are evaluated on how they expended the funds devoted to research and innovation (also see Geuna & Martin, 2003). However, these methods are also used to check on the research inputs and outputs. Braun (2000, cited in Feller (2001:2) applied the principal-agent model to claim that in cases where the government and its other branches (i.e. the principal), loses trust in the skills and capabilities of the research community (i.e. the agent), to be "self-policing", the government applies administrative tools that will ensure accountability and to convince the public/tax-payers that the public funds were expended efficiently and effectively. In addition, aside from the accountability of the public money, promises and expectations indicated by the research institutions in contributing to economic growth and sustainable development are to be achieved hence the growing interest in R&D evaluation (Rip, 2003).

Accountability pressures came on the rise in the 1990s, especially with the establishment of the "government performance and results contracts" in several countries, especially the developed OECD countries. The performance contracts require the public institutions and agencies to "present systematic statements of goals and objectives, to link budget requests to objectives, and to document results from prior expenditures" (Feller, 2001: 4; Kuhlmann, 2003:357). Kenya also introduced such performance contracts, particularly in public institutions. Public reforms through performance contracts were implemented in Kenya in 1993 (Kobia & Mohammed, 2006). As seen in other contexts, introducing performance contracting in the Kenyan public sector was aimed at ensuring "accountability for results and transparency in the management of public resources" (Bomett, Kindiki & Too, 2014:585). However, it has to be noted that this did not lack complexions and tensions specifically in the basic research institutions.

The triangle of R&D evaluation by Rip (2003) illustrates and summarises the main rationales of evaluation (see figure 4-1 below).

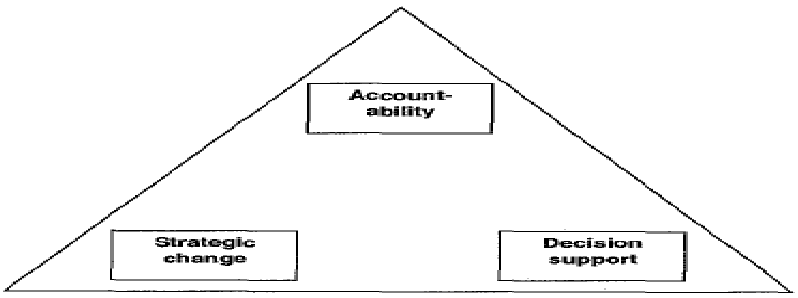

Figure 4-1: The triangle of roles of R&D evaluation.

Source: Rip (2003: 37)

Apart from accountability pressures, Research and innovation evaluation have links to "strategic change" (Rip, 2003:36; also see Geuna & Martin, 2003). In relation to the interest in strategic and learning issues, through Research and Innovation evaluations, policy actors attempt to effect strategic changes in the research system, that is, in the direction R&D is taking, or in the management of the R&D institutions. R&D evaluations ensure the maintenance and improvement of the research system, by illustrating "what works and what does not" and addressing the challenge of maintenance of the "health" and relevance of the system. In addition, R&D evaluations provide information that influences research priority setting. In this context, there is interest in assessing the appropriateness of goals, as well as, evaluating the progress of the R&D and the research system against policy and strategies goals and targets (Kuhlmann, 2003:352; Rip, 2003:36).

Additionally, Research and Innovation evaluations ensure decision support as the data supports the management of the larger national system. R&D evaluation employs both quantitative and qualitative methodologies and tries to assess effectiveness (Rip, 2003). Hence, R&D evaluations provide "evidence or intelligence" that improves understanding of the research system and informs decision-making about funding and resource allocations (Campbell, 2003; Kuhlmann, 2003; Rip, 2003: 36–37). Geuna and Martin (2003) refer to the example of the UK, where the Research Assessment Exercise has direct links to the research funding decisions. In these cases evaluations are used in the allocation of research funds to the universities or research institutions, e.g. the UK research assessment exercises. In some contexts, evaluation is also used as a "management tool" (Geuna & Martin, 2003: 279).

Summary of the primary uses or purposes of evaluation findings

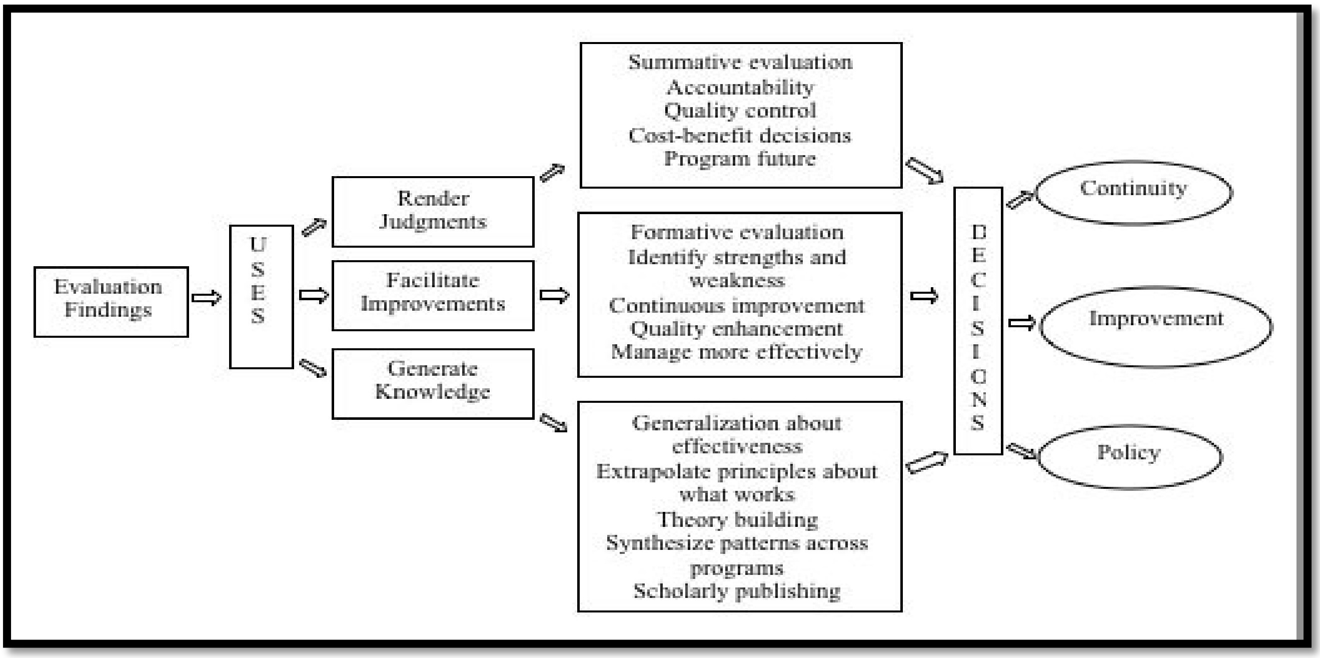

Figure 4-2: Summary of the primary uses of evaluation.

Source: Rhadhakrishnna and Relado (2009)

4.4.1 The dimensions of science evaluated

In relation to the 'dimensions' of research quality, there are several approaches. One of the more standard approaches is to focus on five dimensions of the science enterprise: quality, relevance, efficiency, viability and effectiveness. Several countries have adopted these four dimensions in their evaluation studies. The Kenyan science policies similarly stipulate that, it is important to assess the effectiveness, efficiency and relevance of the system.

Quality

Campbell (2003) notes that, quality relates to the scientific achievement of output (research publications or innovation). Quality is also defined as a measure of excellence, a term which relates to the capability to perform at international levels. This ability is achieved through research rigour and scientific performance. International standards are achieved by the acceptability of science by others.

Efficiency

Efficiency focuses on the relationship between the research output and research input, for instance, the number of papers per researcher published in the web of science, the number of patents submitted per researcher or the number of papers per million of the population (Campbell, 2003).

Relevance

Relevance refers to how relevant the research produced or published is to the other research conducted in the research system or in the knowledge production process. Similarly, relevance mostly entails some alignment between the National Science and Innovation and the country and national or international challenges such as the sustainable development goals. This generally implies the research has a high impact on the society or for technological application (Campbell, 2003)

Viability

Viability focuses on assessing the organisational context of the institutions' research; for instance, whether the institutions outline their mission statements with clear research objectives and goals and facilitate the measures, which directly refer to the research goals. Additionally, the concept of viability refers to whether research institutions develop benchmarking criteria, that the set research objectives could be assessed against (Campbell, 2003).

Effectiveness

Campbell (2003: 110) classifies effectiveness as a "'second-level'" dimension of research quality. Campbell further indicates that effectiveness offers an example for an advanced dimension that focuses on the question: "how effective is the university [national innovation system] research?" Commonly used in the policy, effectiveness assesses the achievement of the stipulated research objectives. Effectiveness, in some cases, can be a model of the first-level dimensions of research quality, hence allows distinctive effectiveness profiles for several research institutions. Subsequently, the "effectiveness" may entail cases where some research institutions perform well in terms of efficiency, while others show improvement in the relevance. Importantly, effectiveness assesses the achievements in terms of national goals.

4.5 The research and innovation evaluation framework

The understanding of the research system discussed above forms the foundation of the proposed research performance evaluation framework. Mouton (2015), illustrates four major dimensions that a research and innovation evaluation framework can be built around. These include Research and innovation investment, research and innovation capacity, research and innovation outputs and research and innovation impacts. These dimensions, as detailed below, can be disaggregated further into research and innovation performance categories, together with the related indicators (Mouton, 2015).

4.5.1. Research and Innovation Investment

Research and innovation investment refer to the financial investment devoted to research and innovation by a given country. The R&D survey, conducted by the ASTII for African countries (Frascati manual used) (OECD, 2002), provides two major categories of investment, public and private expenditure on R&D (OECD, 2002). According to the R&D surveys, the conclusions are that, there are pronounced differences for resources spend on R&D, amongst the different countries around the world. Godin provides the example of the US, which devotes more resources on R&D compared to the other member countries (OECD). Notably, none of the countries had devoted both financial resources and capacity (researchers and scientists) to R&D (Godin, 2003; 2007).

The Kenyan government has aimed at devoting more resources for research and innovation. The Kenyan government stipulates in the science policy that "at least 1% of GDP will be mobilized from the Government and other sources to support the development of the required ST&I capabilities and capacities" (Republic of Kenya, 2012:vii). However, as illustrated in the later sections of the framework, this intended figure of the GERD is far from being achieved.

4.5.2 Research and Innovation Capacity

Research and innovation capacity is described as the "human resources capacity" that is involved in undertaking the research and innovation activities in the research system. The R&D surveys, in its measures, include all the R&D personnel (researchers, technicians and other staff supporting R&D activities. Mouton (2015) also notes that the research and innovation capacity might include the capacity that is drawn from collaborations and collaboration networks.

4.5.3 Research and Innovation Outputs

Research and innovation can be described as the "measurable products" that result from scientific and technological activities. Research outputs may include different categories of publications. However, in some contexts, the masters and doctoral graduates are seen as research outputs. Innovation outputs consist of patents and trademarks (Mouton, 2015: 10).

4.5.4 Research and Innovation Impact

Research and innovation impacts are defined as "the short-to-medium-term effects of research and innovation activities" (Mouton, 2015:10). Research impact has different measures such as citation impact where the peers in a field recognise a publication or accept the science. The table below summarises the research and innovation dimensions, the research and innovation performance categories and their associated indicator categories.

A conceptual Framework for Research and Innovation Evaluation

Table 4-1: A summary of the indicators for the conceptual framework

Research and innovation dimensions	Research and innovation performance categories	Indicator categories
Research and Innovation impact	Scientific impact	Citation impact
	Socio-economic impact	Economic growth
Research and Innovation outputs	Research publications	Papers in the web of science
	Graduate outputs Innovation outputs	Doctoral graduates Masters graduates
	Innovation outputs	Patents
Research and Innovation capacity	Human resources for STI Level of collaboration	Researchers R&D personnel
		Academic staff International collaboration

Research and Innovation Investment	Public investment	Public expenditure on research and innovation
	Private investment	Business expenditure on research & innovation

Source: Mouton (2015)

Section Two

Research Methodology

4.6 Research design

The study employed a case study design. Yin (2014:16) provides a twofold definition of a case study, as he notes that "a case study is an empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-wold context, especially when, the boundaries between the phenomenon and context may not clearly be evident". In other words, case study research is conducted for the understanding for "a real-world case and assume that such an understanding is likely to involve important contextual conditions pertinent to your case" (Yin, 2014: 16). In addition, Gerring (2004:342) defined a case study as "an intensive study of a single unit for the purpose of understanding a larger class of (similar) units. A unit connotes a spatially bounded phenomenon e.g., a nation-state, revolution, system, political party, election, or person observed at a single point in time or over some delimited period of time".

A case study is suitable for exploratory and descriptive questions (Babbie & Mouton, 2001). One of the strengths of the case study design is that it facilitates the construction of detailed and in-depth insights into the phenomenon being studied (Babbie & Mouton, 2001; Hodkinson & Hodkinson, 2001). Baxter and Jack (2008) also noted that, qualitative case study research design offers tools for researchers to investigate complex phenomena within their contexts. Yin (2012) also noted that, case study research can be applied as an exploratory tool prior to the use of other methods, such as surveys and experiments. In addition to its application in exploratory research, case study research design can also be applied in descriptive, explanatory, and evaluative approaches (Yin, 2012).

A case study research design should be applied when: (a) the focus of the research is to answer "how" and "why" questions; (b) you cannot manipulate the behaviour of respondents in the research study; (c) you want to cover contextual conditions because you believe they are pertinent to the phenomenon under investigation (Yin, 2012). Nevertheless, the study design cannot be generalised and are unlikely to produce results that have predictive value (Hodkinson & Hodkinson, 2001). Yin (2012) noted that, when case study research is conducted poorly, all of these limitations can bring about unreliable research findings. Thus, the nature and setting of this study suit the application of the case study design. The question often raised in the literature is, "can a case study be used to do evaluations?" (Yin, 2014:15).

The sun-section below discusses how case studies can be applied to evaluations in research as is the case of evaluation of Kenya's science system.

4.6.1 The application of case study research design in evaluation research

The use of case study design in evaluations is determined by the definition of case study research highlighted above, the need to "gain an in-depth (and up-close) examination of an "a case" within its real-world context" (Yin, 2014:220). In comparison to other research designs adopted for evaluation research such as experiments, quasi-experiment and surveys, case study evaluations have the following advantages, as they can 1) "capture the complexity of a case, including relevant changes over time, and 2) attend fully to contextual conditions, including those that potentially interact with the case" (Yin, 2014:220).

Case study research is appropriate for evaluation given several features. First, to study the complexity of a case and its context requires evidence from multiple sources which may include survey data, interviews, documents, bibliometric data, field observations and so on. Yin (2014:220) notes that case study evaluations need to the triangulation of data from the multiple sources so as to corroborate and confirm the findings. Second, the evidence of the case study research can also include quantitative data, qualitative data or mixed (both quantitative and qualitative) data. Thirdly, a case study evaluation also allows the use of "an initial but tentative theory about the case." Yin (2014) notes that the initial theory can be descriptive or explanatory theories. The descriptive theories attempt to hypothesise about the characteristics of the case while the explanatory theories attempt to address the "why" and "how" questions about the case.

4.7 Research Methodology

Mixing quantitative and qualitative methods in a single case study build complementary strengths of both methods (Neuman, 2011:163). "Mixed methods research involves philosophical assumptions that guide the direction of the collection and analysis and the mixtures of quantitative and qualitative approaches in many phases of the research process. As a method, it focuses on collecting, analysing and mixing both qualitative and quantitative data in a single study or series of studies. Its central premise is that the uses of quantitative and qualitative approaches, in combination, provide a better understanding of research problems than either approach alone" (Ivankova, Creswell & Plano Clark, 2007:5).

The study applies a mixed-method design, which encompasses four elements. The first is a historical study, which comprises an overview and history of research in Kenya pre and post-independence. The second component utilised scientometric and bibliometric analysis of the scientific output, trends, and distribution across the scientific fields, top performing R&D institutions, citation impact, relative field strengths and positional analysis across scientific fields, collaboration patterns. The third component utilised the survey data from Kenyan researchers, which investigates the factors influencing the performance of young scientists and career development. The last component is qualitative in nature and involved the re-analysis of the interviews for selected respondents from Kenya.

4.7.1 The historical analysis

In order to provide a broader context for the research performance assessment for Kenya, the thesis commences with a historical overview of research in Kenya pre and post-independence. The R&D activities in Kenya have a long history dating back to 1900 when the British government established the first agricultural experimental farms to conduct research on crops and animal stocks. It is important to understand the history of science in Kenya to provide a necessary context for the scientometric, survey and qualitative data analysis of this study.

The first part of the historical study collected and analysed the relevant documents related to the establishment and organisation of the R&D institutions in the country during the colonial and post-colonial era. The second part of the historical analysis involved the collection of information on the R&D setup, legal and institutional frameworks of Kenya science and technology after independence in 1963. The study analyses the organisation and establishment of the R&D institutions (public research institutes, higher education institutions and international research agencies and institutes), the R&D landscape and evolution of science and technology policies. The analysis provided information on the trends, characteristics of R&D support in terms of institutional and legal frameworks; research and innovation investment; research and innovation capacity; research and innovation outputs etc. The historical account starts by discussing the history of agricultural research, followed by medical research and higher education research. The study used institutional documents, the STI Act and other Act(s) of parliament in relations to the establishment, structural organisation and mandates of the scientific institutions in Kenya. I also used annual reports, annual reviews, policy reports and briefs as well as other secondary sources (where available) to provide information on the institutional development and changes and the bodies responsible for advisory and coordination of research. An elaborate exposition of the historical analysis of science in Kenya is provided in the second chapter of this thesis.

4.7.2 Scientometric and Bibliometric methodologies

The second component of the methodology of the study entailed the use of scientometric methods. According to Ivancheva (2008:1) scientometrics relates to the "process of scientific knowledge production". In this case, it examines the quantitative characteristics of scientific communication, research productivity, research collaboration, evaluation of scientists and research institutions. In a further description of scientometrics, Ivancheva states that:

> The wider thematic scope of scientometrics includes issues as: quantitative studies of scientists, projects, funding of research, research infrastructure, etc.; quantitative studies of publications, patents, and citations by institutions, countries, languages, co-authorships, thematic fields, etc.; investigations and monitoring of individual, institutional, or state research production; identification of relations between different research disciplines … (Invancheva, 2008:1).

The description of scientometrics above offers the key themes that this study considered in its analysis. I interpreted Ivancheva to mean that scientometric entails a description of the quantitative measures of research funding, scientific output, impact through publications and citations enables, and collaboration through co-authorships enables the understanding of the state of the science of a science system. Scientometric methodologies also include bibliometrics. Bibliometrics has emerged as a branch of the wider field of infometrics that focuses on the quantitative studies of science and technology (Invancheva, 2008) Bibliometrics as one of the primary methods of statistically analysing publications (articles, conference reports, patents, discoveries etc.) forms an important part of the scientometric research approach (Borgman & Furner, 2002). According to Pritchard (1969:349), bibliometrics can be described as, "the application of statistical and mathematical methods to books and other media of communication". Bibliometric analysis is mostly applied to publications as they provide "elements for 'measuring' important aspects of science" (Van Raan, 2004: 25). Van Raan further notes that these publications include names of authors, institutional addresses, the journal-title (indicating both the field of research and 'status'), the references (citations) and the concepts (keywords and keyword combinations) (Van Raan, 2004). When the above elements are analysed, they can indicate the researchers' output, co-authorship and citation profiles.

From the above descriptions, I identify two key main indicators of scientometrics. Firstly, the "input indicators" that are linked to the research process, that is, the individual scientists, research investment (grants), research infrastructure and organisation entities and human resources for research. Secondly, the "output indicators" that are linked to the research products, that is, the projects, publications (other related documents), their citations and co-authorships (Ivancheva, 2008:2). In measuring and assessing the research performance for Kenya, the scientometric and R&D indicators described above were applied in this study to explore the state of Kenya's science system. It is important to note that, this analysis was conducted at the aggregate levels of the country.

4.7.2.1.1 Advantages and disadvantages of bibliometrics

The literature identifies several advantages of bibliometrics that make it appropriate for the evaluation of research. First, "bibliometrics analyses data which concerns the essence of scientific work" (Bornmann & Leydesdorff, 2014:1228). Publishing of relevant research findings is essential in all scientific fields. The work published by scientists is often cited by other researchers. In the scientific community, citations form part of the reputation system of scientific work, as scientists show the recognition of other scientists' work (Bornmann & Leydesdorff, 2014:1228). The second advantage of using bibliometrics in the evaluation of research is that bibliometric data is more accessible and can be assessed for several scientific fields from different data sources, such as, Scopus and Web of Science. Thirdly, the results of bibliometrics corroborate well with other indicators such as the standard R&D indicators (i.e. research investment and research capacity), research quality and other indicators that measure excellence (scientific awards). Importantly, given that evaluation of research often involve counting of publications and citations, it's argued that bibliometrics has become a more reliable tool for assessment of research (Bornmann & Leydesdorff, 2014: 1228).

Apart from the different advantages, several disadvantages of using bibliometrics as a tool of research evaluation have been identified in the literature. First, bibliometrics is only applicable to scientific fields where its research publications and citations are available in research databases such as the [CA]Web of science or Scopus. It has been shown that the health and natural sciences are more represented in these databases compared to the social sciences and humanities. Therefore, for these fields (social sciences and humanities) the bibliometric results are limited. To solve this limitation, scholars have made suggestions for studies using bibliometric as a tool, there is a need to control for the field differences. Apart from controlling for field differences, some scholars have suggested that triangulation of the data from different sources such as Google Scholar. However, google scholar is said to have several challenges such as the validity of the data. Thirdly, since citations take time to accumulate, a research assessment using bibliometrics does not say much about recently published work. This disadvantage of bibliometrics is mainly a challenge when evaluating research institutions, where the recent research performance of the institutions shows little about the performance of the institutions. In relation to the assessment of recent performance, bibliometrics is suitable in the evaluation of the recent performance of the individual researchers in the institutions unlike the performance of the institutions.

Bibliometrics analysis was employed to evaluate Kenya's research performance, particularly analysing the research output, research collaboration and citation impact. In particular, the analysis of the research output looks at the publication outputs over the years, publication trends, top performing R&D institutions in the country, distribution of output across the scientific fields, relative field strengths, positional analysis across scientific fields, collaboration trends and patterns and other related indicators. Bibliometric data for Kenya was extracted from the WoS and Scopus and it covers the time period from 2000-2016. Authors with an affiliation of Kenyan address were one of the criteria for extraction of the bibliometric data. Both full counting and fractional counting were used in the analysis of publication output in this study. The choice of using both full counting and fractional counting in this study is based on the fact that the two methods of measurement illustrate different perspectives: fractional counting illustrates the contribution of a unit of research, whereas full counting illustrates the participation of the unit (Moed, 2005).

4.7.2.1.2 Bibliometric indicators

This section lists and discusses the main bibliometric indicators that are analysed in this study.

Number of papers: The number of scientific papers by institution and country and by country, based on author addresses in a specific dataset

Papers per capita: The number of papers at the country level, weighted per capita using population statistics

Specialisation Index (SI): An indicator of the intensity of research of a given entity in the research area relative to the intensity of the world in the same area"

Average of relative citations (ARC): Provides an indirect measure of scientific impact based on journals' impact factors

Collaboration rate (national, international & total): This is an indicator of the relative intensity of collaboration between entities (e.g., countries, institutions).

How to measure Relative Field Strength (Specialisation index)

The specialisation index (SI) also referred to as Activity Index or the Relative Field Strength (RFS), "is a measure of the degree of specialisation of a country in a particular field. It highlights the relative research efforts devoted to a given field in relation to a national or group baseline. The concept was suggested by Frame (1977) and elaborated by Schubert and Braun (1986) to compare the performance of any scientists, groups, institutions or countries with the average (Siripitakchai & Miyazaki, 2015:7).

In this study, SI or the Relative Field Strength (RFS), is interpreted as the research intensity or concentration of the country [or particular university] for a given research field relative to the average in the world [for the case of the country] or in a country, region, or group of countries [for the university]. The RFS is calculated as follows:

$$RFS = \frac{\text{the given field's share in the particular country [university] publication output}}{\text{Field share of publication by the world}}$$

$$rfs_f = \frac{\frac{n_f}{n_t}}{\frac{N_f}{N_t}},$$

Where n_f is the number of publications produced by the entity in the field f, while n_t is the number of publications produced by an entity across all fields, N_f is the number of publications produced by the world in the field *f* and N_t is the total number of publications produced by the world.

Relative Impact

Citations are a measure of research impact as a citation can mean recognition or validation of one's research by others. Citations per paper (also called 'impact') were computed by dividing the sum of citations to some set of papers for a defined time period by the number of papers (paper count)" (Thomson-Reuters 2008, quoted in Siripitakchai & Miyazaki, 2015). The citations per paper are an attempt to weigh the impact with respect to output since a larger number of publications tend to produce a greater number of citations"(Siripitakchai & Miyazaki, 2015: 426). Thus, this indicator is computed based on the number of publications and their accumulated citations. In order to take account for the "variation in the citation windows of the papers and the different citation patterns across fields and subfields of sciences, the RI is defined as:

RI =

$$\frac{\dfrac{a\ country's\ [university's] impact\ in\ a\ particular\ field}{a\ country's\ [university's] impact\ in\ total\ field}}{\dfrac{a\ world's\ [country\ or\ region\ or\ group\ of\ countries'] impact in\ a\ particular\ field}{a\ world's\ [a\ country\ or\ region\ or\ group\ of\ countries'] impact\ in\ total\ field}}$$

= $I_{ij}/I_{it}/I_{cj}/I_{ct}$

Where *I* represent an impact (citations per paper), i is the particular country [university], j is a given field, and t is a set of fields. c indicates the world [a country, a region or a group of countries]. In cases where RI is 1, it shows that “a set of papers of the evaluated country [university] is cited exactly at an average rate of the world [a country/region/group]. If the country’s RI is more or less than 1, it illustrates that “the country’s [institution’s] publications are cited more or less than the world [a country/region/group] average in the given field (Siripitakchai & Miyazaki, 2015). This step allows us to identify the country’s or particular institution’s high research performances. The figure below shows a positional analysis of the research performance of a country.

Field Normalised Citation Score

The calculation of the Mean Normalised Citation Score begins with a calculation of the expected number of citations for any number of citations for any publication in a specific field. Publications are related with several fields, thus, all the citations received for each publication are attributed in equal proportions to all the scientific fields related with it (Mouton, Basson, Blanckenberg, Boshoff, Prozesky, Redelinghuys, Treptow, van Lill & van Niekerk (2019).

$$e_i = \frac{\sum_{j=1}^{N_i} \frac{c_j}{f_j}}{\sum_{j=1}^{N_i} \frac{1}{f_j}},$$

where e_i is the expected number of citations for any publication in the field for any publication in the field i, Ni is the number of publications in the field *i*, c_j is the number of citations received by publication *j* and f_j is the number of fields associated with publication *j*. The calculation of the mean normalised citation score of the publication is as follows:

$$ncs_j = \sum_{i=1}^{f_j} \frac{c_j}{e_i f_j},$$

$$ncs_j = \frac{c_j}{f_j} \sum_{i=1}^{f_j} \frac{1}{e_i}.$$

The mean normalised citation score for a set of publications is calculated as follows:

$$mncs = \frac{1}{n} \sum_{j=1}^{n} ncs_j.$$

The citation window considered when calculating the mean normalised citation score varies as a studying evaluating performance may consider a two-year citation window or a three-year citation window. In other words, this implies that the only citations counted are those that accumulate after the second or third year of publication.

Positional Analysis of Research Performance of a country

In the cases where the values of SI and RI of the observed country [or institutions] are in the first or second quadrant, as illustrated in the figure below, the country is described as having high performance in the field being studied (Quadrant 1 [“Rank 1”] and quadrant 2 [Rank 2]). Quadrant 3 illustrates that the country [university] “has high research effort and specialization [intensity] in the field, but other scholars do not recognize the work”. Quadrant 4 (“Rank 4”) illustrates the worst scenario where the country [university] does not actively play a role in the particular observed field. Similarly, the research work of the country is neither recognised nor has a lower impact on the field.

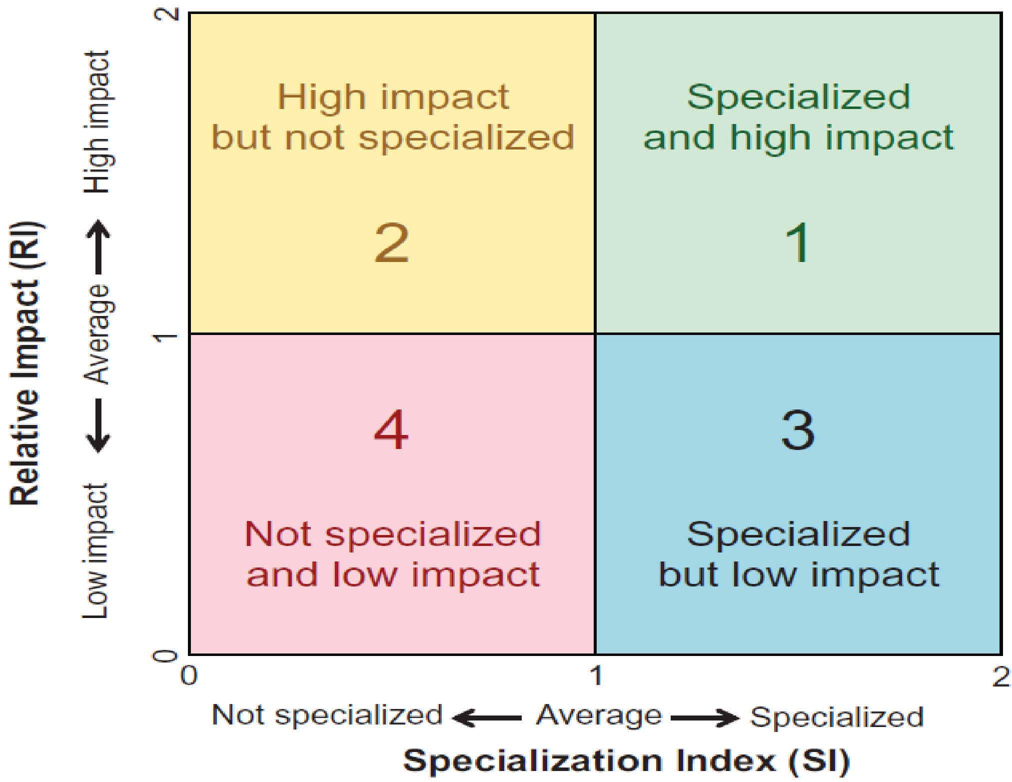

Figure 4-3: Positional analysis citation impact versus specialisation index (Relative field strength)

Source: Siripitakchai and Miyazaki, (2015).

Note: If the country's performance is in quadrants 1 or 2, the studied country is considered to have high performance in the particular observed field. 4.7.3 Secondary analysis of survey data The third component of our methodology involved the secondary analysis of web-based survey data, collected under the African Young Scientists Project at the Centre for Research on Science and Technology (CREST) between May 2016 and February 2017. The target population of the Africa Young Scientist Study mainly constituted Young African scientists who were identified through several proxies in the study. Firstly, they were involved in institutionalised research activity in one or more scientific disciplines. Forming part of the scientific community, the communication of their results and findings to their peers is through publications and other means. Another characteristic of these scientists was that they needed to have been born and currently working in an African country. The primary issue, in this case, was the influence of the national and/or continental contexts on the scientists' career trajectory. Although the study had its focus on "young" scientists, age was not the key criterion used for identifying respondents. In actual fact, the only 'entry point' of the target population of the study was their publications. Therefore, the study was able to get responses from all the members of the scientific community in the African countries surveyed. From the responses to the survey received, it was possible to disaggregate by age and a range of other demographic variables such as the scientific field, nationality, gender, sector of employment and highest qualification.

Kenyan researchers were identified through corresponding authors' emails from the Web of Science (WoS) and Scopus databases with bibliometric data from 2005 to 2015. The total number of corresponding authors' emails identified from the WoS and Scopus databases for Kenya was 5406. A total of 3928 structured self-administered questionnaires were distributed through the CheckBox[12] platform. The data collection process for Kenya begun on July 2016. This questionnaire was distributed in 3 waves. Firstly, potential respondents were asked if they were willing to participate in the survey (wave 1). In Kenya, wave 1 was at the end of June 2016. After wave 1, undelivered emails and inactive emails were identified. For the individuals who were willing to participate in the survey, an email containing a link of the survey was sent to them (CREST, n.d.). Wave 2 entailed, sending reminders to the potential respondents who had not responded after a week. During wave 3, an email with the link to the survey was sent to all the individuals with an active address who had not previously responded. Data collection for Kenya was concluded at the end of February 2017.

At the close of the survey exercise, a total number of 345 individuals responded to the questionnaire. In this regard, in reference to the emails, the response rate was 9.06%. However, it is important to note, the response rate indicated here is an underestimation since the individuals in the initial list used for the study often had two or more active emails addresses.

The dataset used in the final analysis consisted of 224 respondents who are African nationals with a Kenyan affiliation address. These show that some categories of respondents were excluded in the final analysis. The categories of respondents included those who: were not Kenyan nationals, were not currently residing in Kenya, who had not acquired a PhD, did not report any research output in the last three years preceding data collection.

The secondary analysis of the survey data investigated the reported research publication outputs, publication trends across the scientific fields. The analysis of the survey data also analysed the reported research funding of the respondents, and factors influencing the research performance of young scientists and career development. The study also analysed the reported collaboration patterns and the challenges that influence the performance of research of young scientists. The main aim of the primary survey was to study young scientists

[12] https://www.checkbox.com/

of a particular age group (40years and below) and the factors that contribute to their research performance. What this means is that the age variable was key in this analysis.

The survey questionnaire of the YSA project considered several dimensions to capture factors that influence the research performance of scientists and career development. These dimensions included educational background, employment category, research output, research funding, challenges, international mobility, collaboration, mentoring, demographic background and working conditions. The questionnaire was adapted from the Global State of Young Scientists precursor study (GLOSYS) by Friesenhahn and Beaudry (2014) and for GLOSYS in ASEAN by Geffers *et al.* (2017) taking into account the African context and the knowledge gap intended to be filled.

After data collection of the Young Scientist project, I embarked on data cleaning and (re)coding. All the responses to the open-ended questions and "other" responses were cleaned by standardising and creating new categories. The Statistical Package for the Social Sciences (SPSS) software was used to create new variables for statistical descriptions and analysis.

4.7.4 Qualitative field study

The qualitative component of the study in this project involved in-depth semi-structured interviews with selected respondents (30 respondents) who agreed during survey exercise to be contacted for the further interview. Of these 30 respondents, 11 were interviewed, thus providing the qualitative survey data. From the YSA survey, 189 scientists indicated that they could be contacted to further participate in the in-depth interviews. Of these scientists, 142 scientists form the sample of this qualitative study as they published a research paper that appears in the Scopus or WoS, have a Kenyan address affiliation and a doctoral or equivalent as the highest academic qualification.

The in-depth interviews aimed to provide deeper insights into the factors that influence the research performance and career development of scientists in Kenya. Respondents were asked to expound on several themes in the survey such as research funding, research collaboration, international mobility, mentoring and training and challenges that impact on the academic or scientific career. This study adopted a semi-structured questionnaire during the interview. The sampling frame of the respondents who were interviewed can be referred to as the 'outliers' in the survey exercise, for instance, those researchers who managed to produce the high quantity and quality research outputs despite limited support in terms of funding and time resources from the research institution or the country's science system. Another set of outliers consist of respondents who had indicated that they collaborated more often or less often. Therefore, the in-depth interviews intended to triangulate the results of the bibliometric analysis, the survey data analysis and other relevant data about factors, which influence research performance and career development of the young scientists in Kenya. The mode of the interview was through skype and telephonic interviews. All interviews were recorded, transcribed, and analysed by using the qualitative data analysis software (Atlas/ti). These results were interpreted against the reviewed literature on research productivity, funding, and collaboration, as well as the conceptual and analytical framework of this study.

4.7.5 Data Presentation

The presentation and the results of the bibliometric, survey and qualitative data have been grouped under the themes and subthemes based on the conceptual framework adopted for the study. Table 3-2 below displays the identified themes and subthemes analysed, presented and discussed in this thesis.

Table 4-2: Analytical framework outlining the main themes and sub-themes for the presentation and results of bibliometric indicators, survey and qualitative analysis.

	Main theme	Sub-themes	Data Sources
1	Research Output	i. Trends and distribution of output across the scientific fields ii. Top performing R&D institutions iii. Relative Field Strengths iv. Factors	- Bibliometric - Survey data - Interview data
2	Research collaboration	v. Collaboration profiles and trends vi. Collaboration intensity vii. factors that influence research collaboration	- Bibliometric data - Survey data - Interview data
3	Citation Impact	i. Citation MNCS ii. Positional analysis across scientific fields	- Bibliometric data
2.	Research capacity	i. Human resources base of Kenya's R&D institutions ii. Research collaboration profiles and intensity iii. International mobility iv. mentoring and training	- R&D survey data - Bibliometric - Survey data - Interview data -
4	Research investment	i. National and International research funding ii. Trends in terms of investment by scientific field and institution iii. Factors that influence receipt of research funding	- R&D survey - Web-based survey data - Interview data
5	Scientists working environment	i. Main factors influencing the performance of scientists ii. Challenges of the academic or scientific career	- Web-based survey data - Interview data

Summary and Conclusions

This study used the research and evaluation framework proposed by Mouton (2015) in understanding the state of science in Kenya's science system. This framework focuses on the four main dimensions of the study: research and innovation investment, research and innovation capacity, research and innovation outputs and research and innovation impact. Using the R&D data, the research and innovation investment focused on measuring the public investment available for research and innovation in Kenya. Public investment is indicated by public expenditure on research and innovation. Similarly, survey and interview data was used to analyse several aspects of funding including: the amounts of funding received by researchers and the barriers of accessing research funding. The research and innovation capacity focused on analysing the researchers and R&D personnel available for research. Similarly, this dimension also focused on analysing research collaboration using co-authorships. The research and innovation output focused on measuring research publications produced by Kenya (using both the full counting and fractional counting methods) indicated by the number of papers available in the Web of science. Using survey and qualitative data, this dimension also analysed the factors that influence research production. The citation impact dimension focused on measuring the citation impact of Kenya's publication output using scientific output.

A case study was selected for this study given its suitability for the exploratory and descriptive questions addressed in this study. This study also covered the contextual conditions that influence research performance, the historical perspectives of science in Kenya, making the case study a suitable research design. Given the use of the case study design, this study mixed both the quantitative and qualitative methods to evaluate the state of science in Kenya. To address the question of 'what the state of science in Kenya is, this study conducted a historical analysis, a secondary data analysis, a bibliometric data analysis as well as used interview data. The main aim of combining the different research approaches and data collection methods was to ensure an in-depth study of the study as well as well as build the complimentary strengths of the different research methods used in the study.

The historical analysis provided a historical account of science in Kenya, especially in the agricultural sciences and health sciences. The historical analysis also provided a discussion on the developments of key research and development institutions including the higher education institutions, public research institutions, government parastatals and the Non-government research institutions. The secondary data analysis involved the statistical analysis of the survey data drawn from the African Young Scientists project. The statistical analysis focused on the following themes: funding, research output, research collaborations, research mobility, and career challenges. Similarly, the bibliometric data was analysed to provide information on Kenya's science system in relation to publication output (counted using both fractional and full counting methods), citation impact, research collaboration. The qualitative data used was aimed at complimenting the quantitative data in the study as well as expounding on the earlier themes analysed: funding, collaboration, research production and career challenges. Lastly, research and development data drawn from the UNESCO statistics institute was analysed to provide information on research investment and human resources in Kenya.

The following chapter discusses the empirical finding on research investment and funding. The chapter on research investment discusses the standard research and development indicators (e.g. GERD as a proportion of GDP, GERD by scientific field, GERD by research sector, GERD by research activity) for Kenya. In addition, using the R&D indicators, this chapter benchmarks Kenya with other selected African countries.

Chapter 5 Investment in research and development

5.1 Introduction

In this chapter, I first describe and analyse the trends of research and innovation investment in Kenya. I start by providing information on research and innovation investment in Kenya with regard to the following standard research and development indicators: gross expenditure on R&D (GERD), R&D intensity (GERD/GDP), GERD by the source of funding, GERD by scientific field, GERD by sector of R&D performance and GERD by type of research activity. In the second part of the chapter, I discuss the self-reported results pertaining to funding as produced in the survey and interview data. In this discussion I analyse and present results pertaining to the relationship between research and funding and other factors (such as age, gender, academic rank, scientific field, funding, mobility and collaboration. Before presenting the results of the benchmarking on standard indicators of research investment and the more qualitative data from the survey and interviews, I discuss briefly why an analysis of a country's investment in R&D is important.

5.2 The importance of and trends in investment in Research and Development

A key assumption in the science policy literature is that investment in research and development results in both socio-economic and scientific benefits (Martin & Tang, 2007; Salter & Martin, 2001). Over the past five decades, there have been numerous studies looking at the "value of research" and the "return in investment on research" or "the benefits from public-funded research" (Martin & Tang, 2007; Salter & Martin, 2001). In these studies, several scientific benefits of public-funded research have been identified including new knowledge created in the form of ideas, theories, models, methods, and data that allow the tackling of specific research problems (Martin & Tang, 2007; Salter & Martin, 2001). The new knowledge created is applied in the development of technological advances which are then integrated into innovation and ultimately result in some economic and/or social benefits for instance, increase in productivity, increased wealth, enhanced quality of life and/or improved environment (Martin & Tang, 2007). This new knowledge is often codified in publications such as journal articles, reviews, conference papers, books and book chapters (Martin & Tang, 2007). In addition, the university sector supplies skilled graduates and researchers. These new graduates and researchers join the industry and/or labour market with knowledge and skills needed to perform research, develop new ideas, solve complex problems, handle advanced instruments and techniques and develop new innovations and technologies that can help enhance peoples' livelihoods (Martin & Tang, 2007:10). Highly skilled knowledge workers include doctoral graduates who are employed in the different sectors of the industry. Other doctoral graduates become academics who continue to produce new knowledge and train more skilled knowledge workers.

Apart from the scientific benefits, scholars (Martin & Tang, 2007; Salter & Martin, 2001) identified channels through which publicly funded research contribute to economic growth. Among others, new ideas from basic research can be translated into new or improved technologies, products, services and improved processes, which have value added to the economy. Secondly, scientists who later work industrial sector apply theoretical knowledge accrued from basic research. Thirdly, the networks created between the private researchers and users may result in co-operation in production of knowledge needed for problem-solving, and hence have an impact on the economy. The figure below provides a broad overview of the benefits of publicly funded research.

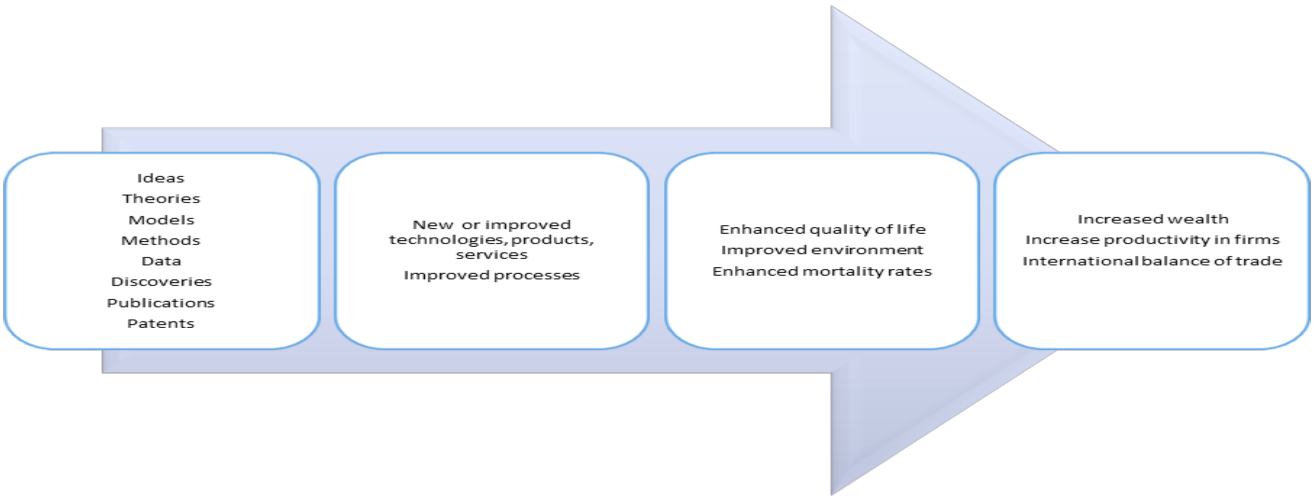

Figure 5-1: A summary of the benefits of public funding.

Source: Adapted from Salter and Martin (2001) and Martin and Tang (2007)

Trends in investment in research

In line with the benefits of investment in R&D and the attainment of the Sustainable Development Goals (SDGs), countries have pledged to increase their investment in R&D (United Nations, 2016). The UNESCO World Report (UNESCO, 2015) reported an increase of the world Gross expenditure on R&D (GERD) from a total of Purchasing Power Parity of $1, 132 billion in 2007 to a Purchasing Power Parity of $1, 478 in 2015. Though this increase was significant, it was lower than the 47% increase reported between the previous period of 2002 and 2007. The UNESCO report also showed a rise in global R&D intensity (i.e. a country's GERD as a percentage of its GDP [GERD/GDP]) from 1.57% of GDP in 2007 to 1.70% 2013. The rise in R&D intensity was attributed to faster growth in GERD as compared to global GDP (UNESCO, 2015:24). Similarly, the R&D funding magazine (2018) estimated that the global R&D investment would be about $2, 190 billion in 2018 for the 116 countries that have high investments in R&D. Global R&D spending by 2018 was also dominated by developed countries: the USA (25.25%), China (21.68%), Japan (8.52), Germany (5.32%), South Korea India (3.80), (4.03%), Turkey (3.3%), Israel (3.0%), Canada (2.34%) and France (2.25%). With the exception of South Africa and Egypt, African countries have contributed the least share of total global R&D investment compared to the amounts invested by the USA, Europe and Asia (R&D Magazine, 2018).

Despite the minimal share of global R&D spending by Africa, African countries are committed to increasing their investment in R&D (NPCA, 2010; 2014). Investment in R&D is imperative for the growth of knowledge economies in Africa. Knowledge economies rely on highly skilled graduates as well as new knowledge for economic growth (Asongu & Nwachukwu, 2017; Chen & Dahlman, 2005). The importance of knowledge in economic growth has also led to calls for increased investment in R&D. The ASTII report shows that African countries committed to increasing their investment in R&D by devoting at least 1% to 2% of their GDP to R&D. Despite these targets, current statistics show that many of the African countries spend less than 1% of their GDP on R&D (NPCA, 2010; 2014). Kenya belongs to the category of African countries that spend less than 1% of its GDP on R&D.

5.3 Benchmarking Kenya's investment in R&D

The science, technology and innovation Act of 2013 of Kenya established three new organisations that are in charge of support, promotion and regulation of STI activities and research. The National Research Fund is the key research funding body in Kenya. KENIA also provides funding for innovation. This section outlines in detail the investment in research Kenya using the research and development indicator data.

Table 5-1: Navigation Table: Research Funding research Funding
GERD
GERD/GDP
GERD per capita (in current PPP$)
Percentage of GERD by source of funds
Percentage of GERD by source of funds
Percentage of GERD by sector of research performance
GERD by type of R&D activity
GERD per researcher

Source: Author's own compilation

According to the science, technology and innovation Act of 2013, Kenya aims to invest 2% of its gross domestic product into research and development. By 2010, the gross expenditure for research development (GERD/GDP) was at 0.79% which translates into a doubling from 0.36% in 2007 (UNESCO, 2015). The relative variations of GERD have to be seen in the view of absolute numbers: in 2007 the overall GERD was at 288, 477, 800 USD (PPP in 2005 constant prices) and increased to 716, 316, 700 USD in 2010. The figure below lists the indicators of R&D investment discussed below.

5.3.1 GERD by source of funding

Between 2007 and 2010, Kenya has seen three main trends in the funding of research: first, a huge increase in funding from abroad, which nearly tripled from 17.62% in 2007 to 47.14% in 2010 as a share of GERD (UNESCO, 2015). Secondly, the relative decline in higher education funding of R&D as well as a huge decline in business as well as private non-profit organisation sectors funding of R&D. Lastly, government funding as a share of GERD remained stable at around 25%. The relative shifts in GERD by the source of funding have to be discussed in view of absolute numbers: within three years, the government sector rose its investment in R&D from 75, 435, 944 USD in 2007 to 185, 955, 815 USD in 2010 (UNESCO, 2015). The business sector invested 48, 521, 965 USD in 2007 and decreased the investment to 31, 088, 144 in 2010 (UNESCO, 2015). The decrease in this R&D investment could be attributed to the economic crises of 2008. The UIS statistics shows that the dominance of external funding only began in 2010: in 2007 the foreign sources were at 50, 829, 788 USD, only slightly above the business sector, increasing to 337, 671, 692 USD in 2010, which translates to about half of Kenya's GERD. In addition, foreign funding surpasses the government's investment in research and development by about 100% (UNESCO, 2015).

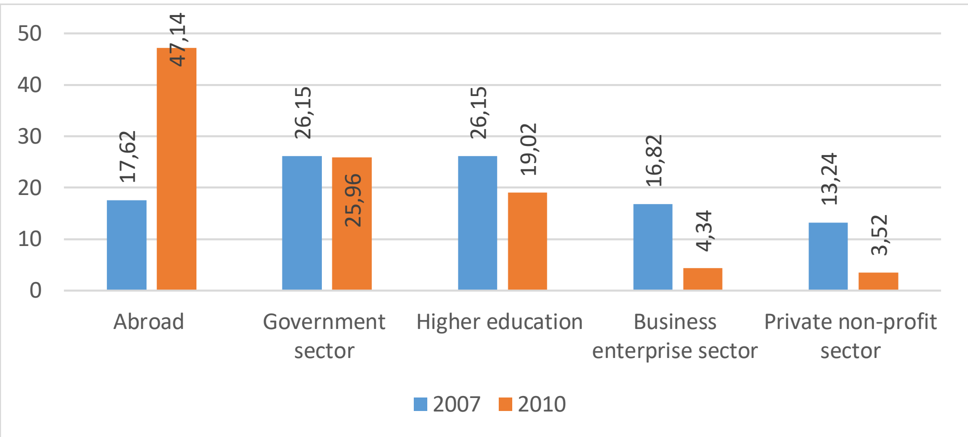

Figure 5-2: GERD by the source of funding, 2007 & 2010.

Source: UNESCO Institute of Statistics (2015)

According to this data, Kenya is increasingly dependent on external donor funding. Studies have shown that an overdependence on donor funding may affect the type of research undertaken and how it is undertaken, as "donors, multinational corporations, and international organisations continue to maintain a diversity of goals and interests in developmental issues … S&T policy does not have its institutional locus 'within' the country" (Shrum & Beggs, 1997:62–63). In other words, excessive funding from international sources tends to be skewed towards the priorities of the funders and not the local needs of the country. Despite this view, other policy makers are of the opinion that funds from foreign funders and international development partners should be seen as "an enabler", to work with local partners and also ensure the country's needs are realised (Hanlin, 2017). An example cited as an "enabler" case is the recently created Newton-Utafiti Fund jointly and equally funded by the UK and the Kenyan governments. The priority setting was done by the Vision 2030 Medium Term Plan for STI realised (Hanlin, 2017). (see Author, date).

5.3.2 GERD by scientific field

In 2010, the distribution of R&D investment by field reflects the distribution in the publication output as illustrated below: the agricultural sciences and medical sciences received the largest share of R&D investment, that is 44.82% and 27.47% of GERD respectively, followed by engineering and technology with 13.2% and the social sciences with 6.23%. The natural sciences and humanities received the least (below 5%) R&D investment share.

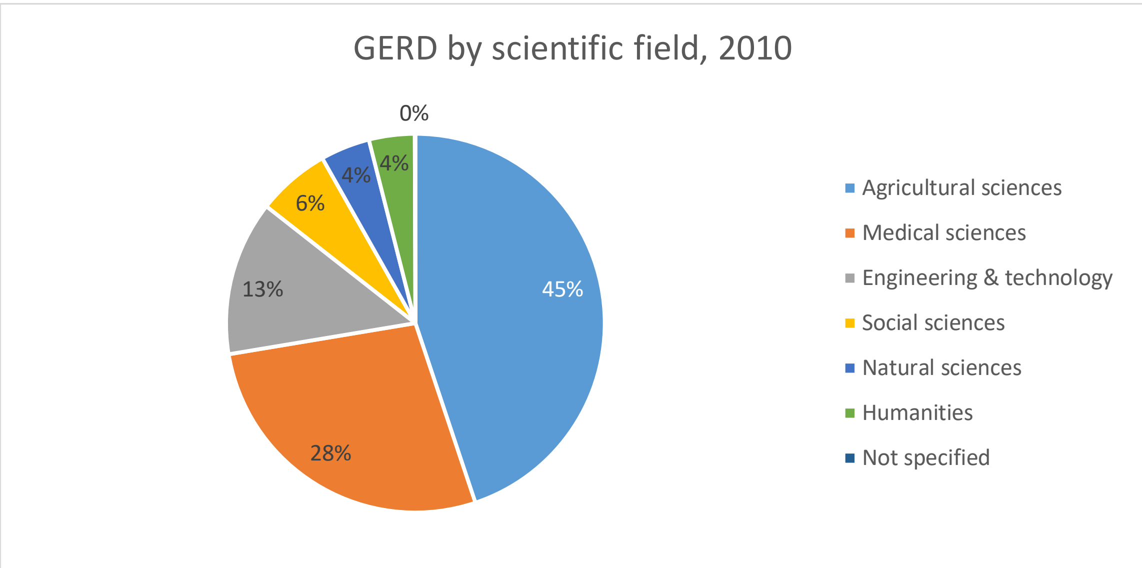

Figure 5-3: GERD by scientific field, 2010.

Source: UNESCO Institute of Statistics n.d.

5.3.3 GERD by sector of R&D performance

Between 2007 and 2010, investments into research and development by sector of R&D performance illustrates two main trends: on the one hand, a slight increase in the R&D investment into the government and higher education sector. This increase was mirrored by a more drastic decline in the R&D investment in the business and private non-profit organisation sectors. As illustrated below, this distribution is reflected in the patterns of publication output: the government research institutes, and higher education institutions produce the largest shares of Kenya's scientific output.

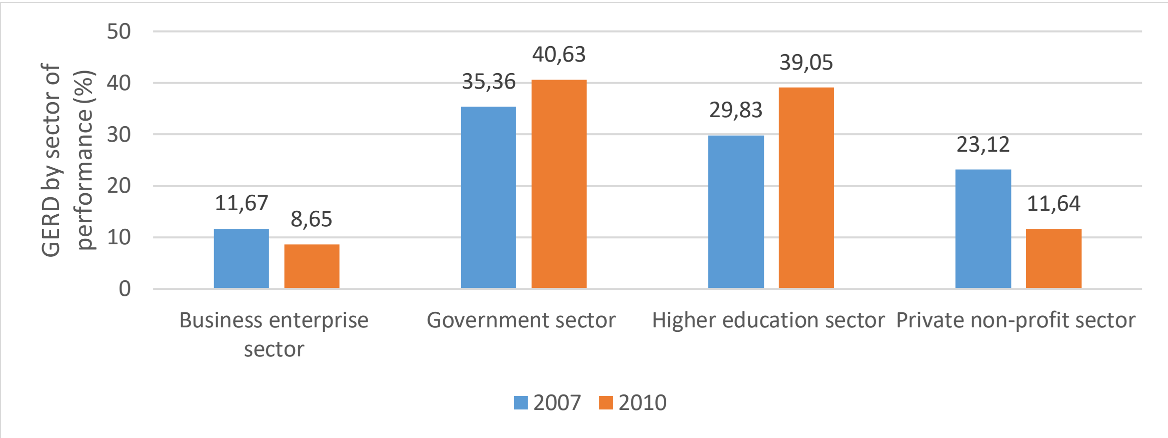

Figure 5-4: GERD by sector of R&D performance, 2007 & 2010

Source: UNESCO Institute of Statistics n.d. ()

5.3.4 GERD by type of research activity

In 2010, the distribution of investment in research and development shows that basic research receives more than half (57.49%) share of GERD followed by applied research with 24.63% and experimental research with 17.86% share of GERD.

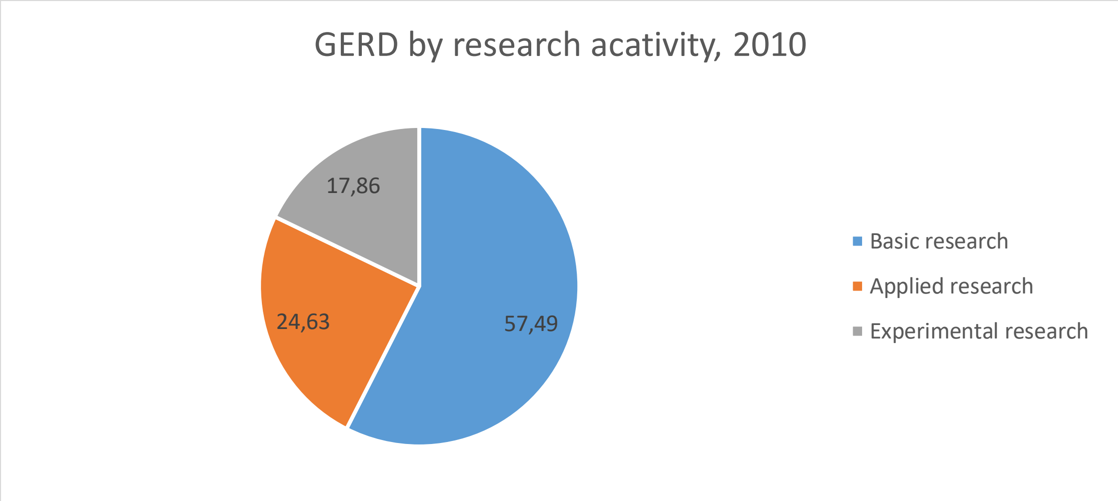

Figure 5-5: GERD by type of research activity, 2010

Source: UNESCO Institute of Statistics n.d. ()

5.3.5 International benchmarking: Comparing Kenya with selected African countries

In this section I discuss the different research and innovation investment indicators for selected sub-Saharan African countries. The aim of the discussion is to establish how Kenya compares with other selected African countries in relation to GERD/GDP, GERD per scientific field, GERD by research activity, GERD by source of funding and GERD by sector of research performance.

5.3.5.1 GERD/GDP of selected African countries

The table below presents the most recent results on various indicators related to investment in R&D. Statistics show that in terms of GERD/GDP, in 2010 or the most recent year, this value for Kenya was 0.79% which places Kenya third overall in Africa, after Malawi (1.06%) and South Africa (0.8%) (UNESCO, 2015), which is about twice the average for sub-Sahara Africa. This is followed by other African countries that have increased their GERD/GDP in the recent years: Mali (0.66%), Ethiopia (0.61), Gabon (0.58), Senegal (0.54), Uganda (0.48) and Mozambique (0.42). Despite some increases in some countries, these proportions of the GERD/GDP remain below the targets set by the individual countries or by the African Union.

Overall, for most of these countries, the government is the main source of R&D investment; this is despite the small amounts in absolute terms. Countries with the highest proportions of government funding are Mauritius 72.4%, Botswana (73.9%), Ethiopia (79.1%), and Nigeria (96.45). Overall, the business/private sector invests the lowest amounts in R&D with the exceptions of South Africa (38.3%), Gabon (29.3%), Namibia (19.8%) and Uganda (13.7). In addition, foreign sources contribute a substantial proportion of GERD in Uganda (57.3%), Kenya (47.1%), Tanzania (42.0%) and Burundi (39.9%). Some of the countries with minimal reliance on foreign funding include Botswana (6.8%), Ethiopia (2.1%), Gabon (3.1%) and South Africa (13.1%) (See table below).

Table 5-2: Kenya in comparison with selected countries on GERD/GDP: 2011 or latest year

Country	GERD/GDP
Malawi (2010)	1,06
South Africa (2015/6)	0,80
Kenya (2010)	0,79
Mali (2010)	0,66
Ethiopia (2013)	0,61
Gabon (2009)	0,58
Senegal (2010)	0,54
Uganda (2010)	0,48
Mozambique (2010)	0,42
Ghana (2010)	0,38
Tanzania (2010)	0,38
Seychelles (2005)	0,3
Zambia (2008)	0,28
Botswana (2013)	0,26
Nigeria (2007)	0,22
Togo (2012)	0,22
Burkina Faso (2009)	0,2
Mauritius (2012)	0,18
Namibia (2010)	0,14
Gambia (2011)	0,13
Burundi (2011)	0,12
Madagascar (2011)	0,11
Congo, Dem. Rep (2009)	0,08
Cabo Verde (2011)	0,07
Lesotho (2011)	0,01

Source: UNESCO (2015)

*Whenever data do not add up to 100% for this indicator, it is because part of the data remains unattributed. Note: Data are missing for some countries

5.3.5.2 GERD per Capita (current US$ PPP$)

As far as GERD per capita of the population is concerned, a comparison of Kenya with other countries show that in 2010, the value for Kenya was 19.8 US$ per person which ranks Kenya 6^{th} overall in Africa, after South Africa which records the highest amount ($93), followed by other countries like Gabon ($90.4), Seychelles ($46.7), Botswana ($37.8) and $Mauritius (31.1). The challenge with data presented below is the inconsistency and unavailability of data in the recent years, thus the data available might not reflect the actual picture in terms of expenditure on R&D in the different countries.

Table 5-3: Kenya in comparison with selected countries on GERD per capita

Country	GERD per capita (current US$ PPP$)
South Africa (2015/6)	93
Gabon (2009)	90,4
Seychelles (2005)	46,7
Botswana (2013)	37,8
Mauritius (2012)	31,1
Kenya (2010)	19,8
Namibia (2010)	11,8
Senegal (2010)	11,6
Ghana (2010)	11,3
Mali (2010)	10,8
Nigeria (2007)	9,4
Zambia (2008)	8,5
Ethiopia (2013)	8,3
Malawi (2010)	7,8
Tanzania (2010)	7,7
Uganda (2010)	7,1
Cabo Verde (2011)	4,5
Mozambique (2010)	4
Togo (2012)	3
Burkina Faso (2009)	2,6
Gambia (2011)	2
Madagascar (2011)	1,5
Burundi (2011)	0,8
Congo, Dem. Rep (2009)	0,5
Lesotho (2011)	0,3

Source: UNESO (2015)

5.3.5.3 GERD per researcher (HC) in US$ current PPP$

As far as GERD per researcher is concerned, a comparison of Kenya with other sub-Saharan countries show that in 2010, the value for Kenya was $62.1 which places Kenya at the 13th position overall in Africa. Although, this data hasn't been updated in the past decade for some countries, the data shows some African countries with higher amounts of GERD per researcher are Seychelles ($290.8), Gabon (258.6), Zambia ($172.1), Mali ($168.1), South Africa ($113) and Tanzania ($110).

Table 5-4: Kenya in comparison with selected countries GERD per researcher (HC)Country	GERD per researcher (HC) in US$ current PPP$ thousands
Seychelles (2005)	290,8
Gabon (2009)	258,6
Zambia (2008)	172,1
Mali (2010)	168,1
South Africa (2015/6)	113,7
Tanzania (2010)	110
Botswana (2013)	109,6
Mauritius (2012)	109,3
Ghana (2010)	108
Ethiopia (2013)	95,3
Uganda (2010)	85,2
Nigeria (2007)	78,1
Kenya (2010)	62,1
Mozambique (2010)	60,6
Gambia (2011)	59,1
Namibia (2010)	34,4
Togo (2012)	30,7
Burundi (2011)	22,3
Senegal (2010)	18,3
Cabo Verde (2011)	17,3
Lesotho (2011)	14,3
Madagascar (2011)	13,3
Congo, Dem. Rep (2009)	2,3
Malawi (2010)	
Burkina Faso (2009)	

Source: UNESCO, (2015)

5.3.5.4 GERD by Source of funds

The table 5-5 below shows GERD by source of funds for selected sub-Saharan countries. A comparison of Kenya to other sub-Saharan countries shows that in 2010, the government contributed 26% to R&D. Kenya is ranked low compared to other African countries where the government contributes the highest proportions of GDP on research and development, such as, Nigeria (96.4%), Mali (91.2%), Togo (84.9%), Ghana (68.3%), Burundi (59.9%). A comparison of Kenya with other African countries in relation to the expenditure on R&D by the higher education sector shows that the higher education sector in Kenya provides about 47% of funding to research and development, compared to other countries such as Mozambique, Uganda, Senegal and Ghana whose higher education sectors provide slightly higher proportions of funding. As far as funding from abroad is concerned, Kenya is one of the countries that receive slightly higher proportions of funding from international sources, as well as Mozambique, Burkina Faso, Uganda and Burundi. As far as funding from the business sector is concerned, data below shows that Kenya is one of the countries with the least funding from the business sector (4.3%), compared to other countries such as South Africa, Gabon, Botswana and Namibia, whose business sector contributes above 20% to R&D.

*Table 5-5: GERD by source of funds (%), 2011**

	Government	Higher Education	Private non-profit	Abroad	Business
Cabo Verde (2011)	100	-	-	-	-
Congo, Dem. Rep (2009)	100	-	-	-	-
Madagascar (2011)	100	-	-	-	-
Nigeria (2007)	96,4	0,1	1,7	1	0,2
Mali (2010)	91,2	-	-	-	-
Togo (2012)	84,9	0	3,1	12,1	-
Ethiopia (2013)	79,1	1,8	0,2	2,1	0,7
Namibia (2010)	78,6	-	-	1,5	19,8
Botswana (2013)	73,9	12,6	0,7	6,8	5,8
Mauritius (2012)	72,4	20,7	0,1	6,4	0,3
Ghana (2010)	68,3	0,3	0,1	31,2	0,1
Burundi (2011)	59,9	0,2	-	39,9	
Gabon (2009)	58,1	9,5	-	3,1	29,3
Tanzania (2010)	57,5	0,3	0,1	42	0,1
Senegal (2010)	47,6	0	3,2	40,5	4,1
South Africa (2015/16)	44,6	0,8	2,5	13,1	38,3

Gambia (2011)	38,5	-	45,6	15,9	-
Kenya (2010)	26	19	3,5	47,1	4,3
Uganda (2010)	21,9	1	6	57,3	13,7
Mozambique (2010)	18,8	-	3	78,1	-
Burkina Faso (2009)	9,1	12,2	1,3	59,6	11,9
Lesotho (2011)	-	-	-	-	-
Malawi (2010)	-	-	-	-	-
Seychelles (2005)	-	-	-	-	-
Zambia (2008)	-	-	-	-	-

Source: UNESCO, (2015)

5.3.5.5 GERD in sub-Saharan Africa by field of science

According to UIS, natural sciences and agricultural sciences are the scientific areas that receive the majority of funding in sub-Saharan countries. For instance, Burundi had the highest investment of about 95% for the natural sciences. In addition, Botswana, Madagascar, Nigeria and South Africa invested at least 30% of their funding in the natural sciences. In 2010, Kenya had the smallest investment in the natural sciences with 4.2% as a share of GERD, followed by Ethiopia (6.5%), Mozambique (7.4%) and Uganda (9%). Sub-Saharan countries like Ethiopia, Kenya, Mauritius and Togo invested over 40% of the research funds in the agricultural sciences. Medical sciences also received a substantive proportion of R&D investment, with countries like Botswana, Kenya and Mozambique investing at least 20% as a share of GERD. Comparatively, Uganda recorded the highest proportion (29.8%) of its funding to the social sciences (UNESCO, 2015).

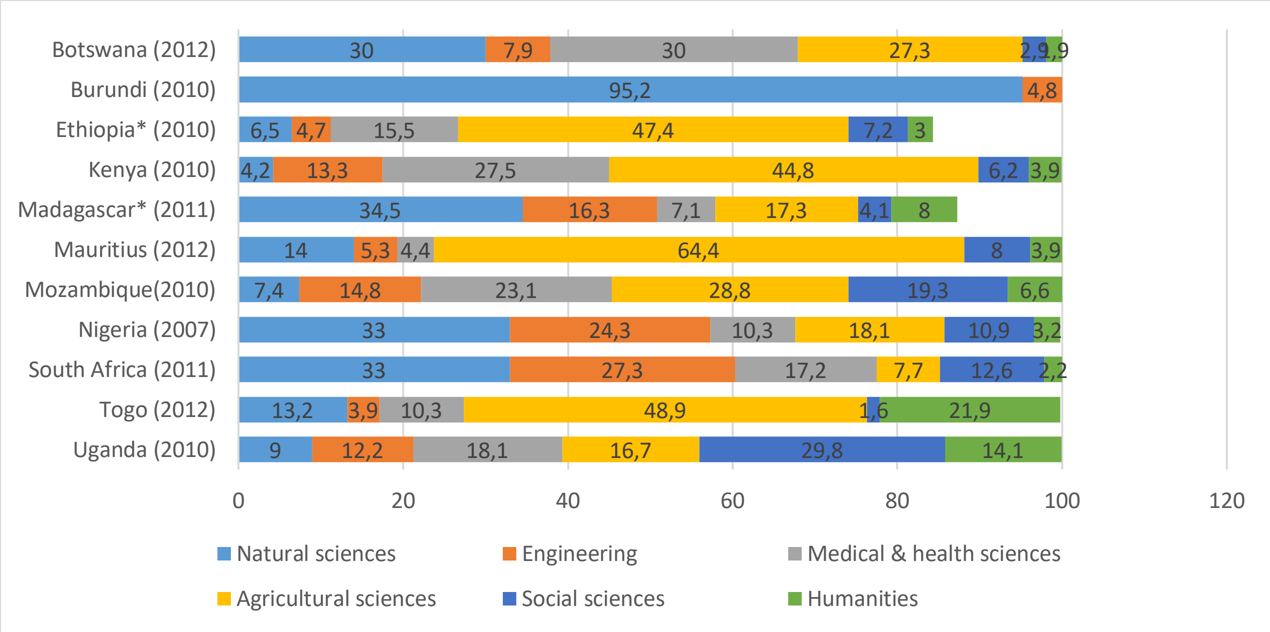

Figure 5-6: GERD in sub-Saharan Africa by field of science, 2012 or closest year (%)

**When data does not add up to 100% for this indicator it is because part of the data was unattributed.*

Source: UNESCO Institute for statistics (2015)

5.3.5.6 Summary: International and historical benchmarking

The historical and international benchmarking of research investment in Kenya reveals several aspects. First, in relation to GERD, there has been a slight increase in the proportion spend on R&D in Kenya between 2007 and 2010. The results discussed above shows that, in relation to GERD by source of funding, the Kenyan government and higher education contributes a slightly lower proportion to R&D compared to the funds from international sources, which is about 50%. The results show that basic research receives the highest proportion of GERD, compared to the proportion received by experimental research.

International benchmarking shows that, in relation to GERD/GDP Kenya compares well with other sub-Saharan countries such as South Africa, Malawi and Mali, that registered over 0.6% of the GERD/GDP. However, as far as GERD per researcher is concerned, Kenya is ranked slightly lower, compared to other selected countries like South Africa, Uganda, Nigeria, Tanzania and Botswana which reported higher proportions of GERD per researcher. As far as GERD by source of funding is concerned, Kenya records slightly lower proportions of funding from the government and higher education compared to countries Nigeria, Uganda, Tanzania and Uganda which record slightly higher proportions of GERD. Kenya is of the countries that registers a higher proportion of funding from international sources (about 50%), together with other countries such as Mozambique and South Africa. Compared to other African countries, Kenya is one of the countries with the smallest proportion of funding (less than 5%) from the business sector. In relation to GERD by scientific field, Kenya compares well with other countries (Ethiopia, Togo Mauritius) and for the proportions (above 40%) invested in agricultural sciences. Similarly, Kenya and Botswana record the highest proportions of funding invested in the health sciences. When compared with other countries, Kenya is one of the countries with the smallest proportion (less than 5%) of funding invested in the natural sciences.

5.4 Factors that influence receipt of research funding

Age has been identified as one the main factors that influence receipt of research funding. Studies have shown that as scientists rise in the science hierarchy, they tend to accumulate advantages in various aspects of science (Merton, 1968; Zuckerman & Merton, 1973). Older scientists tend to have more research networks, lead large research groups, have more research assistants and post-doctoral students, easily access equipment and infrastructure, and are also more likely to secure more funding compared to the younger scientists (Gingras, Lariviere, Macaluso & Robitaille, 2008). In addition, given their large research networks, older scientists are more likely to collaborate more and share the research resources (research funding and research equipment and infrastructure) with other researchers (Birnholtz, 2007; Lee & Bozeman, 2005).

Some studies have shown gender differences in access to research funding (Larivière, Vignola-Gagné, Villeneuve, Gélinas & Gingras). Larivière *et al.* (2011) analysed the relationship between gender and research funding and found that, beyond the age of 38 years, women receive less research funding as compared to men. The study further shows that, for all the three broad fields (health sciences, natural sciences and engineering and social sciences and humanities) analysed, women received less research funding than men on average. In particular, the study observed that, in the health sciences, men received more than twice as much funding as women, with lesser and significant differences observed for the natural sciences and engineering and the social sciences and humanities. A study by Stack (2004) found that a slightly large proportion of men receive more funding grants, compared to women: 43.3% for men compared to 37.7% for women. In a classic earlier study, Fox (1991, citing Zuckerman, 1987) shows that both men and women receive a number of research grants proportionate to the funding applications submitted. Thus, Fox further argues that the disparities in the funding by gender are more likely reflection of the differences in the grant applications submitted by both men and women.

Several reasons have been cited in the literature to explain the gender differences in research funding: 1) marginalisation of female researchers within the scientific community and their smaller research and social networks, which impacts on their access to information on funding processes and opportunities; 2) diverse sources of funding for men; 3) motherhood and childcare; 4) the choice of research topics (Kyvik & Teigen, 1996; Larivière *et al.*, 2011; Xie & Shauman, 1998).

During the African Young Scientists Survey with African young scientists (CREST, n.d.) (see Author, date), respondents were asked to report if they had received funding in the preceding three years. The other questions asked included the amount of funding received, the amount allocated to equipment and infrastructure, the sources funding and the major funding organisations. This section reports and discusses the finding of the respondents' responses to these questions.

5.4.1 Research funding: impact on scientific output, quality and collaboration

Several studies have looked at the relationship between public funding and scientific production and output. But the findings are mixed Payne and Siow (2003) found that public research funding of university research has a large positive effect on the number of articles and a small positive effect on patents at research universities. Their results illustrated that increasing $1 million of public research funding to university research results in 10 more articles (…) and 0.2 more patents (Payne & Siow, 2003). Some studies show that an increase in research investment by a country has a positive effect on the country's scientific production. Leydesdorff and Wagner (2009), conducting cross-country analysis found various differences between expenditure on R&D and the world share of publications. Another cross-country analysis by Shapira and Wang (2010) found a positive effect of the investment by China on the number of publications, but no great impact on quality.

Some studies show that scientists who access more funding are likely to be more productive and receive more citations compared to scientists who are less-funded (Beaudry & Allaoui, 2012; Beaudry & Clerk-lamalice, 2010; Godin, 2003). Godin (2003) concluded that the researchers who received funding produced more publications and their papers appeared in high quality journals. Arora and Gambardella (1998) show that the scientists' publication track-record has an effect on accessing funding in the future. Access to research funding acts as an attraction to funding in the following years. Jacob and Lefgren (2011) found that receiving a grant (of about $1.7 million) results in one more publication over the subsequent five years, which equals an increase of 7 per cent. Zucker & Darby (2007) found a positive effect that research funding has on the number of scientific publications. In contrast, another study found a significant negative impact of increased public funding on output (Huffman & Evenson, 2003).

Studies have shown that research collaboration and research funding are intertwined. Collaboration is seen as a way to raise research funding. Scientists and institutions are encouraged to collaborate so as to share the available research funding and other state-of-the-art equipment available for research (Zucker & Darby, 2007). Investigating collaboration choices and strategies, Bozeman and Corley (2004) reported in their study, those scientists who indicated to have received greater funds also stated to have more collaborators.

According to Adams, Black, Clemmons & Stephan (2005:259), scientists who received larger amounts of public funding were more likely to be involved in larger scientific groups. This finding confirms the results by Bozeman and Corley (2004), above, that funding received has a positive significant effect on collaboration. In another study, Gulbrandsen and Smeby (2005:932) found that professors who were funded by the industry were more likely to "collaborate more with other researchers both in academia and industry", as well as produce more scientific publications.

5.5 Funding received

As signalled above, respondents were asked to report if they received funding in the preceding 3 years prior to the survey. Our analysis shows a high proportion of respondents, about 71.7% reported they had received funding. When the data is disaggregated by scientific field, the results show no huge field differences.

For the respondent who indicated (Yes), they received funding.

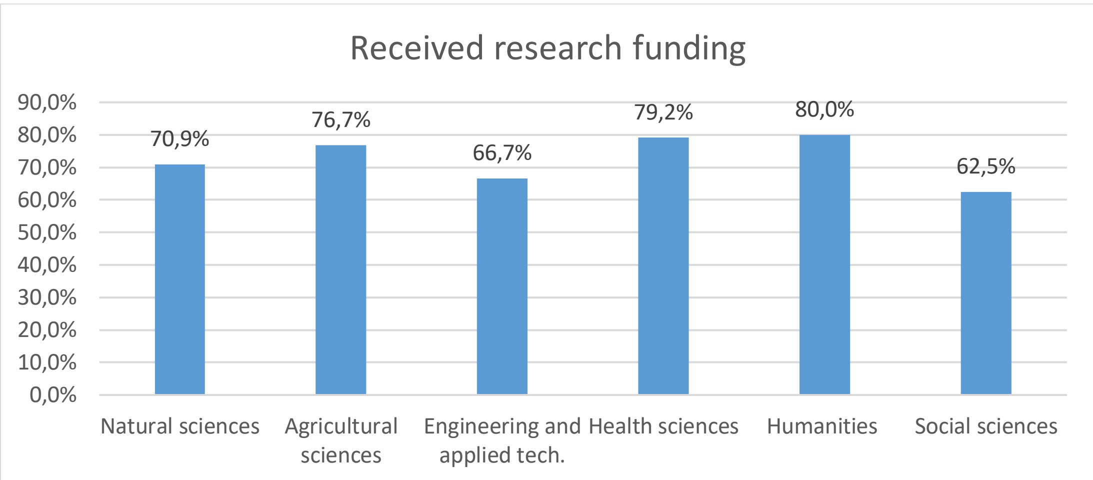

Figure 5-7: Receipt of funding (Yes) by field. Source: CREST (2016).

I used a three-way analysis of variance, with age, gender and scientific field as predictor variables, to show the relationship between these variables and receiving funding. The three-way analysis of variance shows that age and scientific field does not correlate significantly as to whether a respondent received funding in the preceding three years. Older respondents (those older than 50), across all scientific fields, reported they had received research funding. In relation to the scientific fields, respondents in humanities surprisingly, as well as those in the health and agricultural sciences mostly indicated to have received funding. Respondents in the natural sciences followed by those in engineering and applied technology were more likely to have received funding.

Reported receipt of funding by age, gender and scientific field

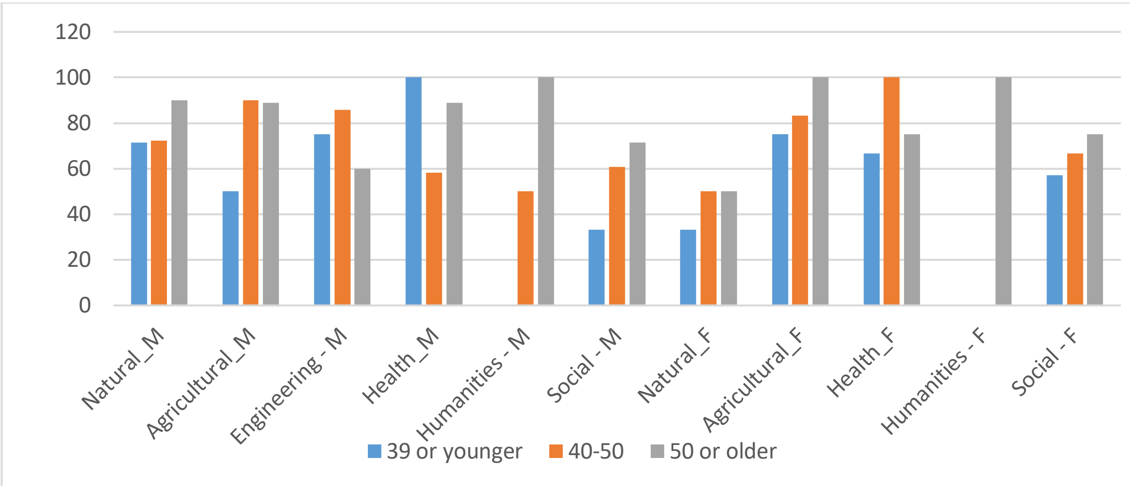

Figure 5-8: Receipt of funding by age, gender and scientific field. Source: CREST (2016).

5.6 Sources of funding

The R&D statistics illustrated above show that as 2010, funding from international sources had increased by about 50% from 2007. The huge increase is an indication of the overdependence of Kenya's science on international funding. During the survey, respondents were asked to indicate what proportions of their funding are from the national and international sources respectively.

Proportions of funding received from the national and international sources (39 or younger only)

The results between the sources of funding and the age of the respondents (39 or younger only) show interesting results. Of the younger respondents, a slightly higher proportion indicated they received most of their funding (above 75%) from the national sources as compared to the international sources. Whereas for the older respondents, a higher proportion indicated over 50% of their funding came from international sources.

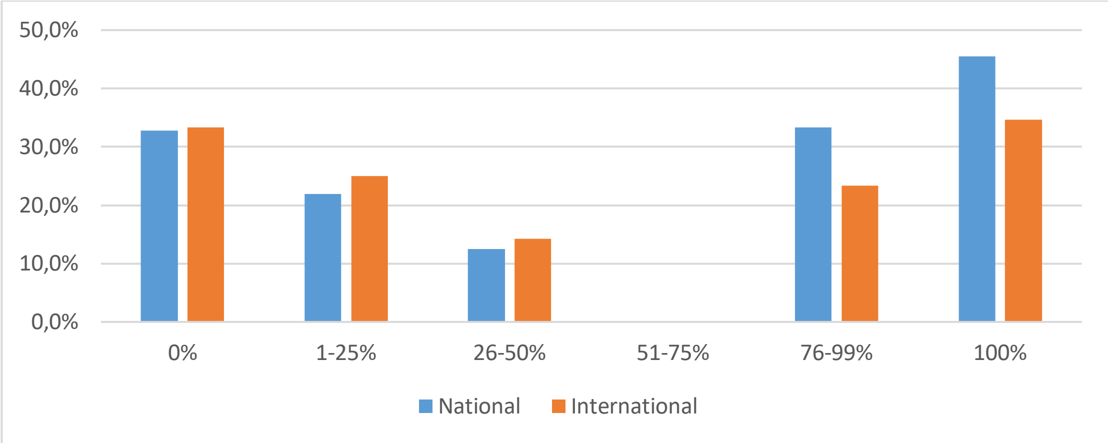

Figure 5-9 Proportions of funding received from national and international sources (39 or younger only)

Proportions of funding received from national and international sources (older than 50 only)

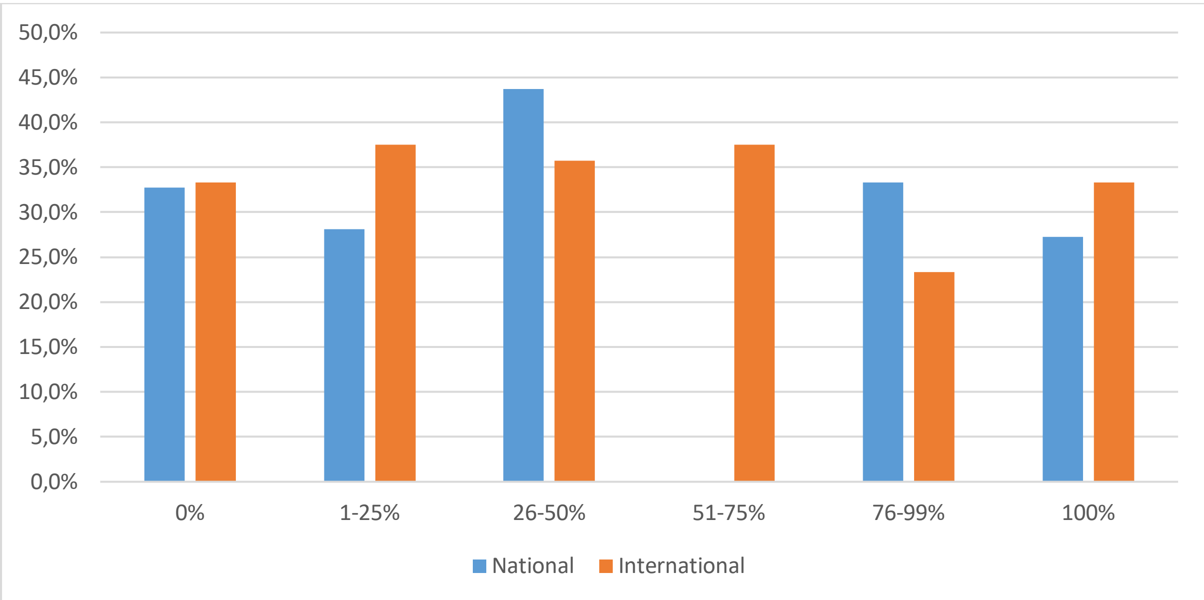

Figure 5-10: Proportions of funding received from national and international sources (older than 50 only)

The following section illustrates in detail the reported funding received from national and international sources of funding disaggregated by scientific field as well as by gender, age and scientific field. For the respondents who indicated they received funding from the national sources, the largest averages are recorded in the natural sciences and engineering and applied technologies.

Table 5-6: The reported proportion of funding from national sources, by field

Scientific field	N	Mean	Median
Natural sciences	31	33,23	20,00
Agricultural sciences	25	20,40	10,00
Engineering and applied technologies	10	45,00	35,00
Health sciences	33	13,64	10,00
Humanities	7	21,43	0,00
Social sciences	24	16,25	5,00
Total	130	22,92	10,00

The reported percentage of funding from national sources by age, gender and scientific field

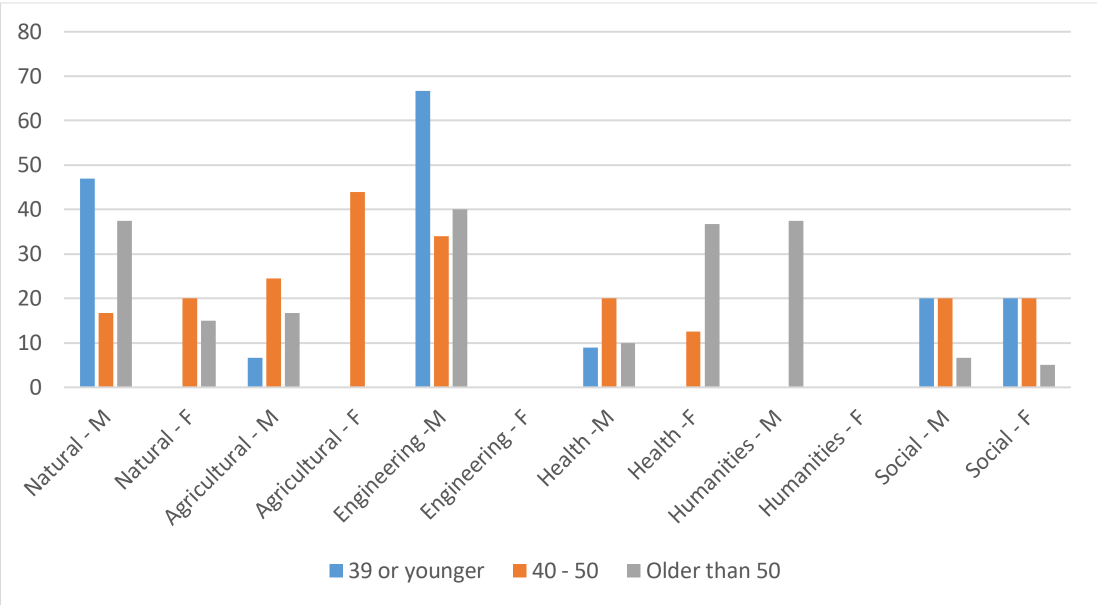

Figure 5-11: Percentage of funding from national sources by age, gender and scientific field

According to the results on the figure above, young male scientists in the natural sciences and engineering and applied technologies reported the highest amounts of funding from international sources. Female respondents in the agricultural sciences, who were between 40 and 50 also reported large proportions of funding from national sources.

Table 5-7: Reported proportion of funding from international sources, by scientific field

Scientific field	N	Mean	Median
Natural sciences	35	75,43	90,00
Agricultural sciences	30	86,33	100,00
Engineering and applied technologies	8	68,75	95,00
Health sciences	37	80,81	90,00

Humanities	8	93,75	100,00
Social sciences	30	81,67	100,00
Total	148	80,88	100,00

A high number of respondents in the health, natural, agricultural and social sciences indicated that their funding was from international sources. Interestingly, respondents in the humanities and agricultural sciences indicated the highest averages of the funding from the international sources.

The figure below shows the means of reported funding from international sources by age, gender and scientific field. According to the results, younger scientists, regardless of gender, in the natural sciences, agricultural sciences, engineering, and health sciences reported they received funding from international sources. Similarly, larger proportions of international funding are also reported by the older respondents, regardless of their gender, in the fields of agricultural sciences, humanities and social sciences.

The reported percentage of funding from international sources by age, gender and scientific field

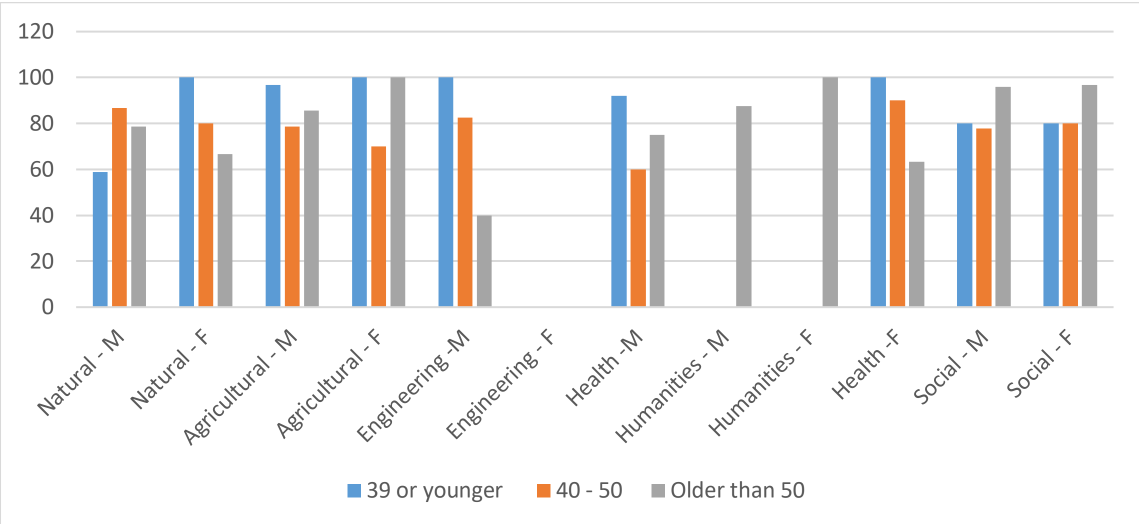

Figure 5-12: Percentage of international sources by age, gender and scientific field

5.7 Major funding organisations

Respondents were asked to mention three major organisations or agencies from which they had received funding in the preceding three years.

Table 5-8 List of main funding organisations

First funding organisation listed	N	Second funding organisation listed	N	Third funding organisation listed	N
National Commission for Science, Technology and Innovation (NACOSTI)	10	The Bill and Melinda Gates Foundation	6	USAID	4
National Institutes of Health	9	USAID	5	DFID	2
The Bill and Melinda Gates Foundation	8	DFID	4	National Institutes of Health	2
USAID	8	National Commission for Science, Technology and Innovation	4	SDC	2
DFID	7	National Institutes of Health	4	SIDA	2
IDRC, Canada	5	World Bank	3	WHO	2
Wellcome Trust	5	BMZ-GIZ	2	Indiana univ health	1
World Bank	5	European Union	2	Africa Harvest	1
European Union	4	IDRC	2	Agricultural Research Council, SA	1
NRF ZA	3	IFS	2	Alliance for A Green Revolution in Africa	1
Swedish International Development Agency	3	TWAS	2	Appear-Austria	1
Bundesministerium fur wirtschaftliche Zusammenarbeit und Entwicklung	2	Media Council of Kenya	1	ASARECA	1
CDC	2	International Initiative for Impact Evaluation	1	Austrian Development Agency	1
DAAD	2	ADRA	1	BMBF Germany	1
DANIDA	2	ASARECA	1	BMZ GIF	1
Government Kenya	2	BMZ-GERMANY	1	British Council	1
International Foundation for Science	2	BMZ-GIZ-SOGA	1	Business/Industry unspecified	1
UNFPA	2	Business/Industry unspecified	1	CDC	1
SEG	1	CCAFS	1	COMESA	1
African Development Bank	1	CDA Kenya	1	DAAD	1

In some instances, respondents reported general information of the funders such as ‘funding agency’, ‘government, ‘university’, ‘science council’ or ‘business enterprise’, making it difficult to identify the funders. The table above illustrates the main funders, as they were frequently mentioned by the respondents.

The results (Table 5.8) show that Kenya’s National Commission for Science, Technology and Innovation (NACOSTI) was mentioned as the primary funding organisation from which respondents received their research funding, followed by international organisations and agencies such as the Bill and Melinda Gates Foundation, National Institute of Health, DFID, USAID, IDRC, the Wellcome Trust, the European Union and the World Bank.

Apart from NACOSTI, the results below show that respondents mainly received funding from international organisations or agencies. A small number of respondents indicated the GoK as their main funder. In general, the list of funders provided by the respondents (table below) is diverse as it comprises of public, private and non-governmental organisations as well as local, national and international institutions.

5.8 Barriers to accessing research funding and the consequences

During the interviews with Kenyan scientists, interviewees were asked to expound on several issues related to access to research funding. One of the main issues that emerge from the interviews is the challenges that scientists face in accessing research funding. The responses the interviewees below illustrate this issue.

> Yes, I do, very much. The research I’m doing currently I’m financing part of it myself, then my professor in Italy has offered to run, if can say it, haematological and molecular tests for pro bono, for free. That’s really, really good for me, so mine is just to now finance the other bit. I tried applying to our National Cancer Institute for funding, but it didn’t go through (35-year-old male respondent, R_189).

> So the issue of funding goes from applications and lack of mentorship, right down to not being able to attend conferences and do your fieldwork because the funding is not there or very limited (40-year-old male respondent from Kenya, R_078).

> It's very limited. Especially when it comes to funding related to research. But perhaps things are changing. Just on the great … I submitted a proposal. My university has opened the call for those who finish their doctorate study around 2015, from 2015 upwards. So I feel it's a good change … But just for 15 positions for the whole country (32-year-old male respondent from Kenya, R_192).

Specifically, participants indicated they face challenges in accessing funding to attend conferences.

> The only challenge which we do have for… as attending the conferences, to meet … the expenses of the conferences. That is where the challenge is. And, for instance, you may… Like I like working on hepatitis B. There will be a conference coming in October but if you do not have ongoing funds that can enable you to go, that is where the challenge is. So, you find that you are limited. Instead of you going, you are supposed to look for money to meet the expenses at that conference (35-year-old male respondent from Kenya, R_073).

> When there is even a conference somewhere, the universities have little funding to fund lecturers to move out and to gain some new knowledge. So the first question you asked, what is the university going to gain … So sometimes missing an opportunity to sit in a conference elsewhere, sometimes very difficult to get that … if you want to present a paper somewhere you might just have to go by yourself. Occasionally the university has sponsored people to present their papers. The question is very occasional because they claim that the government is not supposed to give adequate funding to do so (40-year-old-male respondent from Kenya, R_078).

In some cases, interviewees indicated that they are faced with difficulties of accessing equipment and infrastructure needed for research.

> Most of the grants we usually have locally, it's by the National Research Fund. It's not a big grant that can be able maybe to buy very specialised equipment. If, for example, I want to do genes equality, you find that in Kenya, there are not so many research institutions with such a machine. And then maybe the funding which is there, it's not enough to be able to buy such equipment. I think I can say that there isn't a lot of funding which can help us be able to buy those high-tech machines (33-year-old male respondent from Kenya, R_186).

> The available research funding options are not guaranteed, and they are very competitive. And still, the issue of the research environment. You may have some funding, yes, but you may not really have a well-furnished laboratory for conducting research (40-year-old male respondent from Kenya, R_077).

Young scientists indicated that they mainly received funding from international funders or institutions for their research, further studies, research equipment and infrastructure.

> So my both my master's and my PhD, it was international funding (32-year-old male respondent from Kenya, R_192).

> Right now only I have a small grant I got from an international body that deals with conservation (33-year-old male respondent from Kenya, R_072).

> I did something to do with TWAS. TWAS is not really a collaboration but it is a funding agency and they were able to support us on what we call what you need, that is all the reagents, all the equipment, all the machines that we may need. That is the infrastructure generally (35-year-old male respondent from Kenya, R_073).

Not surprisingly, many interviewees indicated that there is a lack or limited national funding for research and research-related activities, such as, attending conferences. Participants indicated that they have received much support from international funding sources as compared to the limited support they get from the national institutions or the government in some instances.

> I did apply twice and I got funding … I did come to South Africa some time back and I got some funding from NRF. I also did apply when I was presenting in Germany on hepatitis B. I got it from a hepatitis B foundation. There is one which we did in India which I applied, though I was not successful then the institute, that is where I work, had to come in and support. But now if the institute is not so much ready to support and then when you apply you have regret from those funding bodies, then you are left without anywhere to go for. Either you support yourself or you leave to attend. So, that is where the challenge is (a 35-year-old man from Kenya, R_073).

> Funding opportunities are also not very many. Kenya Government does not [give] a lot of prominence to postgraduate research. They are trying, but it is not to that expected level. So a lot of funding goes to undergraduates, so in the unlimited opportunities, I would say so (40-year-old male respondent from Kenya, R_078).

In the instances participants indicated that they received national government funding, the funding was limited or in small amounts, thus not sufficient for their research needs.

> The funding which we have from our own institutions is not that much because remember, we are in the government arm and sometimes the government arm has limited to such kind of funding (35-year-old male respondent from Kenya, R_073).

Participants listed a number of reasons why they found it difficult to access research funding. The interviewees indicated that they face challenges in accessing international funding, following the inability to secure a local partnership that will ensure the international-national co-funding. In some instances, international funders require co-funding from the national government or local institutions.

> [For] most of the international funding … if you are to establish yourself locally, they require that your host institution or your local institution should cater for some other few things, which is not

> most of the time easy, because they most of the time tell you, we do not have availability of funds (32-year-old male respondent from Kenya, R_192).

Interviewees attributed their difficulties in securing research funding also to heavy workloads that hinder them from making grant applications.

> Research funding. When I applied for one, I didn't get it, but I would say the challenge is again, the workload is a lot, so getting time to write, funding, proposals on funding, that is the issue. But otherwise, I think if I will get it that time, I will write and submit and then will get a grant (40-year-old male respondent from Kenya, R_078).

Many and long bureaucratic processes were identified as another barrier to accessing funding. The unavailability of funds to researchers in time slows their research process, and in some instances, the researchers are likely to shift their research interests over time.

> Recently we applied to get more money from the National Research Fund here in Kenya. There are a lot of bureaucratic processes that I do not understand, so I think we have got the money, but the money, I've not yet seen it, therefore I, I don't know whether I can actually say I've got that grant. So, in short, the getting money is a painful process and by the time it comes your ideas have shifted. So, you apply for a grant now, you have certain thinking, if the money comes two years from now you, you've moved on intellectually (33-year-old male respondent from Kenya, R_072).

Some interviewees felt that pursuing their own research interests and not necessarily shifting their focus to align with the demands of international funders could have resulted in the unsuccessful grant applications.

> I think all my proposals have been things that interest me, so maybe that accounts for lack of success. I haven't yet got to a point where I've given up on what I want to do and just decided to play, play to whatever they want, I haven't got there yet (33-year-old male respondent from Kenya, R_072).

How the scientists access funding

Other interviewees indicated that they received funding from international organisations that were interested in their research.

> I was funded by Canadian agencies, basically because of their interest. How I got to know about it is they were in Kenya and they had an interest in [unclear] and it happens that I'm the one who has that publication of what they wanted. So, they contacted me on those grounds, saying you have one, two, three, are we able to work together (35-year-old male respondent from Kenya, R_073).

Following the challenges of securing funding, scientists are compelled to collaborate with international institutions so as to secure funding for research and research equipment.

> I would prefer to be able to work in a group with people from other places because if you can be able to, you see nowadays for you to get some serious funding you have to work with people from all over the globe … So, that is something that I definitely, I'm just looking for people I can collaborate with, concerning our research (34-year-old male respondent from Kenya, R_187).

> In collaboration with West Virginia University and even the University of Vienna … people have been training on palliative care, cancer diagnosis, yes … and through that collaboration also some residents managed to get funding for their pathology projects to we, I think those are the main benefits of collaboration (35-year-old male respondent from Kenya, R_189).

Young scientists are forced to use personal funds to fund their research, pay for further studies and attend research conferences.

> The research I'm doing currently I'm financing part of it myself, then my professor in Italy has offered to run, if can say it, haematological and molecular tests for pro bono, for free. That's really, really good for me, so mine is just to now finance the other bit. I tried applying to our National Cancer Institute for funding, but it didn't go through … So I decided to fund it myself (35-year-old male respondent from Kenya, R_189).

> For the students … a few get lucky to be funded by the … National Research Fund, we have limited funding opportunities. Actually, a good number of my students, all three-quarters of them fund their studies on their own, literally. What they get from the NRF in Kenya also does not go to the fees, so the fees they have to pay on their own. This can simply help in doing the research part [field work analysis] of it only (40-year-old male respondent from Kenya, R_078).

Consequences of difficulties of securing funding

Some interviewees faulted the lack of funding for research equipment, which was seen to result in them not acquiring the required skills.

> I'm specifically training or, you know, honing my skills to be actually master of haematology. Now haematology, for example, have a lot of procedures, learned theorems … So you'll find that basically that equipment or the instruments to perform that particular procedure is lacking (35-year-old male respondent from Kenya, R_189).

In general, respondents feel that the Kenyan government should increase the funding needed for research, research equipment and attending conferences. According to the respondents, this swill ensures that researchers engage in research, acquire the needed skills and training in time.

5.9 Discussion

This section discusses the results presented above on the funding received, the amount of funding, the relationship between receipt of funding and several factors (i.e. age, gender, scientific field and academic rank) and the barriers to funding.

National government funding

Limited research funding has been identified in previous studies as a major constraint for African scientists (Beaudry, Mouton & Prozesky, 2018; Gaillard, Tullberg, Zink, Porter, B. & Hovmoller, 2001; Tijssen & Kraemer-Mbula, 2018). The results in this chapter show that there is a low investment in research and development by the national government. The statistics from the national government and the UNESCO R&D statistics presented above shows that in 2010, the Kenyan government spend 0.79% of its GDP on research and development. These results are corroborated with interview data as participants confirmed that they received limited funding from the national government. This figure is below the government's own 2012 target of spending between 1-2% of its GDP on research and development (Ministry of Higher Education Science and Technology [MHEST], 2012). These results are in support of previous studies that observed limited government support of research and research-related activities (Muriithi, Horner, Pemberton & Wao, 2018). In the context of limited national government funding, participants in the interview and respondents in the survey confirmed that they mostly received funding for research, research equipment and infrastructure and attending conferences from international funders.

International funding

The findings of this study illustrate that scientists are able to successfully access research funding from both national and international sources. However, for the scientists who successfully secured funding, they acquired higher amounts of funding from international funding sources. The survey results confirm that for the scientists who indicated that they had received funding, at least half of these respondents received the funding from international sources. This finding is corroborated the UNESCO R&D statistics which showed that as 2010, much of Kenya's funding was from the international sources (about 47%). In addition, the list of the main research funders of Kenyan researchers shows that apart from Kenya's NACOSTI the other main funders are international funding organisations or agencies such as the Bill and Melinda Gates Foundation, DFID, USAID, IDRC, NIH, the Wellcome Trust, the European Union and the World Bank

In some instances, for scientists to be assured of securing funding, they are compelled to collaborate with international institution. This increases their chances of accessing international funding. These results are consistent with previous studies which showed that African countries are highly dependent on international or donor funding (Mouton, 2008). However, the literature shows that overdependence on international or donor funding may influence how research is conducted and the type of research conducted, as "donors, multinational corporations, and international organisations continue to maintain a diversity of goals and interests in development issues … S&T policy does not have institutional locus "within" the country" (Shrum & Beggs, 1997:62–63). Given that international funders tend to have their own research agendas, the participants in the interviews indicated that shifting from the funders' research interests with the intention to pursue their own research interests resulted in unsuccessful applications of international funding.

My study also confirms that the natural and health sciences receive larger proportions of international funding. The results (survey and interviews) show that scientists in the health, natural, agricultural and social sciences confirmed that they have access to more funding and received higher amounts of funding from the international funders. These results are supported by R&D statistics which shows that the health and agricultural sciences are allocated the larger proportions of funding, much of which is from international sources (47%). This observation confirms the claim by the participants in the interview that research funding allocations are prioritised according to the scientific fields, as some fields are likely to receive more funding than others. In the literature, field differences in research funding and resources available for research can be explained by the cultures, traditions and practices of these fields (Fry & Talja, 2007). Previous studies (Birnholtz, 2007; Fry & Talja, 2007) show that, for fields that have high 'mutual dependence'[13] and low 'task uncertainty'[14] such as health and natural sciences they are likely to attract more international funding through collaborations with international institutions, with the aim of sharing the limited resources (funding resources and equipment) available for research. This might explain the high proportions of international funding in these fields.

Age and funding

The results presented in this chapter about research funding are consistent with previous studies which showed that there is a clear association between age and securing funding for

[13] "'Mutual dependence' relates to the extent to which a field" depends on other fields for knowledge/skills and/or resources needed to make a competent scientific contribution, as well as the level of 'mutual dependence' amongst scientists (Whitley, 2000).

[14] Fields that have clear work techniques and reliable results produced in several scientific fields

research and research equipment and infrastructure. These findings confirm the findings of the literature I reviewed (Cole, 1979; Gingras *et al.*, 2008; Merton, 1968; Zuckerman & Merton, 1973) , which found that as older scientists rise in the science hierarchy, they have cumulative advantages (have large research networks, lead large research groups) and are more likely to access more research funding compared to the young scientists who are only beginning to get established in their science or academic careers.

Barriers to securing research funding

Many interviews that they are faced with the challenges of accessing funding for research, equipment and infrastructure and attending conferences. This finding is consistent with a previous study which shows that African researchers work in research environments where they are faced with less access to infrastructure or outdated infrastructure (Tijssen & Kraemer-Mbula, 2018). In support of past studies (Friesenhahn & Beaudry, 2014), lack of access to research equipment and infrastructure was found to affect especially young scientists, which according to my study resulted in young scientists not acquiring the required training and skills in time.

This chapter presents several challenges that scientists face in securing research funding. In the instances where national government funds are available, participants indicated that they are faced with the challenges of administering the funds. Consistent with a previous study by Muriithi *et al.* (2018), this study shows that the bureaucracy processes at Kenya's National Research Fund and universities delay the availability of funds needed for research. Consequently, the bureaucratic processes in releasing funds slow the research processes; and in cases where it takes too long (i.e. about two years) researchers are likely to have shifted their research interests.

Consistent with past studies (Muriithi *et al.*, 2018; Tijssen & Kraemer-Mbula, 2018), heavy workloads were cited as a problem for conducting research and securing research funding. Participants in the interviews indicated that, heavy workloads many teaching hours accompanied with a lot of marking, with no teaching assistants, large numbers of students to supervise, administrative roles result in insufficient time to apply for research funding, which can be tedious and requires a lot of time. Tijssen and Kraemer-Mbula (2018) noted that African scientists tend to work in environments where teaching is prioritised over research. Therefore, following the few numbers of qualified researchers (see Chapter 7), who are expected to do more teaching and other administrative roles, less time is available for research and application of research grants.

Participants also indicate that they are not able to secure funding following the inability to secure a national government or institutional partnership. In some instances, international funders require national governments to co-fund certain research projects. However, given the challenges of limited funding from the national government as discussed above, the Kenyan government fails to commit to co-funding research projects. Consequently, researchers tend not to secure this funding.

Following the difficulties of accessing research funding, researchers are compelled to collaborate with researchers internationally so as to secure international funding. Previous studies have shown that collaboration and research funding are intertwined. Researchers are encouraged or forced to collaborate so as to share the available research funding and access the 'state-of-art' equipment needed for research (Zucker et al., 2007). On the other hand, other studies showed that scientists who secure more funding are likely to have more collaborators (Beaudry & Allaoui, 2012; Tahmooresnejad, Beaudry & Schiffauerova, 2015) and vice versa a finding my study confirms. In some cases, apart from collaboration as a mode of securing research funding, researchers have been forced to use own funds to fund their research, pay for further studies, and attend conferences.

Following these challenges in accessing research funding, it is not surprising that researchers make recommendations on the need of the Kenyan government and institutions increasing research funding. In their study Beaudry et al. (2018) show that this is a suggestion made by scientists (especially the young) across all the African countries analysed.

Chapter 6 Human resources for science, technology and innovation

Our focus in this chapter is on the human resources capacity for science and technology in Kenya. The first part of the chapter (6.1) reports on and discusses the standard indicators related to research capacity as defined in R&D surveys. The next two sections of the chapter are based on analyses of the survey data from the Young scientists in Africa project. I first discuss the issue of the mobility of scientists and academics in Kenya (6.4), followed by a discussion in 6.5 of the challenges that impact the careers of Kenyan scientists or academics.

Section One: Research and Development Indicators on Research Capacity

6.1 Research and Innovation Capacity in Kenya

The human resources for science and technology of a given country refer to the human resources devoted to research and innovation activities (OECD, 2002). Research and development rely on well trained and skilled persons who are spread across the different sectors of research performance. The skilled researchers are key for research and supervision and training future generation researchers needed for the economy and knowledge creation. Therefore, it is important to measure the R&D personnel who engage directly in research.

According to the Frascati manual, “researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods, and systems and also in the management of the projects concerned” (OECD, 2002:92). In addition, of importance is the information reported on the “headcounts (HC)” and “full-time equivalent (FTE)” (OECD, 2002:92). Headcount statistics provide data on the total number of persons who are largely or partially employed in R&D. Headcount data is also useful in providing data of R&D personnel such as gender, age or nationality. On the other hand, FTE measures the exact working time devoted to research (OECD, 2002:92).

Data on human resource indicators presented below is drawn from the UNESCO statistics and the UN-innovation outlook reports of 2010 and 2014 (New Partnership for African’s Development (NEPAD), 2010; 2014). A review of the data available in these reports shows that the available data is highly problematic. The data shows inexplicably huge increases between 2007 and 2010 specifically for the indicator “R&D personnel”. It is most likely that technical and methodological errors during the R&D survey for Kenya could explain this.

To illustrate this point, we present the basic human resources data for Kenya, Uganda and Tanzania for 2007 and 2010 as reported by the UNESCO UIS and the African Outlook Innovation report.

Table 6-1: Summary of R&D personnel Data for Kenya, Uganda and Tanzania

Category	Kenya		Uganda		Tanzania	
	2007	2010	2007	2010	2007	2010
Total R&D personnel (FTE) Total	4 568	42 566	634	2 006	-	2 928
Total R&D personnel (HC)- Total	6 799	61 964	1 937	4 270	3 593	5 788
Total R&D personnel per million inhabitants (FTE)	123	1055	-	60	-	64
Total R&D personnel per million inhabitants (HC)	183	1537	96	129	87	127
Total R&D personnel per thousand total employment (FTE)	0.33	2.8	-	0.1	-	0.1

Source: UNESCO Institute of Statistics, (n.d.).

Close inspection of the data reveals obvious errors and inconsistencies as well as gaps for certain years. The single biggest problem in the data is the reported HC and FTE R&D personnel for Kenya from 2007 to 2010. The reported increases in headcounts (from 6 799 to 61 964) and FTE's (from 4 568 to 42 566) over a three-year period are simply not believable. These errors in the data are subsequently reproduced when the results for other indicators are reported. In the absence of any independent sources against which these data can be verified, one could only speculate that major survey or data capturing or reporting errors occurred here. Because it is difficult, if not impossible, to draw any credible conclusions from such data.

However, on inspection of other HR indicators, and specifically the number of FTE's for researchers (as opposed to R&D personnel), these seem at face value to be more credible. Hence, in the remainder of the chapter we will only present some results on this indicator (also disaggregated by sector, field and occupation).

6.2 Researchers

The table below (Table 6-2) shows the summary of the human resource indicators (researchers) for the period 2007 and 2010. As indicated earlier, the only recent data available for Kenya is for the period of 2007 and 2010. Although, I use this data in this chapter, it might not reflect the most recent picture in relation to the human resource indicators in Kenya.

Table 6-2: Summary of the human resource indicators

Indicator	2007	2010
Researchers (FTE) Total	2105,4	9305
Researchers (HC) Total	3509	13012
Researchers (FTE) Female	375,6	1861
Researchers (FTE) % Female	17,83984	20
Researchers per million inhabitants (FTE)	55,28029	225,0294
Researchers per thousand labour force (FTE)	0,14984	0,59979
Researchers per thousand total employment (FTE)	0,16497	0,66409
Researchers (HC) Female	626	3338
Researchers (HC) % Female	17,83984	25,65324
Researchers per million inhabitants (HC)	92,13381	314,67841
Researchers per thousand labour force (HC)	0,24973	0,83874
Researchers per thousand total employment (HC)	0,27495	0,92866

6.2.1 Total number of Researchers

The headcount (HC) number of researchers in Kenya recorded a three-fold increase from 3509 researchers in 2007 to 13012 researchers in 2010. Similarly, the full-time equivalent (FTE) number of researchers (FTE) recorded a four-fold increase from 2105 researchers in 2007 to 9305 in 2010. This is shown in the 6-1 figure below.

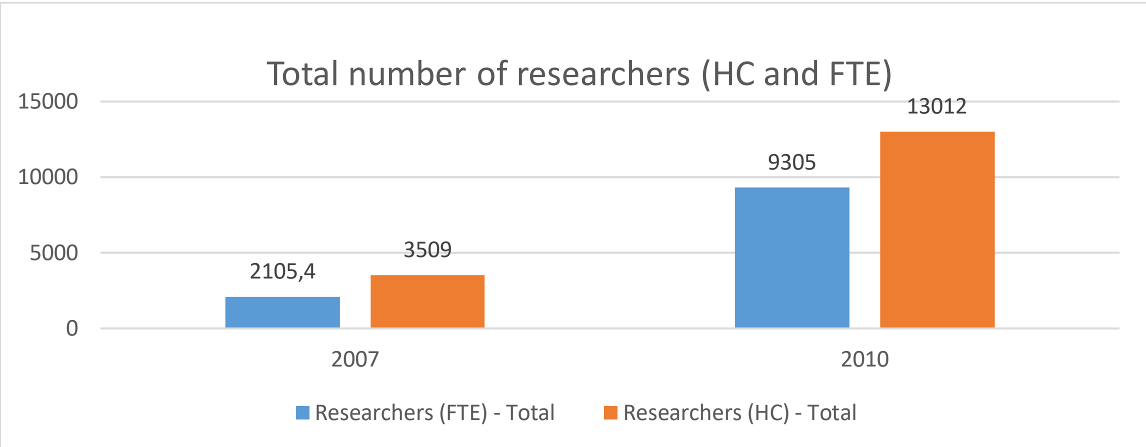

Figure 6-1: Total number of researchers (HC and FTE)

Source: UNESCO statistics, (n.d.).

6.2.2 Researchers per million inhabitants

Data available shows that as far as the researchers per million inhabitants (HC) indicator is concerned, the ratio increased from 92.1 in 2007 to 314.6 in 2010. Similarly, as for the researchers per million inhabitants (FTE), the ratio increased from 55.3 in 2007 to 225.0 in 2010.

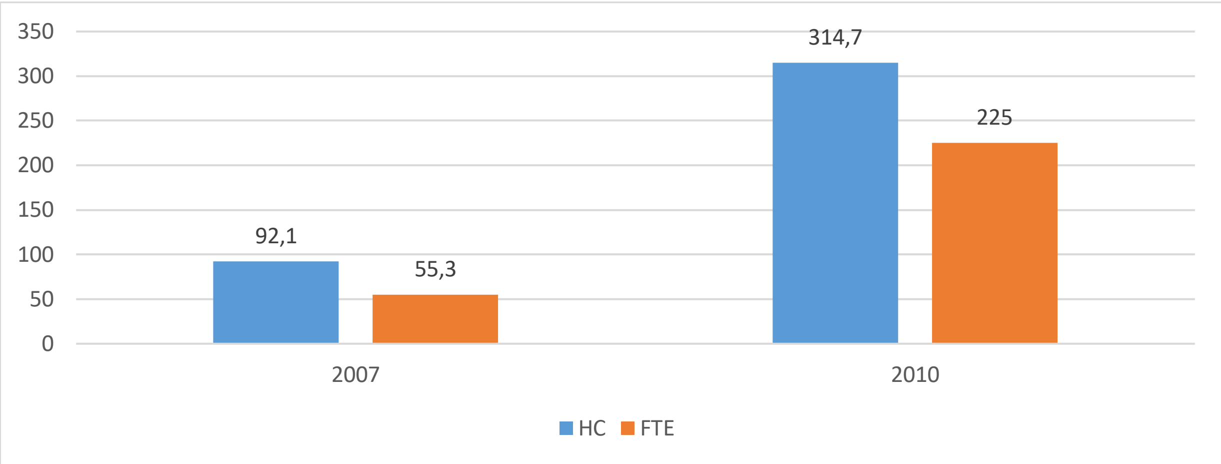

Figure 6-2: Researchers per million inhabitants

Source: UNESCO statistics, (n.d.).

6.2.3 Researchers per thousand labour force

The number of researchers per thousand labour force (HC) shows a four-fold increase from 0.2 in 2007 to 0.8 in 2010. Similarly, the number of researchers per thousand labour force (FTE) increased from 0.15 in 2007 to 0.6 in 2010.

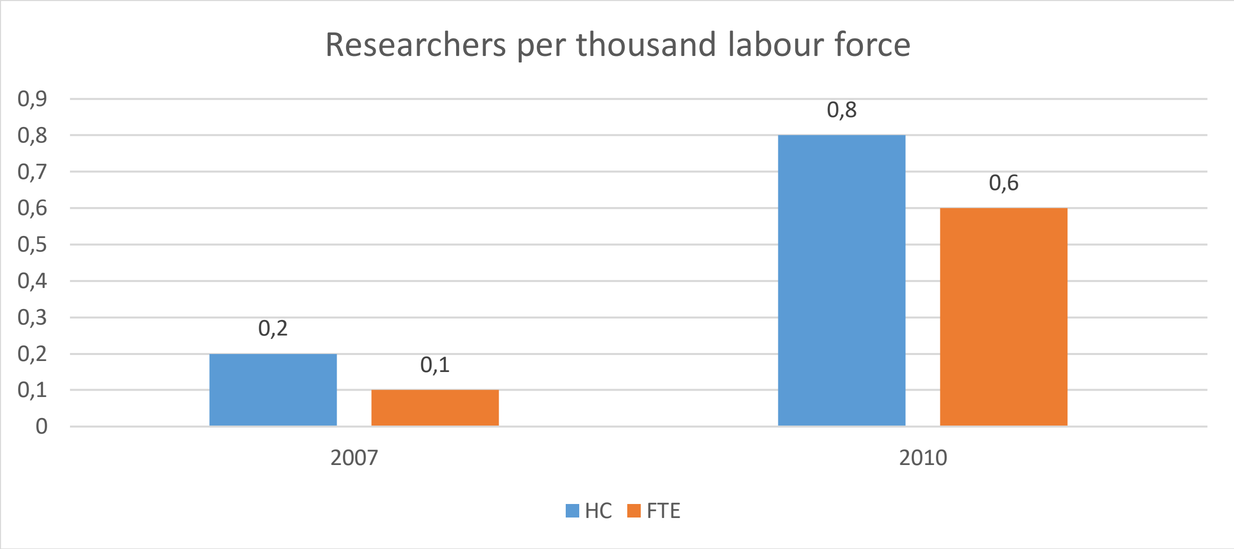

Figure 6-3: Researchers per thousand labour force

Source: UNESCO Institute of Statistics, (n.d.).

6.2.4 Researchers per thousand total employment

Data available shows that for the number of HC researchers per thousand total employment increased steadily between 2007 and 2010. Similarly, the number of FTE researchers per thousand total employment increased from 2007 to 2010.

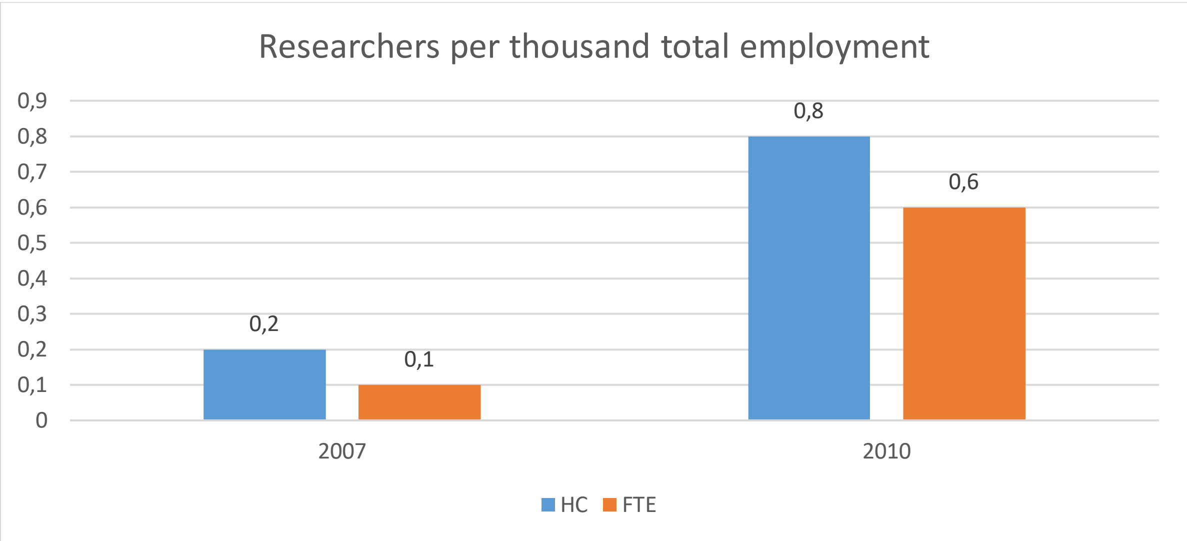

Figure 6-4: Researchers per thousand total employment
Source: UNESCO Institute of Statistics, (n.d.).

6.2.5 Researchers (HC) per sector

The data available shows that between 2007 and 2010 the highest number of researchers (HC) was recorded in the higher education sector, followed by the numbers in the business sector and private sector. The high numbers of researchers in the higher education sector could be linked to a higher number of higher education institutions in Kenya (i.e. 74 public and private universities) that employ a larger number of academics and researchers. Similarly, Kenya has several public research institutes and government parastatals that employ research to engage in public research.

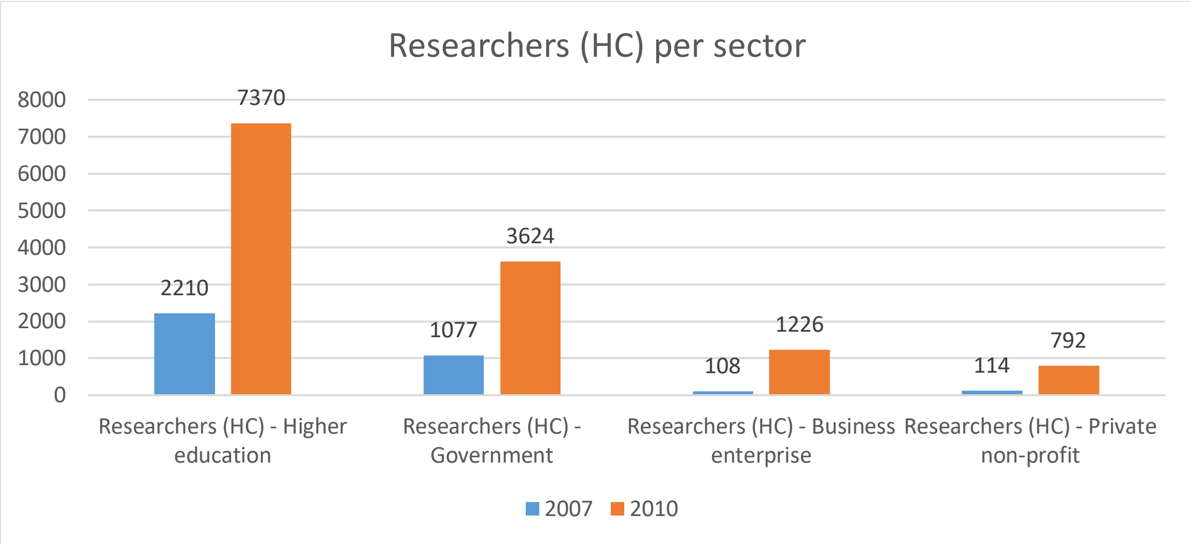

Figure 6-5: Researchers (HC) per sector

Sources: UNESCO Institute of Statistics, (n.d.).

6.2.6 Researchers (HC) by qualification

The disaggregation of the researchers (HC) by qualification shows that, in 2010, the largest proportion of researchers hold a college qualification. This high numbers could be linked to the high number of technicians who hold college level education, as compared to the academics or scientists at universities and research institutes who are required to have a masters or PhD degree.

Table 6-3: Researchers by qualification

Research indicators	
Researchers (HC) ISCED 5 (College level)	8160
Researchers (HC) ISCED 7 (Master level)	3475
Researchers (HC) All other qualifications	710

Researchers (HC) ISCED 8 (Doctoral level)	667
Researchers (HC) ISCED 6 (Bachelor level)	0
Researchers (HC) Not specified qualifications	0

6.2.7 Researchers (FTE) by sector of employment

The government sector recorded the highest numbers and proportions of researchers (FTE) (Table 6-4 and Figure 6-5). As indicated earlier the high numbers in the higher education sector are associated with the large numbers of universities (74 public and private universities) in Kenya, as compared with the number of public research institutes of government parastatals. Given this large number of universities and relative high number of researchers, universities dominate scientific production in Kenya as reported in chapter 7.

Table 6-4: Number of researchers (FTE) by sector of employment

Research indicator	2010
Researchers (FTE) Business enterprise	1062
Researchers (FTE) Government	1883
Researchers (FTE) Higher education	5647
Researchers (FTE) Private non-profit	713

Researchers by Sector of employment: Percentage shares of R&D, 201

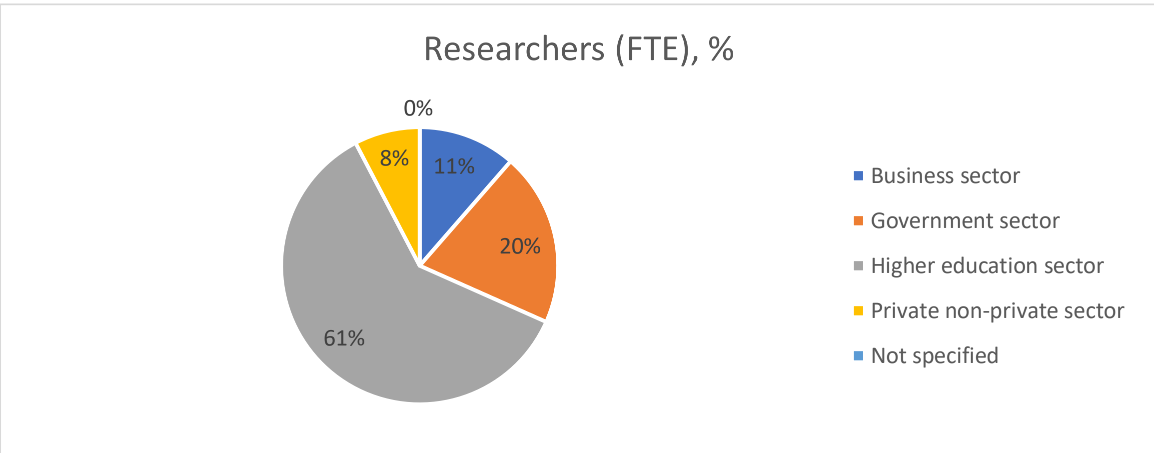

Figure 6-6: Proportion of researchers (FTE) by sector of employment

Source: UNESCO Institute for Statistics (2015)

6.2.8 Researchers (FTE) by scientific field

In 2010, unsurprisingly, the agricultural sciences and medicine and health sciences recorded the highest number of researchers (FTE) followed by engineering and technology and the social sciences. Similarly, the higher numbers in the agricultural and medicine and health sciences are translated in the scientific output as these fields, are the high contributors to Kenya's scientific output.

Researchers by field of science (in FTE): percentage shares of R&D, 2010

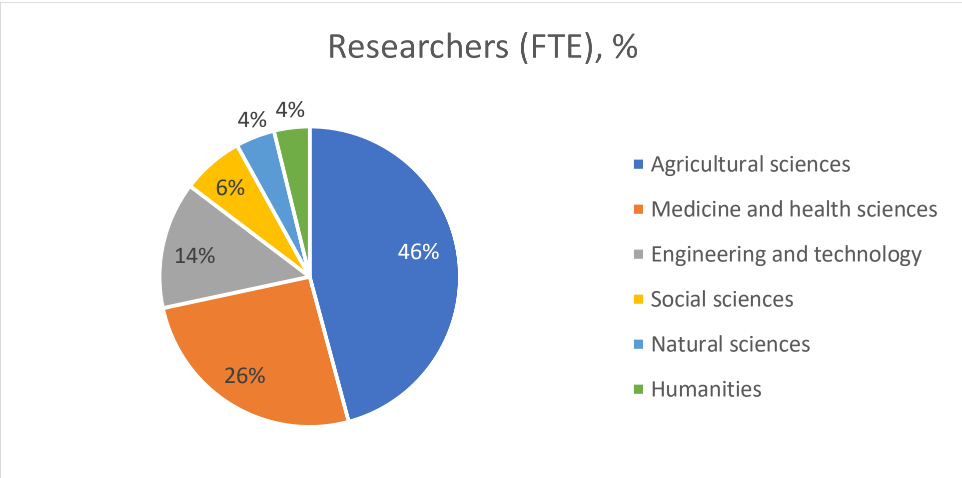

Figure 6-7: Researchers (FTE) by scientific field
UNESCO Institute for statistics (2015)

6.2.9 Researchers (FTE) by field and Sector (2010)

In 2010, the distribution of researchers (FTE) by field and sector correlates largely with the distribution of publication output by research institutions: agricultural sciences and medical sciences topped the group with 2, 889 and 1, 073 researchers working in the higher education and government sectors respectively. This is followed by engineering and technology with 861 and 258 researchers working in the higher education and government sectors respectively. Inasmuch as the social sciences and natural sciences have relatively smaller numbers, the higher education sector hosts the highest numbers of these researchers. In addition, the agricultural and medical sciences had the highest number of researchers, working in the private non-profit organisation and business sectors, followed by engineering and technology. However, engineering and technology recorded the least number of researchers, about 34, working in a private non-profit organisation.

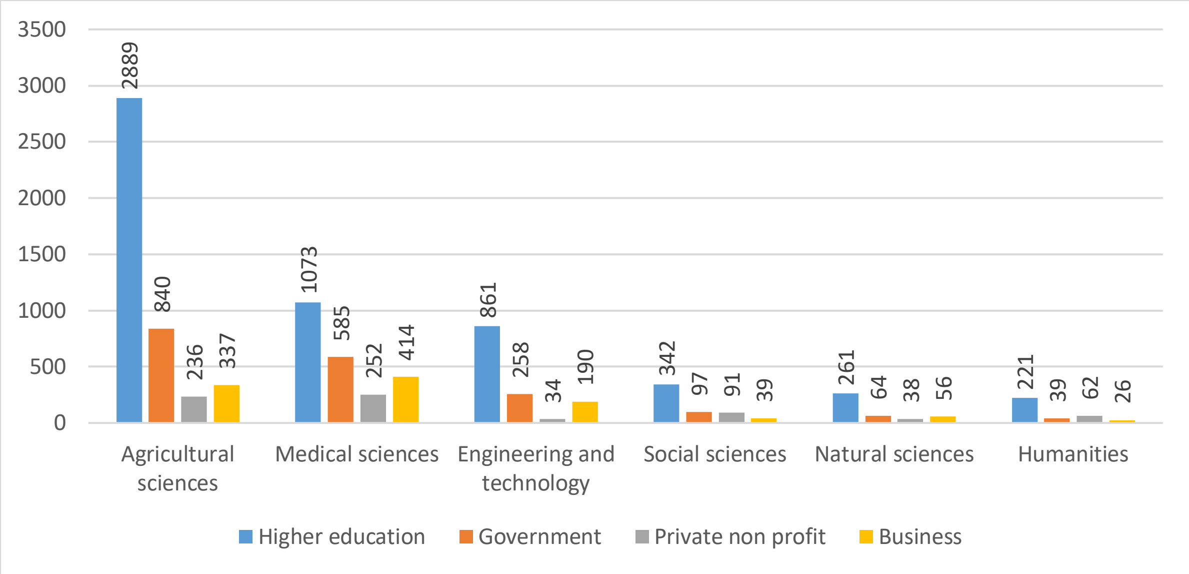

Figure 6-8: Researchers (FTE) by field and sector, 2010

Source: UNESCO Institute for Statistics, (2015).

Overall, the agricultural and medical sciences recorded the highest numbers and proportions of researchers (FTE) working in the higher education and government sectors, followed by the business sectors. The R&D investment and the research capacity in these two main fields and sectors are reflected in their higher numbers of publication output reported in chapter 7 of this thesis.

6.2.10 Researchers (FTE) by qualification

In 2010, the UIS statistics on researchers (FTE) by the qualification of researchers show that the majority of FTE-researchers (more than 60%), hold college/equivalent degrees followed by the researchers who hold a master level degree (29.5%). The researchers with a doctoral degree or equivalent qualification were about 6%. The numbers of the researchers holding a doctoral or masters as highest qualification could be mostly researchers in the higher education and government/public R&D sectors. The appointment and promotion policies of the Kenyan R&D sectors requires that most researchers should hold doctoral or master's degrees for appointment to research or professor positions at universities and in some public or government research institutes or parastatals (University of Nairobi [UoN], 2006).

Researchers by the level of education (in FTE): Percentage shares, 2010

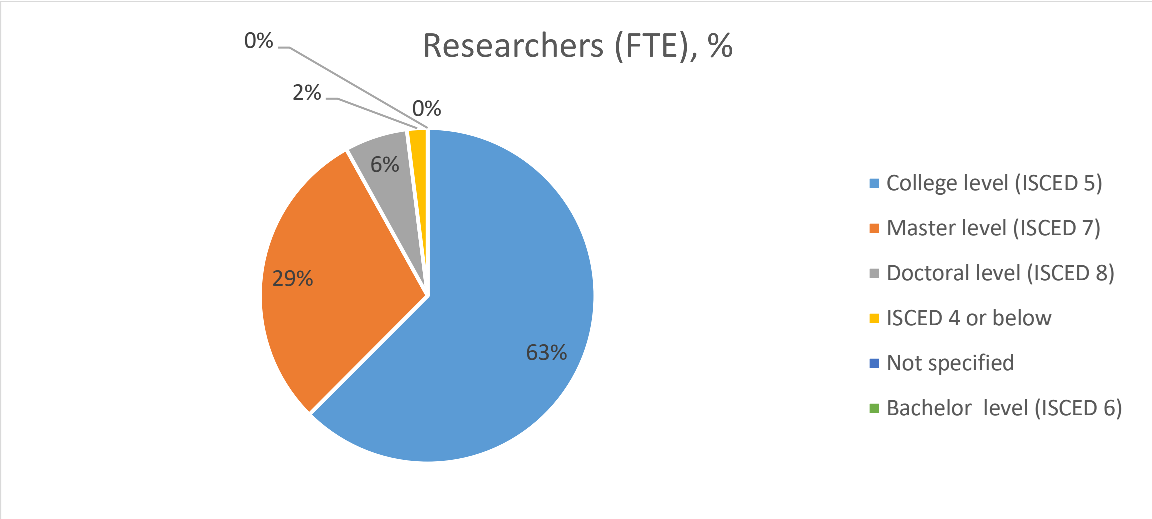

Figure 6-9: Researchers (FTE) by level of education Source

Source: UNESCO Institute for statistics (2015)

6.2.11 Female researchers

UIS statistics show that women are under-represented in science, comprising only 28% of all the researchers globally. Overall, greater disparities are observed in the natural sciences and engineering and applied technology. In several countries, there are few women enrolled in the natural and engineering sciences, thus it is difficult to attract, train and retain enough female students and professionals resulting in male scientists dominating the scientific fields and the top decision-making posts (UNESCO, 2015). The next sections illustrate the representation of women scientists in Kenya and selected sub-Saharan countries.

6.2.11.1 Number and Percentage of female researchers

According to the UIS statistics, in 2010, the share of female researchers per million inhabitants (HC) in Kenya was 25.7% an increase from 17.8% in 2007. The figure below further shows a five-fold increase in the HC number of researchers from 626 in 2007 to 3338 in 2010. Similarly, the FTE number of female researchers increased three-fold from 376 researchers to 1861 researchers.

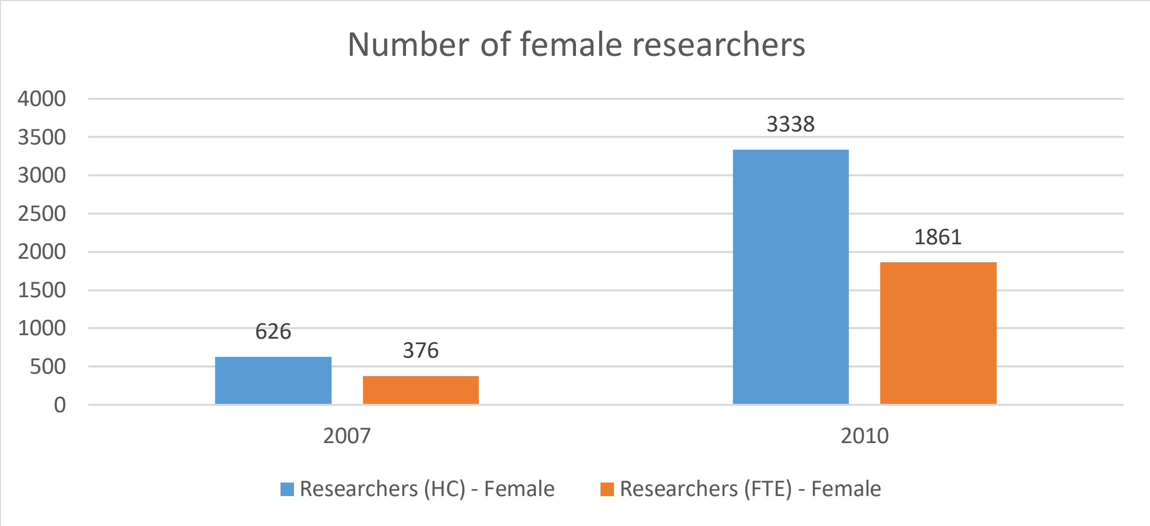

Figure 6-10: Number of female researchers

Source: UNESCO Institute for statistics (2015)

Several governments in East Africa have adopted policies to foster gender equality and greater participation of women not only in education, politics and economic development but also in science. In 2014, Kenya's government developed a policy on mainstreaming gender in the national STI, […] that serves as an addendum to the National Science, Technology and Innovation Policy of 2012" (Kraemer-Mbula & Scerri, 2015:508). Inasmuch as Kenya has made several policy efforts, it still has to integrate enough women researchers into scientific activities especially as researchers and administrators, especially in the engineering and technology and the natural sciences, with below 15% share of women scientists. The social sciences and the agricultural sciences counted the highest proportion of women scientists, 46.95% and 30.43% respectively (see figure 6-11 below).

Share of the female researchers: Gender and scientific field (2010)

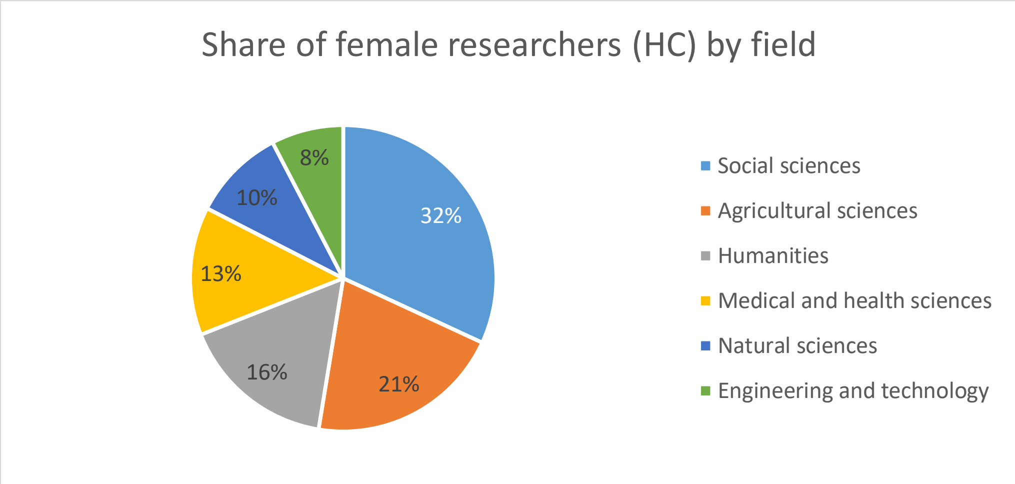

Figure 6-11: Proportion of female researchers (HC) by scientific field

Source: UNESCO Institute for statistics, (2015).

6.3 International Benchmarking of research capacity

This sub-section compares the different indicators of research capacity for Kenya with other selected African countries. These indicators include the researchers per million inhabitants (HC). The sub-section also looks at how different countries compare in relation to women researchers compare across sub-Sahara countries.

6.3.1 Researchers in sub-Saharan Africa per million inhabitants (HC)

Figure 6-12 shows the researchers in Sub-Saharan Africa per million inhabitants. In 2010, the UNESCO statistics (Figure 6-12) shows that, amongst the East African countries, in absolute terms, Kenya counted the highest numbers (318) of researchers per million inhabitants (HC) followed by Ethiopia (87, 2013), Uganda (83, 2010), Tanzania (69, 2010), Rwanda (54, 2007), and Burundi (40, 2011) (UNESCO, 2015).

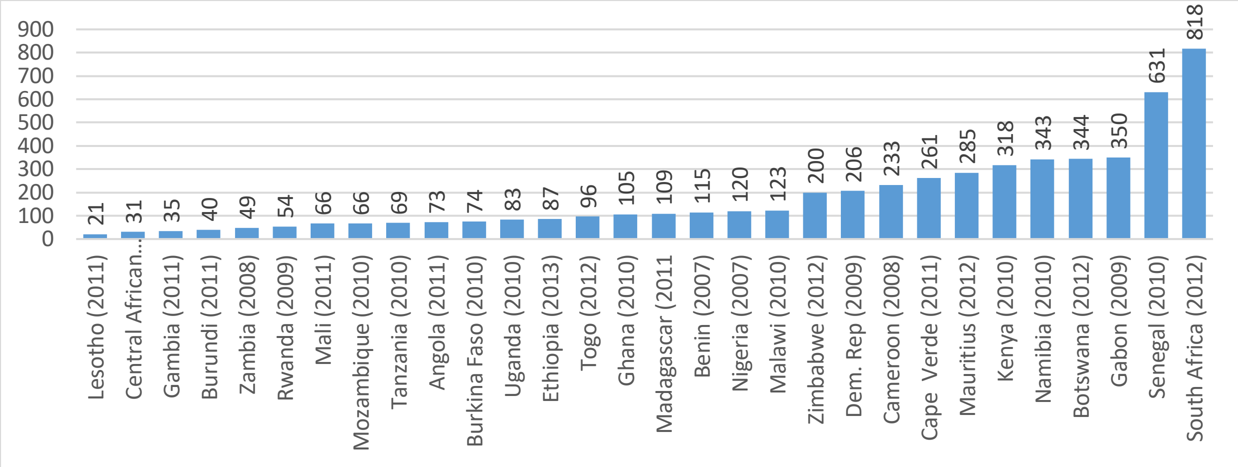

Figure 6-12: Researchers in sub-Saharan Africa per million inhabitants (HC), 2013 OR closest year.

Source: UNESCO Institute for Statistics, (2015).

6.3.2 Female Researchers in Sub-Saharan Africa

Figure 6-13 below illustrates the proportions of women researchers in selected sub-Saharan countries. While Kenya has more researchers in the East African region in absolute numbers, Kenya (25.7) and her neighbouring countries Tanzania (25.4), Uganda (24.3%) and Rwanda (21.8% in 2009) reported having almost the same proportions of female researchers (21.8%) (Kraemer-Mbula and Scerri, 2015). However, the East African group falls below the proportions of female researchers in South Africa (43.7% in 2012) but is above other large scientific producers in Africa, Nigeria (23.3% in 2007).

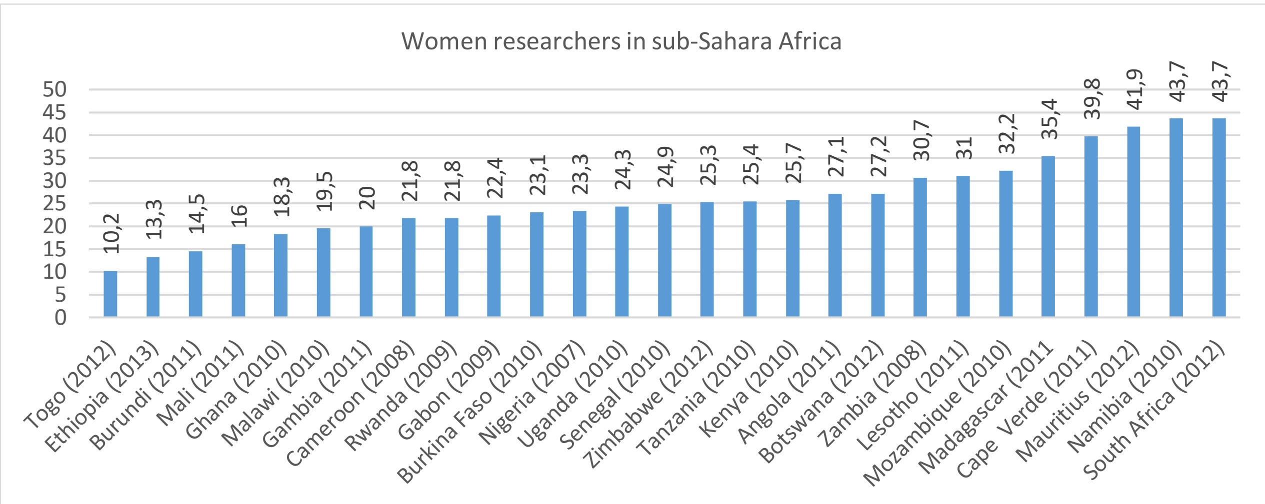

Figure 6-13: Women researchers in sub-Saharan Africa, 2013 or closest year (%)

Source: UNESCO Institute for statistics, (2015).

Summary and conclusion

The above section presented several research capacity indicators: researchers, researchers per million inhabitants, researchers per thousand, labour force, researchers per thousand employment, researchers (HC and FTE) and researchers disaggregated by sector of research performance, scientific field and occupation. The R&D personnel data upon review showed several errors reproduced across the different indicators. Therefore, given the evidently erroneous data for R&D personnel, I chose to present the data for numbers of researchers only.

For all the HR indicators listed above, Kenya recorded increases in the number of researchers (i.e. researchers per million inhabitants, researchers per thousand labour force, researchers per thousand employment and the total number of researchers (HC and FTE). When the researchers (HC and FTE) indicator is disaggregated by sector, data revealed that the higher education sector recorded the highest number of researchers, followed by the government institutions. The business sector and the private organisations had the least number of researchers. As far as the disaggregation by scientific field is concerned, the agricultural and health sciences recorded the highest number of researchers. These findings also reveal that the largest proportion of researchers (HC and FTE) has a college or equivalent as their highest qualification. A small number of researchers, mostly those in the higher education sector, hold a master level degree or doctoral level qualification.

A comparison of Kenya with selected African countries shows several trends. For proportion of female researchers' indicator, when compared to other sub-Saharan African countries, Kenya is ranked tenth behind countries like South Africa, Namibia and Botswana. Kenya records the highest number of research and development staff per million inhabitants compared to Uganda and Tanzania. Similarly, Kenya reported the highest share of female researchers in absolute numbers in the East African region, while her regional neighbours (Tanzania, Uganda and Rwanda) reported similar shares of their country's researchers.

Section Two: Mobility and the careers of young scientists

6.4 Introduction

International mobility of scientists is a key aspect of the global science system (Huang, 2013). There are several positive benefits generally related to mobility, especially for mobile sci,entists and mobile institutions (Welch, 1997). Mobile scientists develop more international research networks and are more productive compared to non-mobile scientists (Franzoni *et* *al.,* 2012), they publish more and receive more citations (Aksnes, Rørstad, Piro & Sivertsen, 2013) and have better access to funding (Aksnes *et al.,* 2013). Furthermore, mobile scientists are more productive in all the different scientific fields

Based on the mobility of African scientists in the past decades, and the effects that have been associated with brain drain in African countries, especially on knowledge production, respondents to the African Young Scientists (AYS) survey (CREST, n.d.) were asked to report on matters of mobility. The aim of the questions was to find the extent of scientists' mobility. The survey also aimed at establishing the importance of mobility that is, studying/working abroad on the scientists' career development. Scientists were also asked to report on their working conditions abroad compared to the local working conditions. During the interviews, scientists further expounded on the importance of international visits and studying abroad. This section also explores the relationship between mobility and the possibility of receiving funding, especially from international resources.

6.5 Recent International Mobility

The results show that about 46% of respondents reported that they have studied or worked in a country other than their home country (i.e. abroad) over the preceding three years. On the other hand, about half of the respondents indicated that they have not studied or worked abroad.

6.5.1 International Mobility by age

The disaggregation by age shows that most respondents who were 39 or younger (38.8%) and those between 40 and 50 (38.8%) reported that they had recently studied or worked abroad. This was followed by 21.4% of the respondents who were older than 50. On the other hand, a higher proportion of respondents between 40 and 50 indicated they had not recently studied or worked abroad. The second-largest proportion of respondents who indicated they had not recently studied or worked abroad were older than 50, followed by 23.3% who indicated of the group 39 or younger. The chi-square (χ^2) statistic shows there is a significant association between age and international mobility, χ^2 (2) = 0.02, p<0.05. This implies that there is a relationship between the chronological age of scientists and international mobility (studying or working abroad).

6.5.2 International mobility by scientific field

Figure 6.14 presents the results of disaggregation by scientific field. The results show that most of the respondents in the natural sciences and agricultural sciences recently studied or worked abroad. The second-highest proportions were recorded by the respondents in the social sciences and natural sciences. The least proportions of respondents in the humanities and engineering and applied technology indicated thy recently studied or worked abroad. The chi-square (χ^2) statistic shows no significant association between the scientific field and international mobility, χ^2 (5) = 0.81, p>0.05. This implies that there is no statistically significant relationship between the scientific field and international mobility (studying or working abroad).

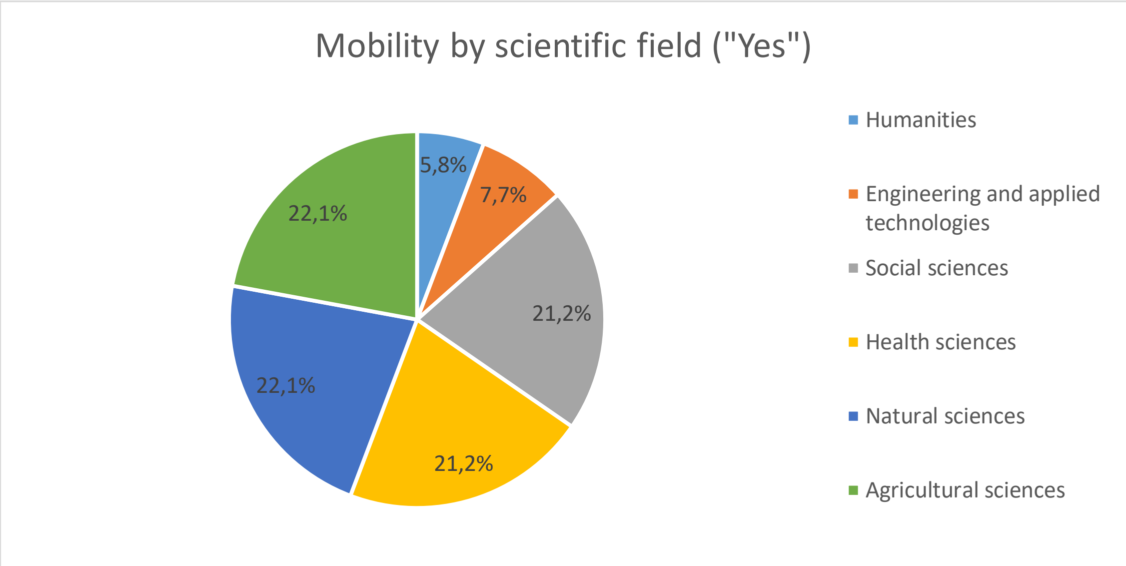

Figure 6-14: Scientific field of internationally mobile respondents

Source: CREST, (2016).

6.5.3 Age, gender and scientific field of internationally mobile respondents

To expound on the patterns of mobility, this analysis further considered age, gender and scientific field as possible predictors for mobility, therefore, a cross-tabulation was run given that the dependent variable (mobility) is a dichotomous variable. The results of age, scientific field and gender of internationally mobile respondents are presented in figure 6-14. For all the predictors, age appeared to be the best predictor of whether the respondents had studied or worked abroad recently. The results also reveal clear gender differences, with more males more likely to have recently studied or worked abroad.

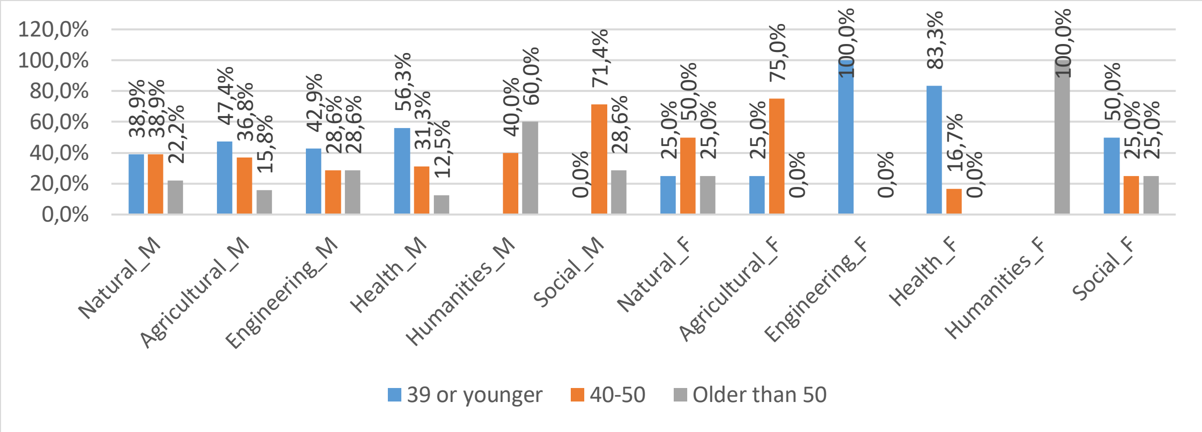

Figure 6-15: Age, scientific field and gender of internationally mobile respondents

Source: CREST, (2016).

Figure 6-15 above illustrates the age, gender and scientific field of the internationally mobile respondents. When controlling for scientific field and gender, our results show that higher proportions of male respondents (with the exception of the 39 or younger scientists in the health sciences and engineering and applied technology) indicated that they have recently studied or worked abroad. In the humanities, more females older than 50 indicated they recently travelled abroad. In the agricultural sciences, a higher proportion of female respondents between 40 and 50 indicated to have travelled abroad recently compared to their male counterparts. Male respondents between 40 and 50 in the social sciences reported having recently studied or worked abroad. Only younger and middle-aged female respondents in the agricultural, health and engineering sciences indicated to have recently studied or worked abroad.

6.5.4 The importance of studying or working abroad for career development

The results (Figure 6-16) show that of those who reported they studied or worked abroad the majority indicated that this experience has been ‘essential’ (29.4%) and ‘very important’ (56.9%) for career development.

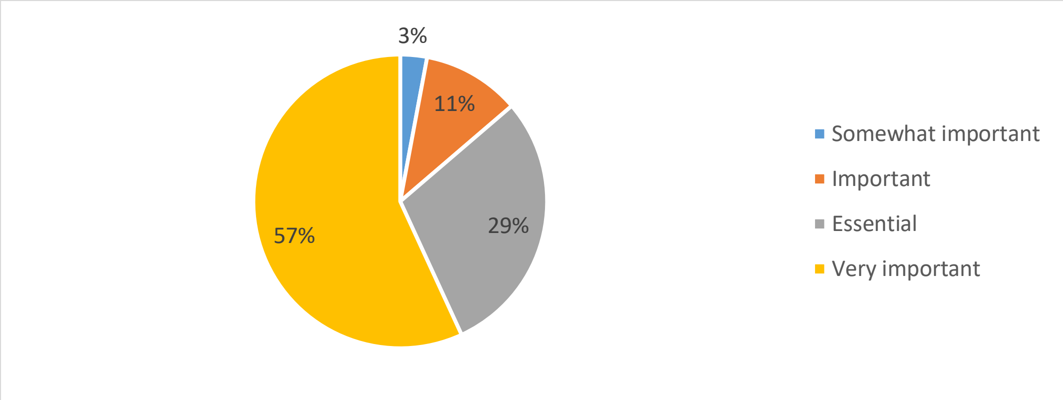

Figure 6-16: Rating of the importance of having studied or worked abroad for career development. Source: CREST, (2016).

6.5.5 International Mobility according to the sector of employment

The results (figure 6-17) show that international mobility differs by sector of employment. The proportion of the respondents who had been internationally mobile three years preceding the survey is proportionately highest among those in the higher education institutions (46.6%) and public research institutions (26.6%), followed by those in non-governmental organisations (13.6%). Small proportions of those in the international (research) organisations (4.9%), government institutions (2.9%) and business enterprises (2.9%) had been mobile.

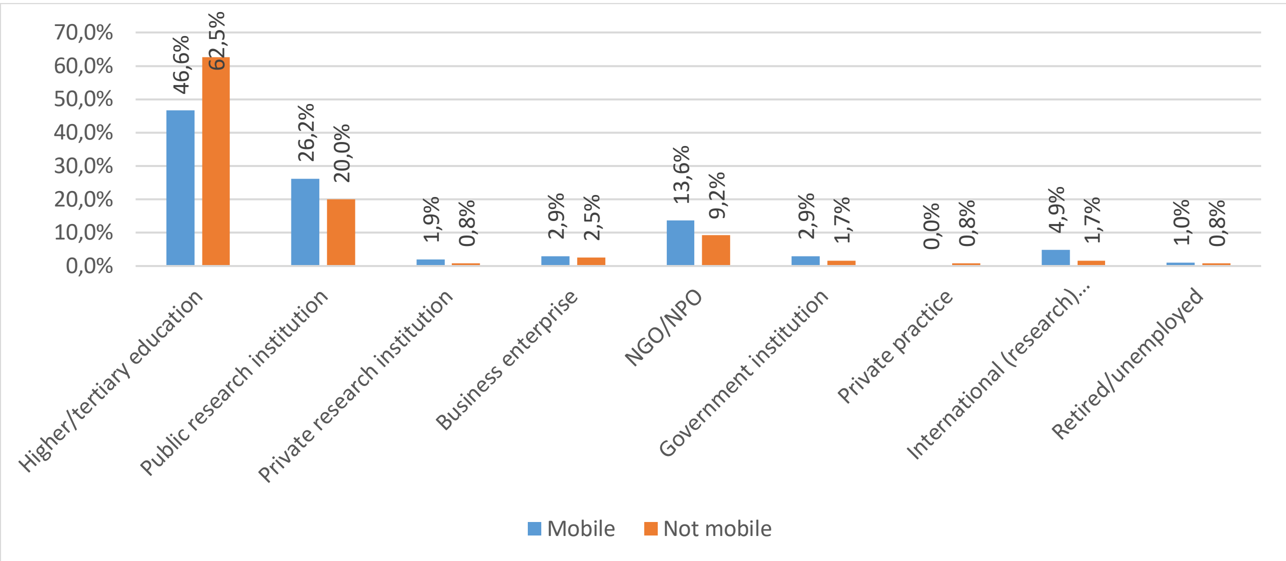

Figure 6-17: international mobility according to the sector of employment

Source: CREST, (2016).

6.5.6 International Mobility according to the region of residence

The results (Figure 6-18) show that as far as the region of residence is concerned, a higher proportion of respondents in sub-Sahara Africa (84.6%) indicated they had recently studied or worked abroad followed by those outside Africa (10.6%) and South Africa (4.8%).

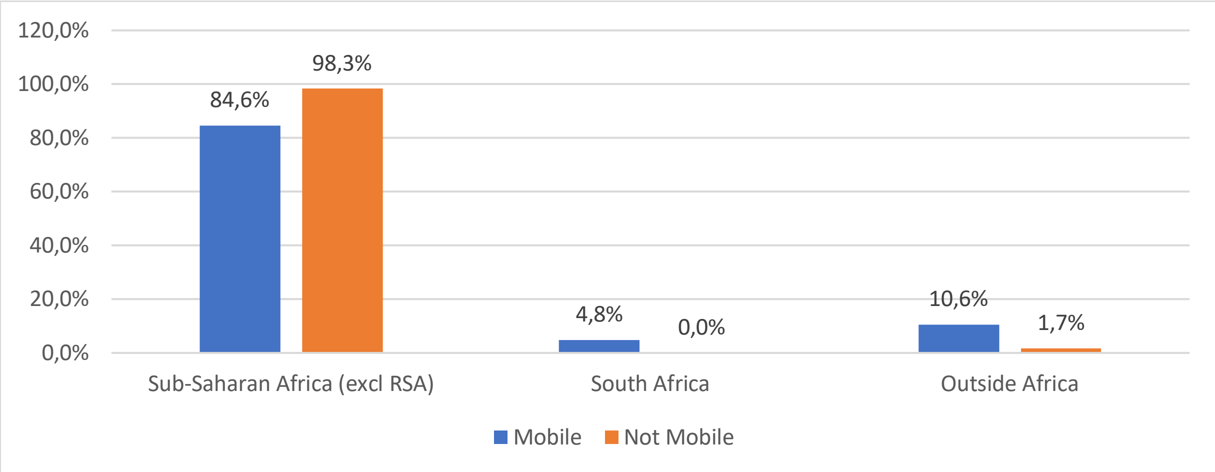

Figure 6-18: International mobility according to the region of residence. Source: CREST, (2016).

6.5.7 Benefits of international mobility

In interviews, respondents were asked to expound on the benefits of international mobility. Interviewees are of the view that international mobility offers individual scientists more research opportunities that enable them to engage in more research.

> Well, there's a lot of advantages … One is the exposure to the new treatment modality; two is the exposure to research. I really recognise that in the US their practice is really … backed by research and they generate their own data. So, you really identify with even some of the treatment that we use here; which is generated from the US basically and parts of Europe (35-year old male respondent from Kenya, R_189).

Interviewees considered international institutions offered more training opportunities.

> I did have more training opportunities there … I received the training from the centre I was working in, on research proposal writing, which I acknowledge that it was very useful (32-year-old male respondent from Kenya, R_192).

International work or study allows scientists to be exposed to research systems that are functional and have a research culture that enables researchers to be productive, resulting in job satisfaction and recognition.

> The other thing is the systems, you will see systems that are working, so it makes your job satisfaction, your input really … It rolls into some really significant output. Your efforts are quite appreciated through the system, the research. And the options of treatment. So if you learn in such an environment, then now you realise that you mastermind a lot (35-year-old male respondent from Kenya, R_189).

The most significant benefit resulting from having studied or worked abroad is also linked to the research networks acquired, that may subsequently lead to collaborating on research projects or funding opportunities. These research networks have resulted in scientists co-authoring with their collaborators thus boosting their scientific output.

> I'm currently working on a funding proposal with my supervisor, who was then at West Virginia, but he moved to Humane [?] Cancer Centre. And we published at least two, a book chapter and an article together, and we still communicate. Yes, so I have a member mentor. He was doing fellowship then, but how he's retained; he works at Virginia and, basically as I told you, we are trying to see if we can, you know, work together and do some research together … I'm currently working on a research proposal … I tend to focus more on the malignant haematology, and we've done a proposal, which I'm collecting data now with the University of Vienna in Italy [with an Italian] Professor [who] basically does a lot of capacity building for the University of Nairobi, School of Medicine. So, we, that is work in progress together (35-year old male respondent from Kenya, R_189).

> … we have had training in collaboration with West Virginia University and [the] University of Vienna. And from that we've had recent training people have been training on palliative care, cancer diagnosis, yes. So, I think those are the key areas. And through that collaboration also some resident students managed to get funding for their pathology projects so … I think those are the main benefits of collaboration (35-year old male respondent from Kenya, R_189)

> But in terms of contacts with people, because during my master's training, I was trained outside, during my PhD training, I was trained outside. So, I managed to link up with some people, and we continue to carry on. But we do not have a specific funded project that we'd say. We just … Whatever we are able to do without funding, we are only… We keep collaborating until we get (32-year old male respondent from Kenya, R_192).

Interviewees emphasised that studying/working abroad allowed them access to the 'state of the art' research facilities, infrastructure and resources.

> … sometimes for you to move forward you need at least to explore other fields outside your country. For instance, when I went to Canada, that is where I was doing my lab work, there, things are easy in terms of the machines that they use, in terms of the skills that they have. That is because they have the ability to buy software and machines that other countries may not have access to buy. So, that makes your research easy and it makes you explore many

> areas. For example, if you were doing lab work on given research, you are able to look at it from four or five dimensions. When you are in a country, for example, Kenya, you are only able to do two or three activities but when you try to go to the fourth and fifth and the sixth, you realise that you don't have the machines to do that … So, in terms of the development of your career, you are able to do multiple activities when you have access to what you have as your raw materials and what you buy from other people unlike when you are within the country where it takes longer for you to get your materials. So, I've talked of infrastructure, I've talked of the machines, I've talked of the people that I was working with and, lastly, the ability to buy what is needed. So, holistically, when I was working in those countries it was better, much better than when I'm working in Kenya (35-year old respondent from Kenya, R_073).

> … I think that the experience being amongst the graduates in a Kenyan university, I felt that I needed that change, I needed a place with more facilities. At that point I perceived the US to have the, you know, the up-to-date items, they had research to be done there. So, that was a long time ago now when I started, that's 2007. So, it's just my perception at that time … but I think it definitely gave me access to a lot of information (35-year-old male respondent from Kenya, R_189).

Studying and working abroad enables individual scientists to be exposed to experts or renown scientists in their specific fields.

> … our country is not as developed as other countries and some of the things which you would like to pursue, you may not find somebody who has those skills and experience. That is one. So, when you are looking for an opportunity, for example, who will train me on this, sometimes within the country you may not find one and therefore you are supposed to look for such opportunities out of your country So, that is where it is a big challenge, especially lack of training opportunities. For you to apply outside the country, you must wait until there is a call for a given kind of skill or some people looking for something for you to go and train. So, sometimes it may not come along the area of your interest and therefore that is where it is lacking… (35-year-old male respondent from Kenya, R_189).

Apart from the benefits indicated above, another key benefit of international mobility mentioned by respondents is access to funding. In the survey, respondents were asked to report if they had received research funding in the preceding three years and whether they were the primary recipients/grant holders of the funding. Respondents were also asked to indicate the proportion of the funding obtained from national and international sources. In this analysis, I 'tested' the hypothesis, that there is an association between greater mobility and access to more international funding, by comparing the respondents who indicated they were mobile and those who were not, in terms of their receipt of research funding from international sources.

6.5.8 International mobility according to receipt of research funding

The results (figure 6-19) show that slightly higher proportions of respondents who indicated that they were mobile received funding (were primary recipients and in some cases primary recipients) compared to the non-mobile respondents.

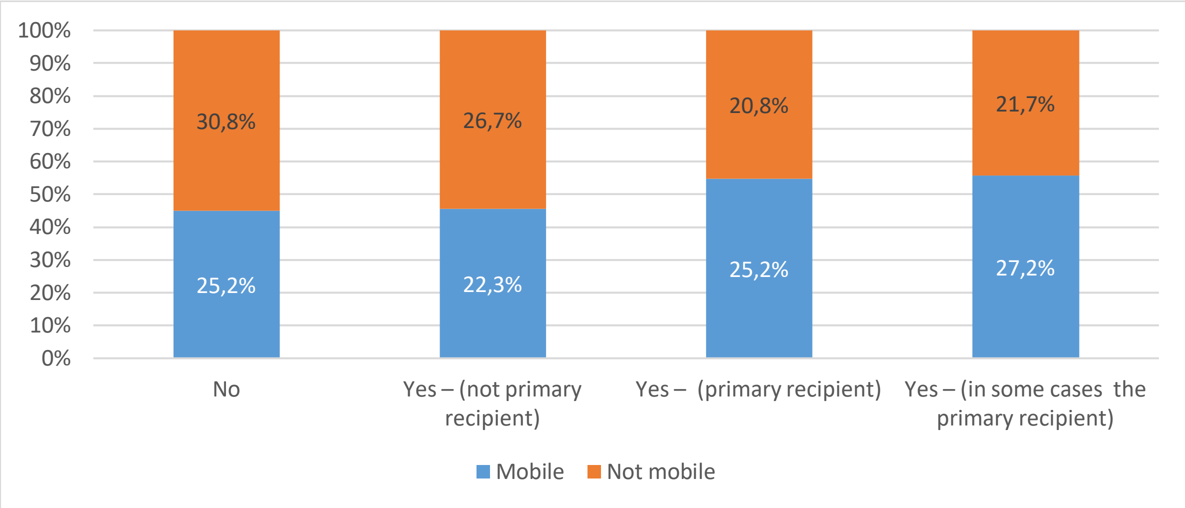

Figure 6-19: International mobility by receiving research funding. Source: CREST, (2016).

The reported percentage of funding from international sources, by age, field and mobility

The relationship between having studied/worked abroad and the proportions of funding accessed from international sources offers a clear picture. The ANOVA results (I controlled for age, gender, scientific field and mobility) reveal a clear association between mobility and accessing research funding from international sources. The results (figure 6-20) suggest that age and the scientific field are more likely to be good determinants of accessing funding from international sources. Overall, the results show that young scientists (39 or younger) working in the agricultural, health and social sciences and older scientists working in the humanities, natural, agricultural and social sciences more likely accessed funding from international sources in the preceding three years. When controlling for mobility, the results reveal that respondents who had studied or worked abroad (mobile respondents) in all fields are more likely to have received funding in the previous years. The results presented also suggest that younger scientists who are mobile are equally likely (and in some fields like engineering, agricultural and social sciences even more) to have accessed funding from international sources in the previous three years.

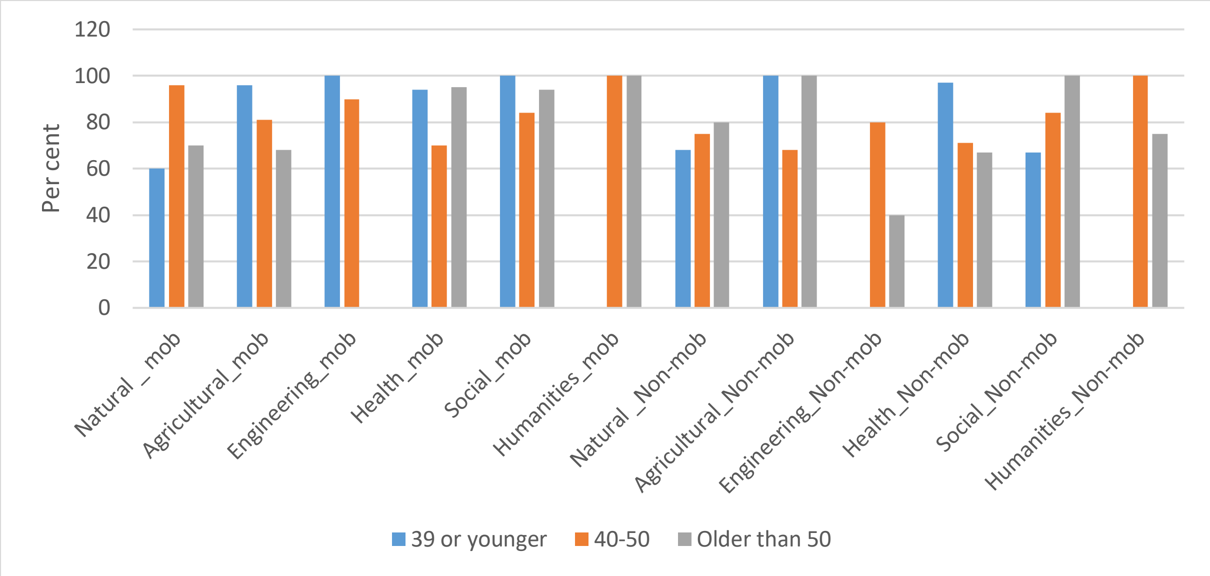

Figure 6-20: Reported percentage of funding from international sources, by age, field and mobility.

Source: CREST, (2016)

6.5.9 Comparison of study/working conditions abroad to those in the home country

Respondents who were internationally mobile were asked to compare the study/working conditions abroad to those in the home country (Figure 6-21). The mobile respondents were asked to rate six main elements: (1) employment/job security; (2) work-family balance; (3) training opportunities; (4) opportunities for research collaboration (5) research resources; and (6) research funding. Unsurprisingly, the results (Figure 6.20) reveal that a higher proportion of mobile respondents rated training opportunities, opportunities of research collaboration, research resources and research funding to be much better abroad compared to those in the home country. On the other end, as expected, work-family balance is the only element rated higher for being much worse abroad.

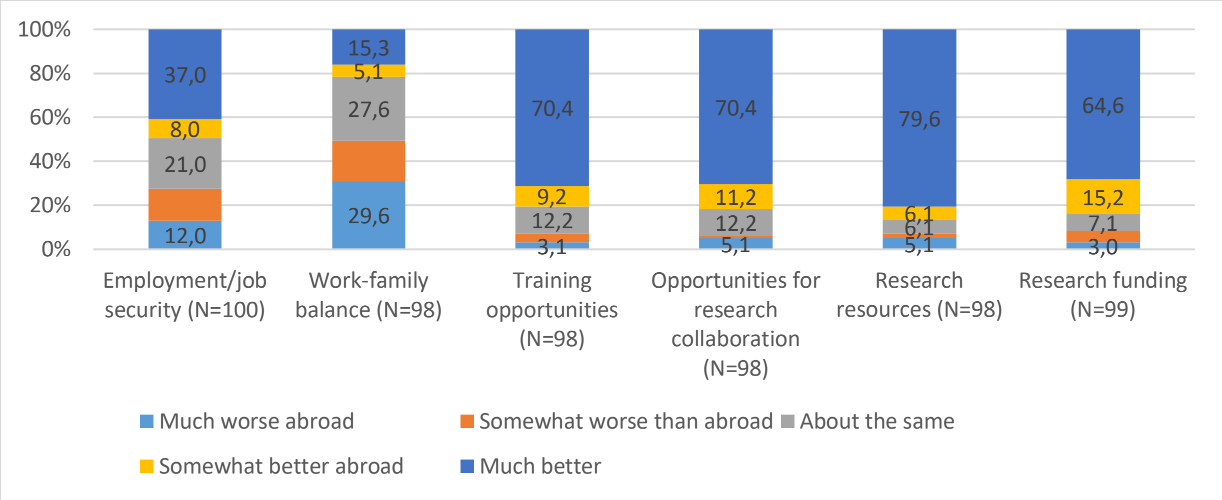

Figure 6-21: Comparison of studying/working conditions abroad to those in the home country.

Source: CREST, (2016).

The disaggregation of the ratings of the studying/working conditions abroad by age show expected results (Table 6-5). For all the six elements rated, larger proportions of young scientists were more likely to indicate that the studying/working conditions abroad were much better compared to the older scientists. The huge differences in the studying/working conditions abroad and those in home country are better shown by the relatively large proportions of young scientists who indicated that the studying/working conditions are much better in relation to employment security (44%), work-family balance (45%), access to research resources (43%), training opportunities (45%), research funding opportunities (41%) as well as opportunities for research collaboration (43%).

Table 6-5: Rating of studying or working abroad, by age category and different factors

	Worse Abroad	About the same	Much better
Employment security			
39 or younger	33%	24%	44%
40-50	58%	57%	31%
Older than 50	8%	19%	24%
Work-family balance			
39 or younger	39%	37%	45%
40-50	45%	40%	35%
Older than 50	15%	22%	20%
Research resources (personnel, scientific literature, material, etc.)			
39 or younger	14%	17%	43%

40-50	71%	67%	36%
Older than 50	14%	17%	21%
Research funding opportunities			
39 or younger	38%	14%	41%
40-50	63%	57%	38%
Older than 50	0%	29%	22%
Training opportunities			
39 or younger	14%	25%	45%
40-50	86%	42%	36%
Older than 50	0%	33%	19%
Opportunities for research collaboration			
39 or younger	0%	33%	43%
40-50	100%	33%	38%
Older than 50	0%	33%	20%

Furthermore, the respondents who were interviewed expounded on the several benefits of international studies, work and travel. Interviewees identified differences in the international and local research environments. For instance, international research institutions are claimed to offer good mentoring opportunities from skilled individuals in their fields, which is key for their skill and professional development.

> … I was looking forward to … if I could get some post-doc out of my country so that I meet other people who can be able to mentor me in other areas, it would be good in my area of study (34 -year old male respondent, R_187).

Let me talk about mentorship. You know, in the countries that I've gone, I have realised that some of the professors and some of the highly skilled people, they'll come and train our students on how to handle some activities, basic activities and even complex activities. However, in some countries I've gone, I've realised that that is really lacking. Somebody is well-skilled but she doesn't have time to mentor the young scientist. This is a big challenge, not only in Kenya, I've experienced it in another East African country, I also experienced it in another Southern African country, that you do not have mentors, people who can show you something from the beginning to the very end as it is and if we can have these kinds of skills, especially for the people who are research scientists, … if they can have some kind of a forum whereby anybody who is interested in a given skill can apply and then they are taken through those skills, I know there are forums like that but they are limited, that is the only way we can promote what we call the skills and professional skills among the young people (35 year old male respondent, R_073). Respondents considered the opportunities for research networking in their own country to be inferior as compared to when they study or travel abroad.

> There’s a lack of opportunities for us to … like here in Kenya, there are problems with, the main problem of us interacting with other scientists outside of Kenya. So, for you to interact with others it will probably only be in the conference, which our institutions do not support you that you have to [sound slip] (34-year old male respondent, R_187).

International work is perceived to offer higher incentives for research and postgraduate training as compared to the local institutions or home country.

> … we have many students who are ready to be supervised, but the remuneration is a bit low. And when I compare myself of where I did my PhD at the University of the Western Cape, in Cape Town, there are a lot of opportunities, staff in South Africa have extremely good opportunities to support them, because of the initiatives that I think the South African government has put in place. Well not that we lack that locally, because I will tell you that if I supervise one doctoral student here in Kenya, as a supervisor I am paid like R1,500 for the whole work. R1,500 (40-year old male respondent from Kenya, R_078).

Given the poor incentive schemes and remuneration at local institutions and countries, interviewees indicated that they are not motivated to spend much time on research as compared to teaching.

> … another challenge is that even though I have interests in doing research, since doing research, it doesn't add any monetary value. You always tend not to spend much time on it, because your salary will not change, and you find that, like, specific to my country, that salary is really very limited also because the university's taken as a government institution. So what's happened is that we're ending putting more time on teaching from one institution to another. And the time left for research is also very limited because even if we're getting funding from outside, the funding will not allow salaries just for research

6.5.10: Considered leaving one’s country

Respondents were asked in the survey to indicate if they considered leaving the country where they currently work/reside. On the one hand, over half of the respondents indicated that they sometimes (58%) considered leaving their current country of work or residence, while 17% have often considered leaving. On the other end, 24% of the respondents indicated they never considered leaving the country where they currently reside or work. The results (Figure 6-22) reveal that a large proportion of respondents between 40 and 50 indicated they often consider leaving the country where they currently work/reside, followed by the 39 or younger respondents (34%). The highest proportion of older respondents indicated that they never considered leaving the current country where they currently work/reside. The high proportions of the respondents between 40-50 and those who are younger could be explained by their need to access training opportunities, funding opportunities, opportunities of research collaboration and access to 'the-state-of-art' equipment and facilities for research.

Considering Leaving the country where you reside/work, by age category

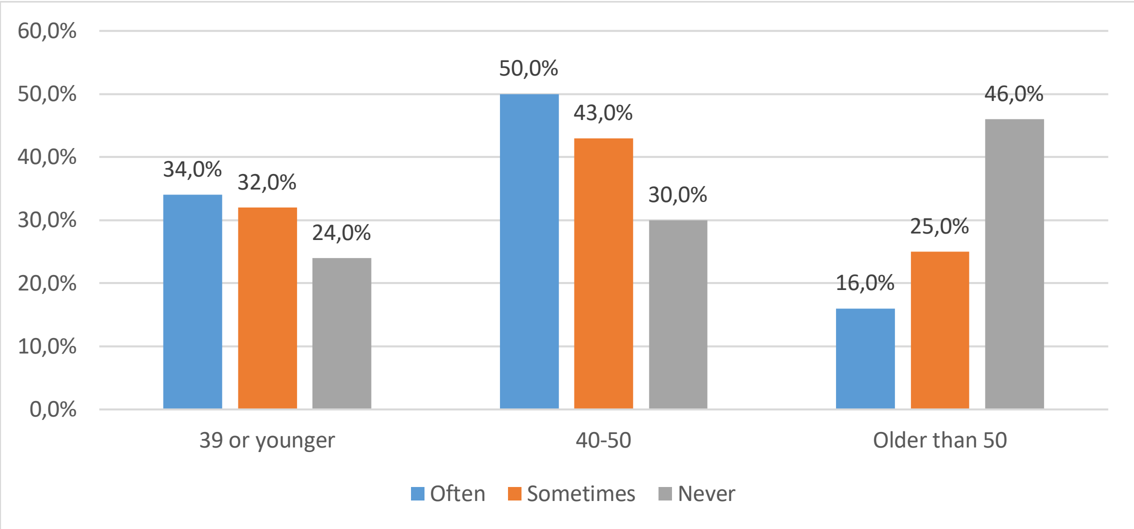

Figure 6-22: considering leaving the current country of work/residence.

Source: CREST, (2016).

Reasons for leaving the country

Respondents who indicated that they considered leaving the country where they currently work/reside were asked to report three reasons for considering leaving the country. The results (Table 6-6) shows that the main reasons for considering the country reported include: career prospects/job opportunities, academic reasons, funding, salary, resources/equipment, social welfare and state provision.

Table 6-6: First 10 reasons for leaving the country

First Reason	N
Career prospects/Advancement of career/Job opportunities/Job security	31
Salary/Income/Revenue	20
Education/Training/Mentoring/Studies	19
Working conditions/environment	11
Acquire new skills/knowledge/expertise/experience	8
Better opportunities/Greener pastures/Better prospects for the future	8

Funding	8
Resources/Equipment/Facilities/Infrastructures	8
Health care/Social amenities/quality of life/Family/General Infrastructures	7
Return to home/Help (home) country/Homesickness	5
Second Reason	N
Academic reasons	26
Career prospects/Advancement of career/Job opportunities/Job security	13
Salary/Income/Revenue	12
Social welfare and state provision (Education/healthcare/family security/quality of life/infrastructure country)	9
Career opportunities (Employment prospects/working conditions/mobility)	8
Institutional reasons (Administration/bureaucracy/efficiency/corruption/infrastructure institution)	6
Funding	5
Resources/Equipment/Facilities/Infrastructures	5
Acquire new skills/knowledge/expertise/experience/development	3
Insecurity/Crime/War/Instability	3
Third Reason	N
Funding	10
Career prospects/Advancement of career/Job opportunities/Job security	6
Resources/Equipment/Facilities/Infrastructures	5
Salary/Income/Revenue	5
Health care/Social amenities/quality of life/Family/General Infrastructures	4
working conditions/environment	4
Administration/Bureaucracy/System/Corruption/General governance/Research policy	3
Education/Training/Mentoring/Studies	3

These results (Table 6-6) also show that respondents perceived career opportunities, academic reasons, further studies, salary/remuneration, institutional reasons and funding as the main reasons for leaving the country where they work.

Table 6-7: Reasons for leaving the country where one works

First Reason	N	%
Career opportunities (Employment prospects/working conditions /mobility)	55	35.5
Further studies/training/acquire new skills/expertise/experience	28	18.1
Salary/remuneration	20	12.9
Academic reasons (Freedom/Collaboration/mentoring and support/recognition /conferences/visibility/impact)	13	8.4
Institutional reasons (Administration/bureaucracy/efficiency/corruption/infrastructure institution)	8	5.2
Funding	8	5.2
Social welfare and state provision (Education/healthcare/family security/quality of life/infrastructure country)	7	4.5
Return to home country (Contract expire /homesick/limited opportunities)	7	4.5
Personal security (crime/war/instability/fear for the wellbeing of self and family)	3	1.9
Second Reason	N	
Academic reasons (Freedom/Collaboration/mentoring and support/recognition /conferences/visibility/impact)	28	26.4
Career opportunities (Employment prospects/working conditions /mobility)	22	20.8
Salary/remuneration	12	11.3
Institutional reasons (Administration/bureaucracy/efficiency/corruption/infrastructure institution)	11	10.4
Social welfare and state provision (Education/healthcare/family security/quality of life/infrastructure country)	9	8.5
Further studies/training/acquire new skills/expertise/experience	6	5.7
Funding	5	4.7
Personal security (crime/war/instability/fear for the wellbeing of self and family)	3	2.8
Political/social/economic climate of country and/or institution (Protests/weak currency & economy/limited market/barrier	3	2.8
Third Reason	N	
Career opportunities (Employment prospects/working conditions /mobility)	12	20.3
Funding	10	16.9
Institutional reasons (Administration/bureaucracy/efficiency/corruption/infrastructure institution)	8	13.6
Academic reasons (Freedom/Collaboration/mentoring and support/recognition /conferences/visibility/impact)	6	10.2
Salary/remuneration	5	8.5
Further studies/training/acquire new skills/expertise/experience	5	8.5
Social welfare and state provision (Education/healthcare/family security/quality of life/infrastructure country)	4	6.8

6.5.11 Lack of mobility opportunities

A large proportion of respondents indicated that they did not have an opportunity to study/work abroad in the preceding three years by the time of the survey. Respondents were asked to report on what extent (that is, 'not at all'; 'to some extent'; or 'to a large extent') a lack of mobility opportunities had a negative impact on their careers as academics or scientists. The results show that the highest percentage of respondents indicated that a lack of mobility opportunities to some extent (40%) negatively impacted their careers as academics or scientists, followed by 33% who indicated that lack of mobility to a large extent negatively impacted on their careers. Only about 27% of the respondents indicated that a lack of mobility opportunities negatively impacted their careers as academics or scientists.

For comparisons between the different sub-groups of respondents, I created a binary variable consisting of two categories ('not at all' and 'at least to some extent') by collapsing response categories (combining 'to some extent' and 'to a large extent' to form 'at least to some extent'). A large proportion of respondents reported that a lack of mobility opportunities at least to some extent (73%) impacted negatively on their careers.

6.5.11.1 Lack of mobility opportunities, by age categories

A comparison between respondents in different age categories in terms of their perceived negative impact of lack of mobility opportunities show (Figure 6-23) show minimal differences. Large proportions across all age categories indicated that lack of mobility opportunities at least to some extent negatively impacted on their careers 39 or younger (70.5%); 40-50 (74.7%); and older than 50 (72.7%).

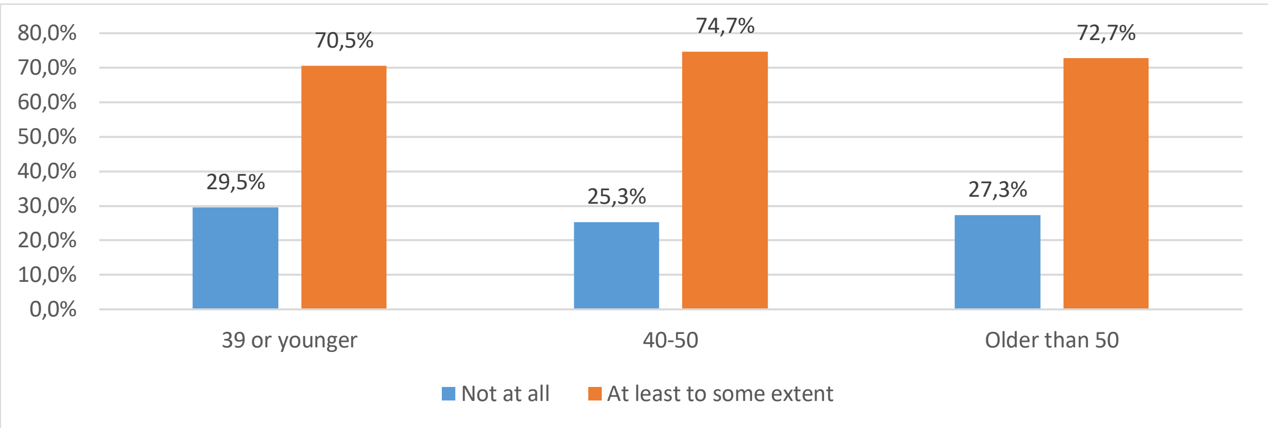

Figure 6-23: Lack of mobility opportunities by age categories

6.5.11.2 Lack of mobility opportunities, by scientific field

A comparison between respondents in various scientific fields in terms of how the lack of mobility opportunity negatively impacted the careers reveal some differences (Table 6.8). The most noteworthy result is that a lack of mobility opportunities had the least negative impact on the careers of scientists in the engineering and applied technologies (33.3%) and social sciences (30%). Surprisingly, the highest proportion of respondents who indicated that the lack of mobility had some negative impact on their careers are the scholars in the humanities. Similarly, scientists in the natural sciences, agricultural sciences and health sciences reported that a lack of mobility opportunities had some negative impact on their careers. Perhaps, the access of research resources and facilities, as well as research networks, could explain the higher proportions of respondents in these fields, that indicated that the lack of mobility of opportunities.

Table 6-8: Lack of mobility by scientific field

The negative impact of lack of mobility opportunities		Scientific field						Total
		Natural sciences	Agricultural sciences	Engineering and applied technologies	Health sciences	Humanities	Social sciences	
Not at all	N	14	10	6	12	1	12	55
	%	28,0%	25,6%	33,3%	25,0%	11,1%	30,0%	27,0%
At least to some extent	N	36	29	12	36	8	28	149
	%	72,0%	74,4%	66,7%	75,0%	88,9%	70,0%	73,0%

During the interviews, respondents were asked to expound on the challenges they face in accessing mobility opportunities. Several interviewees stated that they have challenges in attending international conferences mainly as a result of funding constraints.

> There are limited opportunities, like when there is even a conference somewhere, the universities have little funding to fund lecturers to move out and to gain some new knowledge. So, the first question you asked, what is the university going to gain, what is going to come in? So sometimes missing an opportunity to sit in a conference elsewhere, sometimes very difficult to get that opportunity … if you want to present a paper somewhere you might just have to fund yourself. Occasionally the university has sponsored people to present their papers. The question is very occasional because they claim that the government does not give adequate funding to do so … We do apply to attend conferences even outside the country, but you are told, we can't fund the air tickets, but we only give you, but then at the [unclear]. So, funding the air tickets, you know that is almost three quarters the cost. So, it brings a challenge … So, you find that for you to get much more information from other colleagues from conferences, for me sometimes it's difficult (40-year-old male respondent from Kenya, R_078).

> The funding which we have from our own institutions is not that much because remember, we are in the government arm and sometimes the government arm has limited to such kind of funding. The only way for you to attend to such conferences is when you have a grant on your own or you have a grant that is granted by the institute, so you get some amount from a grant … to meet your expenses … those expenses especially from my country, they are so much limited, the number of conferences you attend. You have to specify … only one conference, not all that you can attend … So, you have to calculate your mathematics well to see which of the many conferences will you attend (35-year-old male respondent from Kenya, R_073).

Apart from funding, interviewees feel that limited opportunities to travel abroad and acquire skills and knowledge in other research centres also inhibit mobility.

> Back home, you see, for example, if you needed to go and… You wanted to go to a different centre you basically… do not have support for even something as basic as transport. I would have really wished to go to a different centre and learn more … That opportunity is not there (32-year-old male respondent from Kenya, R_192).

6.5.12 Summary and Conclusions

The results in this chapter show that a considerable proportion of respondents were mobile in the preceding three years. The analysis revealed that scientists in all age groups and scientific fields consider studying/working abroad beneficial to their careers. A further disaggregation by age shows that a larger group of younger scientists had mobility opportunities in the preceding three years, however, this is a small proportion compared to the majority who lack mobility opportunities. The individual scientists who had the opportunity to study/work/travel abroad stated several benefits which include acquiring research networks, training in research proposal and funding applications, access to research facilities/equipment, publishing opportunities among others. For the respondents who were non-mobile stated their challenges that are related to the lack of information about the mobility opportunities as well as funding challenges. In some instances, scientists are not to travel for conferences or training because their local institutions or the government is not able to fund international travels. The lack of mobility opportunities was reported to have the most negative impact on the careers of scientists in the humanities, health sciences, agricultural sciences and natural sciences. This could be attributed to the research networks, training opportunities and access to 'state-of-art' equipment that is needed for research in these fields.

This chapter also shows that respondents have several reasons why they often or sometimes consider leaving the country they currently work or reside. The main reasons reported include career opportunities, salary/remuneration, academic reasons, further studies, funding, institutional reasons and social welfare and state provision.

Section three: Lack of mentoring and support

6.6 Introduction

In the previous section, respondents hinted how mentoring opportunities are perceived as vital for their skill and career development. This was in relation to the mentoring opportunities that are available to mobile scientists who had studied/worked abroad. In the African Young Scientists Survey, respondents were asked to indicate if during their careers they had received mentoring, support or training in the following aspects: career decisions, introduction to research networks, attaining a position/job, research methodology, fundraising, scientific writing, presenting research results. Respondents were asked to indicate whether they never received or had received mentoring, support and training and, and whether it had been valuable. In addition, respondents were asked to report on how a lack of mentoring and support have negatively impacted their careers as academics or scientists. Apart from lack of mentoring opportunities, other challenges likely to have a negative impact on career development included the lack of the following different aspects research funding, training opportunities, access to library resources, limitation of academic freedom, funding for research equipment, balancing work and family demand, job security and political instability or war.

Recent studies in the literature identified various factors that determine the success of science or academic careers (Jungbauer-Gans & Gross, 2013; Van Balen, Van Arensbergen, Van der Weijden & Van den Besselaar, 2012). These include, individual factors (family situation, family background); organisational or structural factors (availability of research funding, research equipment and resources, incentive structures, mentoring, social capital or networks available, career development system career policies of the universities); contextual factors (labour-market related fluctuations) and academic/research performance (Jungbauer-Gans and Gross, 2013; Van Balen *et al.*, 2012). Previous studies reveal that mentoring support and access to social capital or networks have a greater impact on the careers of scientists and academics. Unlike the strong impact of mentorship and networking on the success of science careers, research performance (measured by the number of publications and citations) did not seem to impact on the success of academic or science careers (Van Balen *et al.*, 2012). In other words, high research performance doesn't necessarily determine the possibility of academics or scientists staying or leaving their careers. Overall, the study concludes that scientific or "academic careers of talented researchers are stimulated … or inhibited … by an accumulation of advantages or disadvantages, including … coincidences" (Van Balen *et al.*, 2012: 331). A recent study by Friesenhahn and Beaudry (2014) identified several challenges faced by early career scientists, including those in African nations. In their study, the authors revealed that 'mentoring and support' is considered to be important for individuals in their early phases of their careers around the global, including those in African countries (Friesenhahn & Beaudry, 2014: 57).

6.7 Factors that negatively impact science or academic careers

The results (Figure 6-23) show that the factors associated with "funding issues" (research funding and research equipment) were identified by respondents as having the most negative impact on their careers as academics or scientists. Conversely, the factors associated with more "political concerns" (limitations of academic freedom, political instability or war) were identified by a smaller proportion of the sample (3-6%) as affecting their science or academic careers negatively. Most of the respondents indicated that balancing work and family demands to some extent influences their career. About a quarter of respondents have identified factors associated with their careers or professional development (training opportunities to develop professional skills, mentoring and support) as having had a negative effect on their careers. Lastly, one in ten of the respondents identified access to library and/or information sources negatively impacts their career as scientists.

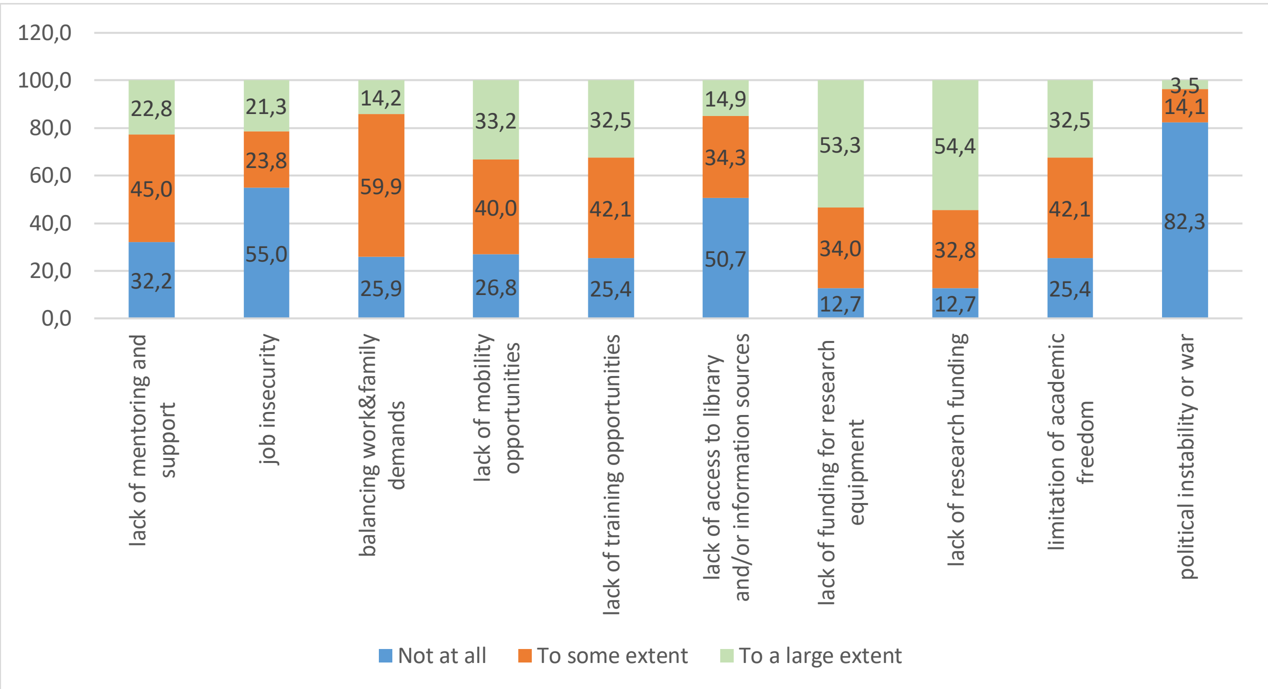

Figure 6-24: Factors that negatively impact the career of an academic or scientist.

Source: CREST, (2016).

Disaggregation of career challenges, by age category

As discussed above, most respondents (75-80%) identified political concerns (limitations of academic freedom, political instability/war) having the least negative effect on their science careers. Disaggregation by age (Figure 6-24) shows a similar trend as higher proportions of respondents in all the age categories (39 or younger (77%); 40-50 (86%); older than 50 (83%)) indicated that political concerns had the least negative impact on their careers. Conversely, small proportions of respondents across all the age categories indicated that political concerns at least to some extent negatively impacted their careers. Furthermore, higher proportions of respondents in all age categories ('39 or younger'; '40-50' and; 'older than 50') consider lack of research funding and lack of funding for research equipment as the greatest challenges to their careers as scientists or academics. A lack of training opportunities to develop professional skills and a lack of mentoring support was also mentioned by a substantial proportion of younger respondents and those between 40 and 50 as the other main challenges to their science and academic careers.

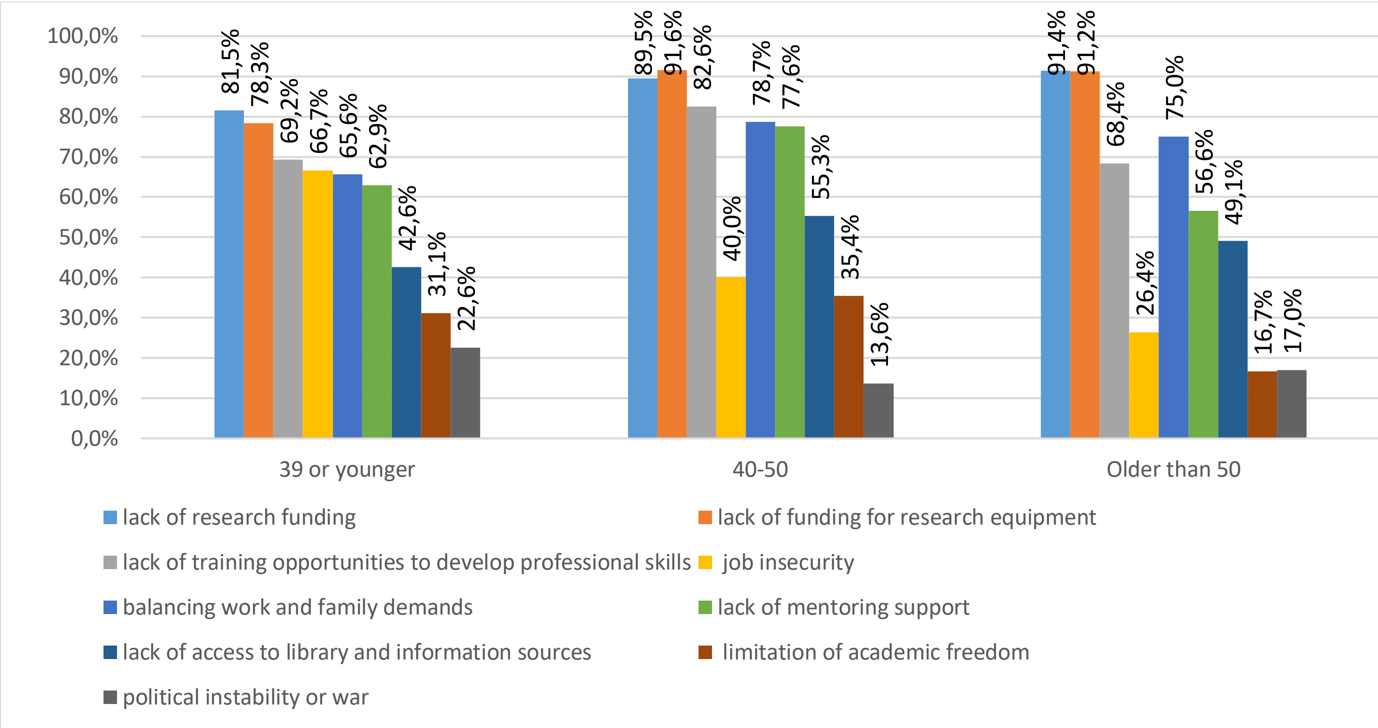

Figure 6-25: Disaggregation of career challenges by age category. Source: CREST, (2016).

6.8 Mentoring received during the career

The results presented (Figure 6-25) here concerns the respondents' mentoring, training and support received during their science and academic careers. The results show, factors associated with research work (research methodology (68.2%), scientific writing (61%), presenting research results (58.6%) and introduction to research networks) were identified by most of the respondents as the main valuable support and training received during their careers. Conversely, a substantial proportion of scientists reported that they never or rarely received valuable mentoring, support and training associated with career-related decisions (55.3%) and fundraising (49.8%). Generally, very few respondents indicated that of the mentoring, training and support they received for the different factors during their careers was not valuable. Most of the respondents indicated they never or rarely received mentoring or support for career-related decisions.

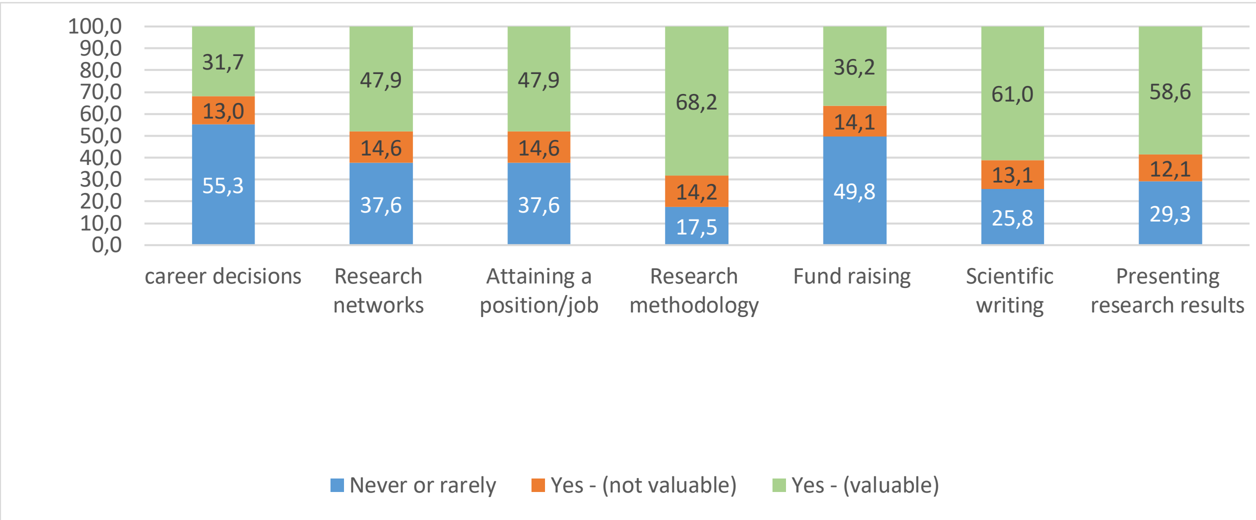

Figure 6-26: Proportions of respondents who indicated they have (or never) received mentoring, support and training. Source: CREST, (2016).

Mentoring received during career by age category

The results (Figure 6-26) below are for the respondents who indicate they received mentoring and support in the different and it was valuable thereof (they selected 'yes and it was valuable') disaggregated by age.

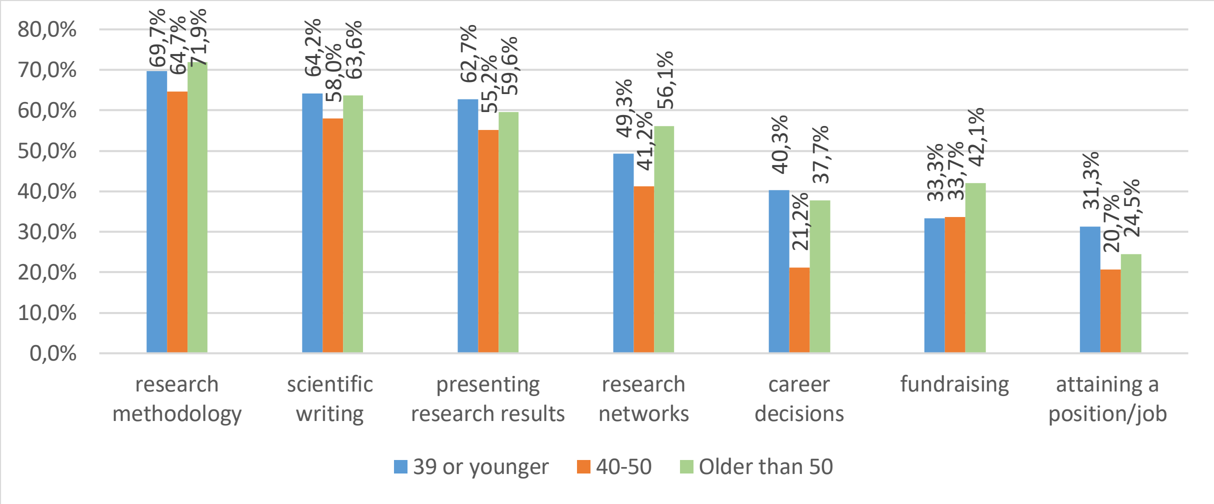

Figure 6-27: Mentoring received during career by age category. Source: CREST, (2016).

The disaggregation by age shows expected results. A higher proportion of the younger respondents identified the research-related factors (research methodology, scientific writing and presenting research results) as the main valuable support and training they received during their science and academic careers. Similarly, respondents between 40 and 50 and those older than 50 identified these research-related factors as the valuable support received during their careers. In addition, higher proportions of respondents older than 50 indicated research networks and fundraising as valuable support received during their careers.

Fundraising

During the interview's respondents were asked to expound on the mentoring, support and training they received in their careers as scientists and academics. In relation to fundraising, respondents indicated they needed to know how to make applications for research grants. Therefore, interviewees desired to receive mentoring, support and training in fundraising from their institutions.

The other areas I'm doing quite well, but this mentorship for fundraising, I think I have an issue there. I need very good mentorship in that area to be able to perform, yes. That is an area where I need good mentorship… (40-year-old male respondent from Kenya_R_078). Despite the desire for mentoring and training on fundraising, interviewees indicated that they are faced with the challenges of a lack of or few mentors who can mentor them on fundraising and help to identify funding opportunities. This challenge is especially experienced by young scientists in fields that are not well established in the institutions.

When I look at my example, I was the first one to complete a master's in applied mathematics … in my university. And you find that those who are there, there is no mentoring initiative, a hint of what do you do after that. Of just there being in that position Did they know something, did they know any funding opportunity, is there anything else you can do? (32-year-old male respondent from Kenya_R-192). Interviewees consider seeking mentoring and training opportunities, especially, in fundraising outside the country. However, they feel that there are limited training opportunities for fundraising.

I think getting a mentor if I got a mentor like outside the country, somebody who I can work with … but if getting in touch with a mentor who can mentally show you the way, give you direction on one or two aspects until you grow … I was trying to see if I could attend the African Doctoral Academy, but I don't see them talking much about fundraising. I think they talk about other aspects of research and not the aspects of fundraising and mentorship. They have not talked about it. I have interests in applying there (40-year-old male respondent from Kenya, R_078). In relation to career decisions, some interviewees indicated a lack of mentoring and support during the early stages of the careers as scientists, especially after the completion of doctoral training. This was attributed to the limited number of experienced senior staff at the institutions or departments that could come up with mentoring initiatives.

> When I got posted into the university where I teach, it was like I came to … a new department. And so, I needed to be mentored because I had just gotten my doctorate, but here I am now where there's nobody to mentor me. I was like the second senior-most scholar in that department because we are beginning that department. So, I felt I needed mentorship to grow, but there I got myself with nobody to mentor me in that area (40-year-old male respondent from Kenya, R_078)

In relation to training opportunities to develop professional skills, interviewees indicated that inasmuch as mentoring is important for skill development, they were more likely to gain knowledge and training in specific fields/disciplines through own initiatives than through mentoring initiatives.

> So, people who are well backed in that skill to… In order to pick you, I mean, we don't have enough of that … The procedures I know in haematology I basically struggled to learn them by myself… in Africa, you ask many young people like me. They will tell you that most learning is more self-driven than learning of the mentorship, the provision, but it's sometimes very, very key at that stage of the development (35-year-old male respondent from Kenya _ R_ 189).

In relation to mentoring in research, methodology interviewees were of the perception that they had received support in research techniques which was valuable, however, these opportunities were limited.

> When I finished my master's, I had a chance to attend a short training on various molecular techniques and especially in terms of research. I would really say maybe that's kind of a

> mentoring course with that … And I was thinking that if there were more opportunities like those, I think it will be able to bring more people into research other than just the lecturing of the… (33-year-old male respondent from Kenya, R_186).

Apart from the mentoring and support received in career-related factors and research-related factors, interviewees were of the view that they needed training and support in relation to university-industry linkages.

> I think, all through my research, I think it would have been good if I had a better understanding of how to work with industry, maybe how to take ideas to research to actual development to things that people use, as opposed to it just being an academic exercise. I think being tenured that is now more important now because I don't think we always have the luxury of just doing research for its own sake (33-year-old male respondent from Kenya, R_072).

Given the desire for mentoring and support, interviewees suggested the use of forums that will enable them to access mentoring opportunities for skill development.

> …if they can have some kind of a forum whereby anybody who is interested in a given skill can apply and then they are taken through those skills, I know there are forums like that but they are limited, that is the only way we can promote what we call the skills and professional skills among the young people… (35-year-old male respondent from Kenya, R_073)

Apart from the information on the mentoring and support received, respondents were also asked to indicate how a lack of mentoring and support has negatively impacted on their science and academic careers.

6.9 Impact of lack of mentoring and support on career

In the YSA survey, respondents were asked to report to what extent ('not at all'; 'to some extent' or 'to a large extent') a lack of mentoring support have negatively impacted their careers as academics or scientists. For comparisons between various sub-groups of respondents, I created a binary variable with two response categories 1) 'not at all' and; 2) 'at least to some extent' (created by combining the 'to some extent' and 'to a large extent').

The results show that nearly two-thirds of respondents (67%) indicated that a lack of mentoring opportunity negatively impacted their careers as academics or scientists. Disaggregation by age shows that a larger proportion of respondents between 40 and 50 followed by the younger scientists indicated that a lack of mentoring support had a negative impact on their careers (Figure 6.). Further disaggregation of the scientific fields shows that large proportions of respondents in the natural and health sciences reported that a lack of mentoring and support had some negative impacts on their careers as scientists or academics (Figure 6.27).

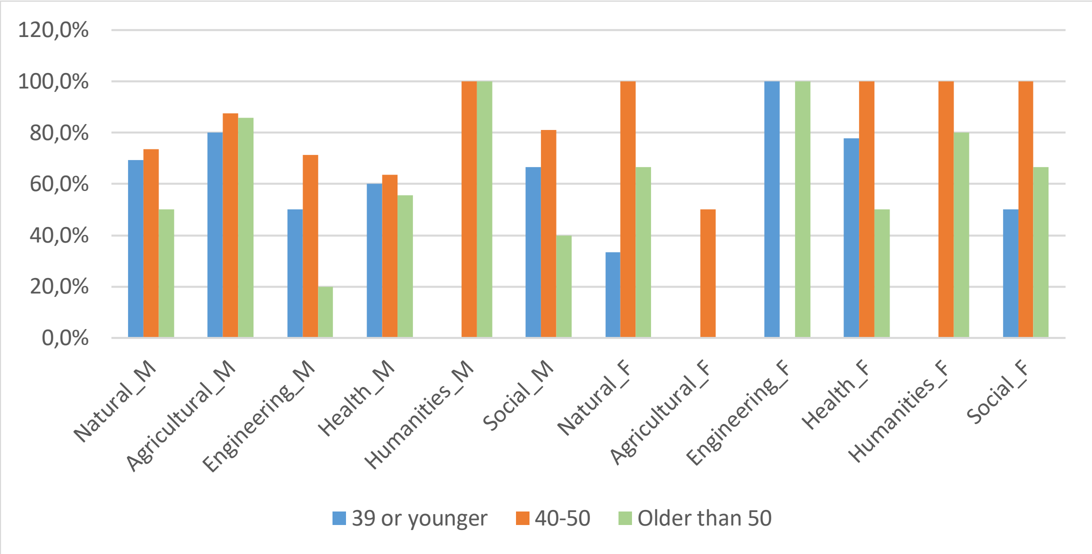

Figure 6-28: Lack of mentoring and support to at least some extent, by age, field and gender

Expounding on the issue of a lack of mentoring and support, interviewees indicated that experienced and skilled scientists who could offer mentorship and training often lack time to mentor young scientists.

> Somebody is well-skilled, but she doesn't have time to mentor the young scientist. This is a big challenge, not only in Kenya, I've experienced it in another East African country, I also experienced it in another South[ern] African country, that you do not have mentors, people who can show you something from the beginning to the very end as it is and if we can have this kind of skills, especially for the people who are research scientists (35-year-old male respondent from Kenya, R_073).

In some instances, mentoring and support are offered, however, it is insufficient, and the mentors are often over-burdened. This is attributed to a few established researchers in some fields in the institutions available to mentor a large number of young scientists.

I have one mentor, but he’s one against many people who want to learn … So, people who are well backed in that skill to… In order to pick you, I mean, we don’t have enough of that (35-year-old-male respondent from Kenya, R_189). Interviewees stated that institutions lack a clear mentoring system for the established scientists to mentor young scientists especially on how to conduct research.

[For] most of the senior people in research, there isn’t a clear system on how to mentor, especially the young and when you come to research. There isn’t a very clear-cut system you can say that this is how

… If you're interested in research, these are supposed to be your mentors, or these are the people we suggest you be working with and they guide you … So there isn't a clear-cut mechanism on how to mentor people in research. I won't really say there is (33-year-old male respondent from Kenya, R_186). There was a perception among some interviewees that the international mentors were more supportive in research-related matters as well as psychologically than the local mentors. The interviewees noted that there are huge boundaries between the local mentors and the young scientists/doctoral students, which is a hindrance to the mentoring process.

Over and above the technical [mentorship], demanding for the proposal from me, continuously demanding the publications, continuously demanding the thesis from me … You also need the psychological support … So, I think he was very supportive. But I think it's a culture he brought from out [of the country] because that's not typical of a Kenyan professor … There's a big gap between a professor here and a PhD student. The interviewees further indicated that the lack of mentoring in research has resulted in most of the scientists focusing more on teaching than research.

The challenge is you find that a lot of the lecturers, they get more immersed into teaching other than combining both teaching and research. But only that maybe they didn't have someone to mentor them so that they can get into research (33-year-old male respondent from Kenya, R_186).Similarly, apart from the survey and interview information on lack of mentoring and support, respondents and interviewees were asked to report on the negative impact of lack of training opportunities to develop professional skills on their science careers. The results are presented and discussed below.

6.10 Impact of lack of training opportunities to develop professional skills

In the survey, respondents were asked to report on to what extent ('not at all'; 'to some extent' or 'to a large extent') a lack of mentoring support have negatively impacted their careers as academics or scientists. Similarly, for comparisons between various sub-groups of respondents, I created a binary variable that had two response categories (1) 'not at all' and; (2) 'at least to some extent' (created by combining the 'to some extent' and 'to a large extent').

The results show that nearly three quarters (75%) of the respondents in the entire sample indicated that a lack of training opportunities to develop professional skills had negative impacts on their career. The disaggregation by age shows that a larger proportion of respondents between 40 and 50 (82.6%) followed by the younger scientists (69.2%) indicated that a lack of training opportunities impacts negatively on their careers as academics or scientists (Figure 6-28). A further disaggregation by scientific field (Table 6-7 and Figure 6-28) shows that a higher proportion of respondents in the humanities, natural and health sciences indicated that a lack of training opportunities to develop professional skills at least to some extent had negative impacts on their careers as academics or scientists.

Table 6.7: Lack of training opportunities to develop professional skills by scientific field

		Scientific field						
		Natural sciences	Agricultural sciences	Engineering and applied technologies	Health sciences	Humanities	Social sciences	Total
Not at all	N	11	11	10	9	1	11	53
	%	20,8%	27,5%	55,6%	18,8%	11,1%	26,8%	25,4%
At least to some extent	N	42	29	8	39	8	30	156
	%	79,2%	72,5%	44,4%	81,3%	88,9%	73,2%	74,6%
Total	N	53	40	18	48	9	41	209
	%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

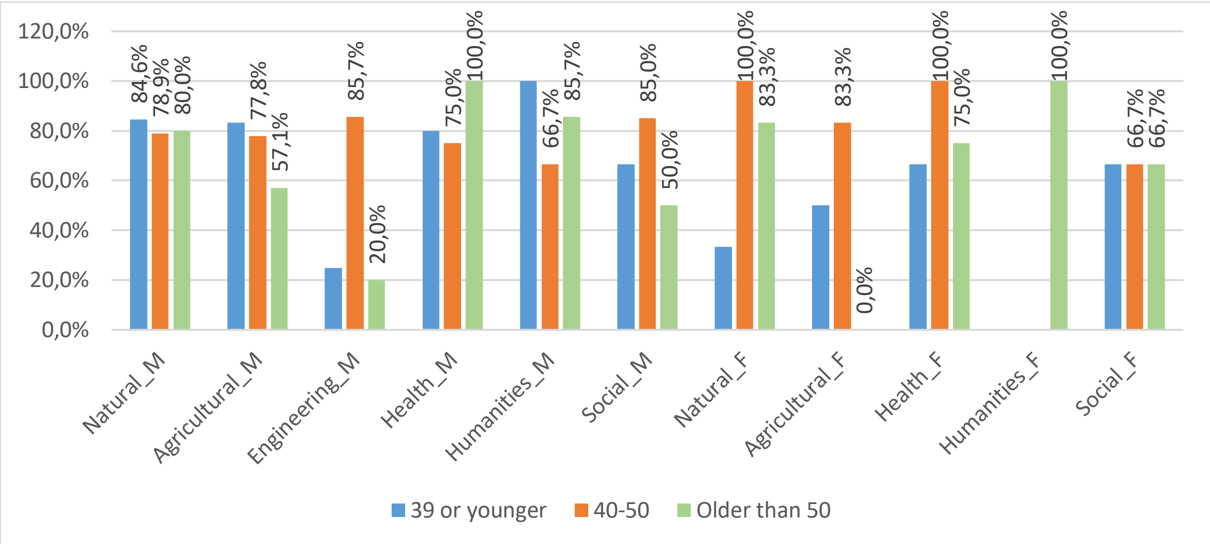

Figure 6-29: Lack of training opportunities to develop professional skills by age, gender and field. Source: CREST, (2016).

Qualitative interviews show that scientist struggle to find training opportunities to develop professional skills in their specific scientific fields in their own countries, thus they consider looking for such opportunities out of the country.

> some of the things which you would like to pursue, you may not find somebody who has those skills and experience … So, when you are looking for an opportunity, for example, who will train me on this, sometimes within the country you may not find one and therefore you are supposed

> to look for such opportunities out of your country (35-year-old male respondent from Kenya, R_073).

In addition, from a different perspective, interviewees were of the perception that there was a lack of training opportunities in skills, for the scientists but also specifically available for their students.

> How I will wish that you can find such opportunities floating like low-lying fruit so that you can pick them and move on. So, another, lack of training opportunities, I look that it's from this direction … for example, I'm a doctor and I have students who are pursuing epidemiological studies, myself, I may have not had those skills or I may supervise the students who are looking for a certain skill which I may not have …So, getting opportunities for them to particularly train on that skill that they are interested in … hands-on training, so sometimes it comes hard ((35-year-old male respondent from Kenya, R_073).

Interviewees noted a lack of training opportunities to develop skills, especially in the industry. Therefore, the suggestions that such opportunities are needed to ensure academia-industry linkages.

> And I think training is literally not there. Okay, there are managerial trainings just to understand the system and so on. But now in terms of maybe taking some time to be out to really meet the industry and really appreciate some of the challenges that are happening to the industry, such opportunities aren't there. The academia and industry linkages are still not strong (40-year-old male respondent from Kenya, R_077.

6.11 Conclusion

The country acknowledges the need to increase these numbers required for research and development in the country if they have to achieve their goal of becoming a middle-income country by 2030. These initiatives are seen in the targets to increase doctoral graduates per annum and the number of academics in the universities who will train more researchers and engage in research. when compared to the countries in the East African region (Tanzania, Uganda, Ethiopia, Rwanda and Burundi) in absolute numbers, Kenya recorded the highest number of researchers per million inhabitants (headcount). While Kenya has a high number of researchers in absolute terms in the East African regions, her neighbours Tanzania, Uganda and Rwanda record the same share of female researchers. when Kenya is compared with other countries that are key contributors to African science, South Africa has twice as many full-time equivalent researchers per million inhabitants.

The results show that, factors associated with research work research methodology, presentation of results, scientific writing and introduction to networks were identified as the main support and training received and which were valuable thereof. For most of the respondents, mentoring and support were never or rarely offered for career-related decisions and fundraising. In the cases where lack of mentoring and support as well as a lack of training opportunities was mentioned as a challenge, a larger proportion of respondents in engineering and applied technology (STEM) indicated to have faced this challenge than their peers in the social sciences and humanities. The scientists in the fields of engineering indicated the need for mentoring and training opportunities to develop skills in the industry, thus emphasising the importance of academia-industry linkages.

According to the results, young scientists in the early stages of their careers identified several needs that would be useful for their careers and skill development. These include guidance on fundraising, preparation on how to conduct research and publish, guidance on teaching-related activities, introduction to academia-industry linkages. However, younger scientists are faced with several challenges in receiving mentoring and support in these areas, including, few established scientists who can act as mentors, the available mentors are often too busy and overburdened given a large number of young scientists in need of mentoring. Given the challenges of a lack of mentoring and training opportunities, respondents suggested the need for information on available opportunities and the availability of forums that can offer scientists the skills and mentoring needed by the young scientists.

Chapter 7 Publication Output

7.1 Introduction

In this chapter, I assess the trends in the publication output of Kenya's science system. To address this objective, this chapter addresses the following research questions:

1. What is the publication output for Kenya?
2. What is Kenya's publication output by field?
3. What is the relative field strength of Kenya's publication output?
4. What are the main scientific institutions that produce Kenya's science?
5. What are the factors that enable or constraint research production?

To address the following research questions, this chapter starts with a literature review on research production, covering the following aspects: the definition and measurement of research production, skewness in research production, reasons for skewness in research production, evaluative studies on research production and factors that influence research production. Subsequently, the chapter presents the bibliometric indicators on research production: Kenya's scientific publication output, scientific output by field, scientific output by research institutions and relative field strength.

Subsequently, the chapter presents the reported volume of scientific output. Several studies I reviewed (Cole, 1979; Cole & Zuckerman, 1984; Dundar & Lewis, 1998; Kyvik & Teigen, 1996; Larivière *et al.*, 2011; Long, 1978; Merton, 1968; Piro, Aksnes & Rorstad, 2013; Smeby & Try, 2005; Zuckerman, 1967) suggest that scientific output is determined by several factors: age, gender, scientific filed, academic rank, research funding and resources, collaboration networks, departmental prestige and size and the teaching load. Following this review, this study analyses the relationship between age, gender, academic rank, scientific output and scientific output. I also present data on the enablers and constraints of scientific production, especially in the context of increased demand to publish. This also includes analysing the consequences of the demand for publishing and the suggestions by scientists on the support and mentoring that can support scientific production. I later provide a detailed discussion on scientific production, integrating the literature review, bibliometric data, survey data, and interview data. Finally, I provide the summary and conclusions of the findings on research production.

7.2 Research production: Definition and measurement

This section provides a discussion on research production and its theoretical underpinnings. According to Sugimoto and Larivière (2018:53), "research production is defined as the amount of scientific output of various research units" in a science system. The scientific output comprises publications categorised into a large number of document types: articles, letters, editorials, review articles, conference papers, book chapters, books, among others (Vinkler, 2010). Publications such as articles are mostly assigned to the journals in which they are published (Pendlebury, 2008). Importantly, Research production as an indicator of research performance is a measure of output, rather than quality.

As already highlighted, the distinction between research production and research productivity is important. Research productivity accounts for the inputs in the research system. For instance, the research productivity of a given unit - department, institution, country – "could be measured by dividing the number of articles it published by the amount of external research funding it has obtained, or the number of researchers in the unit" (Sugimoto & Larivière, 2018: 57). It can be deduced that research production focuses on the outputs, while research productivity focuses on the ratio of outputs and inputs. Given the distinction between research production and research productivity, it is important to measure the research produced by the research units[15] in a given research system.

The existing literature has identified two dominant methods of measuring research production: 1) full counting method and 2) fractional counting method (Gauffriau & Larsen, 2005; Gaffriau , 2008; Huang, Lin & Chen, 2011; Sugimoto and Larivière, 2018; Wouters, Thelwal, Kousha, Waltman, de Rijcke, Rushforth, & Franssen, 2015). Full counting is the first approach. The full counting method attributes full credits or counts to the collaborating individual, institution or country (Huang *et a*l., 2011; Sugimoto & Larivière, 2018; Wouter *et al*., 2015). The full counting approach is represented by two counting methods: "whole counting method" and "complete counting method" (Gauffriau et al., 2008: 149). In in the case of "the whole counting," all the "unique" basic research units or countries (in the cases of country-level assessment) get one credit. While in the case of complete counting all the countries, receive one credit (Gauffriau *et al.,* 2008: 149). Following the above description, Huang *et al.* (2011) illustrated an example to distinguish between whole counting and complete counting: In a country-level research assessment, a paper to be counted has four institutions from three countries collaborating, two from the United States of America, one from Germany and one from Japan. The observers indicate that, in the case of the whole counting, each of the three collaborating countries will be allocated one credit. Whereas in the case of complete counting, the United States of America will be allocated two credits, and Japan and Germany each allocated one credit.

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[15] Research unit here refers to individual author, department, institution, or country.

Inasmuch as the full counting method is dominantly used in bibliometric analysis given its simplicity (Sugimoto and Larivière, 2018), some criticisms against full counting have been identified in the literature. First, full counting results in "inflationary effects" to the real output of the research units. In other words, the total output always exceeds the actual number of articles published by a group of scientists or any other research unit. Thus, full counting thus results in an overestimation of research produced by each research unit or individual (Wouter et al., 2015). Second, the full counting method may also result in "unethical authorship practices" (Sugimoto and Larivière, 2018:54). This is the case in "honorific authorship" which entail placing honorary authors on the byline, an act that results to no added costs to the co-authors (Persson & Glänzel, 2014:1417). Third, full counting may result in invalid comparisons between fields, even in the cases where normalised indicators are used in the analysis (Wouters *et al.,* 2015). These criticisms have been considered undesirable, thus, other alternative approaches such as fractional counting to deal with multi-authorship/co-authorship have been suggested in the literature.

Fractional counting is the second approach used in measuring research production. In fractional counting, all the collaborators share one credit (Huang *et al*., 2011; Sugimoto & Larivière, 2018:55). Scholars identified two counting methods in the fractional approach: whole-normalised counting and complete-normalised counting (Huang *et al.,* 2011). In the case of "whole-normalized counting", all unique collaborating units share one credit, whereas, in the case of "complete-normalized counting", all of the collaborating units share one credit (Gauffriau *et al*., 2018:149). To differentiate between these two methods, authors use an example at a country-level research assessment: where a paper to be counted has four institutions from three countries collaborating, that is, the United States, Germany and Japan. In the case of "whole-normalized counting", a third of the credit is allocated to each country. Whereas, in the case of complete-normalised counting, the United States is allocated half of the credit and, Japan and Germany are allocated a fourth of the credit each.

Several advantages of fractional counting are identified in the literature. First, when fractional counting is used, the total number of articles of the research units in the science system is equivalent to the real number in the system (Huang *et al.,* 2011; Sugimoto & Larivière, 2018). However, it is argued that the interpretation of the results from fractional counting can be more difficult. In other words, fractional counting results indicate the proportional contribution of the output; however, it does not indicate the number of papers that were published. Following the difficulties in the interpretation of results of fractional counting, Sugimoto and Larivière suggested a combined use of full counting and fractional counting methods in bibliometric analysis so as to ensure greater insights on both research production and collaboration

(Sugimoto & Larivière, 2018). Furthermore, Wouters *et al.* (2015:21) note that, "full counting and fractional counting measure different concepts (participation vs. contribution) and both provide full information." Therefore, full counting and fractional counting methods can complement each other when used in bibliometric analysis.

Furthermore, both the full and fractional counting methods have been criticised for the assumption that authors have an equal contribution to the production of knowledge (Sugimoto & Larivière, 2018). Given the problems of using full and fractional counting, scholars have suggested the use of "harmonic counting" or "dominant counting" (Sugimoto & Larivière, 2018:55). In "harmonic counting", it is argued that the order of authors on an article is associated with the level of their contribution to the paper. Specifically, in harmonic counting, the first author receives credit for the highest proportion of contribution and the subsequent author gets the proportion of the authorship credited to the first author, and the third author with the proportion of the second author, the fourth author with the share of the third author, etc. In other words, the first author receives the largest share of contribution and the subsequent authors have apportioned the fraction of the preceding author's contribution. Inasmuch as harmonic counting has the advantage of accounting for the "disproportionate contribution" of the authors to a paper or research, the main role played by the last author – mainly the principal investigator and corresponding author to the research – is not accounted for (Sugimoto & Larivière, 2018). It is argued that several bibliometric indicators mainly focus on the first, last and corresponding authors by computing their production. This approach risks promoting the lack of efficient consideration of the contribution of several other key participants in a research unit. Sugimoto and Larivière conclude that harmonic counting that focuses on the main authors does not indicate the sum of the articles produced by a research unit or their share contribution (Sugimoto & Larivière, 2018:55). The use of dominant authors indicates the leadership roles of articles and can only be applicable to the scientific fields that use the "descending order" of author contribution with dominant last authors (Sugimoto & Larivière, 2018:55).

Notably, the above methods of measuring research production discussed have higher correlations at the highest levels of aggregation such as the country level but very largely at the micro-level or individual level. Scholars also observe huge differences across scientific fields when the different methods of measuring scientific production are used (Sugimoto & Larivière, 2018). To illustrate these field differences, Sugimoto and Larivière cited the example of high-energy physics where there can be disproportionate author contribution to the articles published as compared to authors in other scientific fields. High-energy physics articles are also likely to have numerous co-authors. Thus, in a scientific field like high-energy physics, the full counting method over-estimates the total number of articles or citations whereas when the fractional counting method is used, it represents a lower number of articles or citations. In conclusion, given the differences across fields, when analysists are comparing levels of production across fields, field normalisation is essential (Sugimoto & Larivière, 2018). Field normalisations allow bibliometric analysis to compare research production in different fields.

In conclusion, this section defines research production and identifies as the methods used in the measurement of research production. Research production is identified as the scientific output produced by researchers and several research units. This output may include journal articles, book chapters, books, conference proceedings, and letters, among others. Full and fractional counting methods have been identified as the dominant methods in measuring research production. Several limitations about these methods were identified: the overestimation of output produced by research units compared to the actual numbers in the system for the full counting method. Whereas for fractional counting, it is difficult to interpret the results, as well as shows the share of contribution of the authors and not necessarily the sum of the papers produced. Therefore, given these limitations, authors have proposed the combined use of full and fractional counting in the analysis. In the above section, it was signalled that research production is highly skewed. The next section examines the skewness observed in research production.

7.3 Skewness in research production

Studies have shown the huge differences in the scientific output of researchers. In particular, the studies have illustrated that a relatively small proportion of scientists produce the majority of publications. Conversely, a majority of the scientists contribute to the minority of the documents published (Lotka, 1926, Price, 1963). In 1926, Alfred J. Lotka published a pioneering study on the frequency distribution of scientific productivity determined from a decennial index (1907 -1916) of chemical abstracts. Lotka formulated the renowned “inverse square law” of scientific productivity, commonly known as the Lotka’s law. The Lotka’s law is represented by a function $X^n .y = C$ or $Y=c/x^n$ which shows that the total number of authors y in a given subject, each producing x publications, is inversely proportional to some exponential function n of x. In the above equation, x equals the number of publications; y equals the number of authors credited with x publications; n equals constant (equals 2 for scientific subjects) and C equals a constant. Lotka’s law states: “the number of (authors) making n contributions is about $1/n^2$ of those making one; and the proportion of all contributors, that makes a single contribution, is about 60 per cent” (Lotka, 1926: 323). Based on the hypothesis of Lotka’s law, this implies, for instance, that for the authors in a particular field, 60 per cent produce one paper. To emphasise, the skewness in scientists’ output has been exhibited in several datasets and across scientific fields, where, “20% of researchers account for 80% of published documents, and 80% of researchers are associated with 20% of published documents” (see Sugimoto and Larivière, 2018:11). These statements confirm the argument that large numbers of publications of a given research unit are produced by a few numbers of researchers.

Several empirical studies have confirmed the existence of a pattern of high skewness in scientific production (Allison and Stewart, 1974; Cole, 1979; Cole and Zuckerman, 1984). Using cross-section survey data of chemists, physicists and mathematicians, Allison and Stewart found unequal distribution in productivity as researchers’ career age increased (Allison and Stewart, 1974:596). In addition, a study by Reskin (1977) through regression analysis of longitudinal data of chemists, found that the chemists’ distribution of publication supports the argument that a small proportion of scientists produce the majority of publications. The study observed that only 15 percent of the scientists in the sample produced about half of the 2000 papers by these scientists, and barely 40 percent authored a paper in a year (Reskin, 1977). Similarly, Ramsden (1994) studying academics in the Australian higher education illustrated that most papers are produced by few academic staff.

Despite the confirmation of the hypothesis on skewness in productivity, other studies have shown contrary results. Some studies have revealed that, at the individual level of analysis, the differences in publication rate are smaller contrary to Lotka’s assumptions (Potter, 1981). Potter argues that Lotka’s law does not explain why in a specific field, for instance, an individual scientist produces a majority of the published documents, another researcher produces few publications and a third researcher publishes none. According to Potter (1981), individual author productivity is determined by several factors, which can be clustered into two main conceptual areas: the scientist’s personal characteristics (i.e. achievements, intelligence, expectations, personality, etc.) and the researcher’s environment (i.e. colleagues, rank and prestige of department, information availability, the research problem, scientific field/discipline, among others). The interactions between these personal characteristics and environmental characteristics are also fundamental in explaining the differences in the productivity levels amongst scientists (Potter, 1981:13). These factors will be discussed in detail in the later chapters

7.3.1 Reasons for skewness in research production

Consequently, given the above observations, a number of studies have focused on the reasons for the skewness in the distribution and differences in the publication rates and citation rates at the individual level. The skewness in publication rates has been connected to “social dynamics" such as the cumulative advantage and the "Matthew effect" (Merton, 1968:57), the role of incentive structures and more specific factors such as the age, gender, academic position and the educational level of the scientists, as discussed in the later sections of this chapter. The "Matthew effect" proposed by the American Sociologist Robert K. Merton is often used to explain the skewness in scientific output. Merton (1968:57) studied how "the complex psychosocial processes" affects the reward system and scientific communication. And how the "psychosocial processes" influence the allocation of recognition to scientists for their scientific contributions (Merton, 1968:57). Merton observed that recognition was accorded to renowned scientists who already had higher degrees of recognition for their scientific contributions than the less known ones who tended to receive less recognition for their occasionally comparable contributions. Merton found that "this pattern of recognition, skewed in favour of the established scientist, appears principally in cases of collaboration and in cases of multiple discoveries made by scientists of distinctly different ranks" (Merton (1968:57)). Merton referred to this phenomenon as the "Matthew effect"; this is in reference to the Gospel according to St. Matthew: "For unto everyone that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath" (Matthew, NKJV translation). Therefore, it is noted that some degree of recognition is essential in stabilising the career of scientists (Merton, 1968).

Furthermore, apart from the Matthew effect, a "process of accumulative advantage" can also explain the highly skewed distribution of scientific production (Allison and Stewart, 1974: 596). Just like the Matthew effect, the accumulative advantage is linked to the importance of recognition in science. According to Merton (1988:606),

> Cumulative advantage, applied to the domain of science, refers to the social processes through which various kinds of opportunities for scientific inquiry as well as the subsequent symbolic and material rewards for the results that inquiry tend to accumulate for individuals' practitioners of science, as they do also for organizations engaged in scientific work.

From the above quote, I observe that the initial opportunities that scientists have in the research process contribute not only to their ability to be productive but also to the financial and non-financial rewards linked to their output. Merton maintains that the cumulative advantage could be the initial comparative advantage that scientists possess such as previous training, resources available and structural location. Comparative advantages may result in a subsequent increase of advantage, such that the productive scientists continue to be productive and the less productive continue to produce less (Merton, 1988). From these discussions, recognition from previous works may have an influence on scientists' future output.

Scholars have indicated that the reward system based on recognition for contributions to science has three roles (Merton, 1968; Allison & Stewart, 1974). Firstly, recognition induces effort, which plays a key role in validating the conclusion that researchers hold "exceptional capacities" which have continuous potential and allows them to achieve more. Secondly, the recognition accorded to scientists for their achievement by their fellow scientists could be converted to research instruments such as large facilities availed to the recognised scientists for further research (Merton, 1968; Allison & Stewart, 1974). This kind of recognition is what Bourdieu referred to as "scientific capital" (Bourdieu, 2001:55). Bourdieu defines "scientific capital functions as a symbolic capital of recognition that is primarily, sometimes exclusively, valid within the limits of the field (although it can be converted into other kinds of capital, economic capital in particular)" (Bourdieu 2001; 2004:55; cited in Archer, Dawson, DeWitt, Seakins & Wong, 2015:927). Following Bourdieu's definition (Bourdieu, 2001:55), it is valid to deduce that, through recognition, scientists my access resources, funding and networks needed for the research inquiry. Lastly, recognition could have an effect on the esteem of scientists, which has a positive effect on productivity. Esteem may enable researchers to participate in research networks and lead large research groups.

Following the Merton's Matthew effect study and the reward system based on recognition, sociologists Cole and Cole (1973), cited in Crane, 1974:263) investigated "social stratification" of science. Cole and Cole (1973) define social stratification in science as a study of "the processes that determine social inequalities within the scientific community". Upon closer analysis, of the works of Cole and Cole (1973), Crane (1974) addresses the following: what are the factors amongst the researchers that "determine the allocation of symbolic recognition in the form of honours and prizes to individual scientists as well as the allocation of positions in academic departments" (Crane 1974:264)? The author argues that the institution of science is "highly stratified", however, estimates "the idea of meritocracy" where positions in the system are allotted based on a "universalistic idea" (Crane, 1974:264). The study showed that quality (measured by citations) of the publications was associated with the number of prestigious awards received and the visibility of their research to other researchers. The prestige of the department in which the scientist was affiliated was a determinant of quality but not for quantity. Importantly, from the above results, Cole and Cole concluded that the "scientific stratification system is highly universalistic". However, they identified accumulative advantage processes in the scientific system, which implies that earlier achievements in the system result in higher successive achievements (see Crane, 1974:264).

Similarly, Derek de Solla indicated that the accumulative advantage also applies to how scientists receive citations for their previous work (see De Solla Price, 1963). For instance, scientists who have affiliations with prestigious institutions are more likely to receive more citations (even in the cases where there is control for author and document characteristics). In addition, articles in highly reputable journals receive more citations compared to those in journals of lower reputation (even when controlling for confounding factors). Scientists with more citations are more likely to receive more citations than those with fewer citations (de Solla Price, 1963). Science is equated to social activities and processes, where the rich become richer and the poor become poorer. Essentially, scientists with limited scientific or economic capital have a tendency to become poorer.

7.4 Evaluative studies on scientific output in Africa

This section reviews evaluative studies of Africa's scientific output and those that in part analysed the output of Kenya. These studies focused on different levels of analysis: continent (i.e., Africa as a whole), a region (e.g., sub-Sahara Africa), country, institution, department, scientific field or individual researchers.

Garfield (1983) undertook a 'mapping' of science in Africa. In this study, Garfield observed that as of 1973, South Africa and Egypt were the major contributors to Africa's science in terms of scientific publications. The study showed that Kenya was amongst the countries whose authors had published 50 or more articles and the articles produced by the Kenyan authors had an impact of 4.7. Another study by Gaillard *et al.* (1997),[16] looked at "the status of science in Africa". Gaillard *et al.* (1997) examined "the problem of the emergence of scientific communities" in Africa and made efforts to summarise historical trends, analyse the crises of science as a social institution, and explore the main features of science and society (Gaillard *et al.,* 1997: 146).

Tijssen (2007) conducted a comprehensive bibliometric analysis of the "characteristics of African science". In his analysis, Tijssen showed how "Sub-Sahara Africa has fallen behind in its share of world science quite dramatically from 1% in 1987 to 0.7% in 1996 with no sign of recovery" (Tijssen, 2007:303). Tijssen attributed this decline to inadequate resources, poor investment in research and minimal coverage of the 'African science' in the international databases. However, Tijssen (2007:314) stated that these diminishing shares of African science overall do not reflect a decrease in an absolute sense, but rather an increase in publication output less than the worldwide growth rate." In other words, the output for African countries increased, however, their share to world output decreased. Furthermore, the

[16] In the present context of globalisation, only those countries are able to absorb the shocks of economic globalisation and derive benefits from the international flows of knowledge that have so far established national scientific communities and educational structures (Gaillard *et al*. 1997).

analysis of the research specialisation in the study shows that some fields like the medical sciences are internationally oriented and tend to attract international funds, partnerships, and opportunities to publish in the scientific literature. Given this finding, Kenya was the only country, among the "highly developed African countries with a strong concentration of international research within medical and life sciences" (Tijssen, 2007:314). This could be an indication of high international collaboration in the medical and life sciences, as well as, the influence of international organisations such as Wellcome Trust.

Onyancha (2007) conducted a citation analysis of the library and information science literature between the periods of 1986 and 2006. The author used the web of science as data sources. The study showed that Kenya came fifth in publication output with 37 articles after South Africa, Nigeria, Ghana and Botswana.

Pouris and Pouris (2009) undertook a scientometric assessment of the state of science and technology in Africa (2000-2004). Their scientific field analysis shows that few African countries [including Kenya] have the minimum capacity of researchers needed for the proper "functioning of a scientific discipline". Citing an example of the field of ecology, (a discipline crucial for sustainable development) only four countries (South Africa, Egypt, Nigeria and Kenya) produce 300 or more publications between 2000-2004 (Pouris & Pouris, 2009:8). Adams *et al.* (2010), shows similar results. In addition, Uthman and Uthman (2007) noted that research production in African countries including Kenya is highly skewed across the nation and disciplinary fields.

Adam *et al.* (2010) conducted a bibliometric analysis of African research between 1999 and 2008, using the Web of Science database. The analysis reveals that Kenya as the "leading research economy in the east continent" produced just over 6 500 papers, compared to other dominating research producers: South Africa (47, 000), Egypt (30, 000) and Nigeria (10,000).

Recent studies have shown that publications authored by African scientists were slightly on the increase (NPCA, 2010; Mouton & Boshoff, 2010). In addition, a bibliometric analysis of African science also supported the claim that "African science had turned the tide in recent years", indicated by: increase in research publications, increase in research collaborations with the rest of the world and a steady increase in the citation impact of Africa's scientific publication (Mouton & Blanckenberg, 2018:25).

Studies reviewed above-analysed research output specifically by scientific field, institution, nation or region. The studies show that the research output for African countries has been on the increase in the past two decades. Despite the increase, the African share of the world's scientific output remains below average. The next section discusses the factors that determine scientific production. In summary, on analysing research production, we observe that research production is highly skewed. There are several reasons for this phenomenon including age of the author, rewards and recognition and the availability of resources. Several theories such as the Matthew effect and the process of accumulative advantage explain the skewness in research production. Bibliometric studies on Africa are also analysed in this review. We observe from the studies that, over time the output for Africa, in general, has been on the increase at least in the past two decades. However, despite the increase in this output, we observe the African share to the world output remains very low.

Bibliometric indicators

7.5 Research production

In this sub-section, I present and discuss a number of bibliometric indicators related to research production. These are Kenya's overall scientific output, scientific output by field, scientific output by sub-fields, scientific output by research institutions and Kenya's rank in terms of scientific output among all countries in the scientific output. Apart from scientific output, I will present and discuss data on the relative field strength profile for Kenya.

7.5.1 Kenya's production of scientific publications (articles and reviews)

Our analysis of the Kenyan authored papers in the Web of Sciences using the full counting method illustrates that the annual output has been on a steady increase between 1980 and 2015. Kenya's publication output in the Web of Science (full counting) has had an eight-fold increase from 326 publications in 1980 to 2, 619 in 2016. This increase translates into an average annual growth rate of 5.7%. Particularly, the data shows slow growth in the 1980s and steep growth in the 2000s. A much higher increase in the output is observed over the past decade: from 858 papers in 2005 to 2619 papers in 2016 (figure 7.1). Production in Kenya grew by 11% in the period 2005 to 2016 compared with 1.42% in the preceding decade (1994 to 2004). What is important to note is that, in the recent four years, this rate of increase surpassed the world's growth rates from 2013 to the 2016 period (figure 7.1). Figure one shows Kenya's share of world output has more than doubled from 0.06% in 1980 to 0.15% in 2016.

Figure 7-1 below shows the trend in the production of scientific papers for Kenya over the past 36 years.

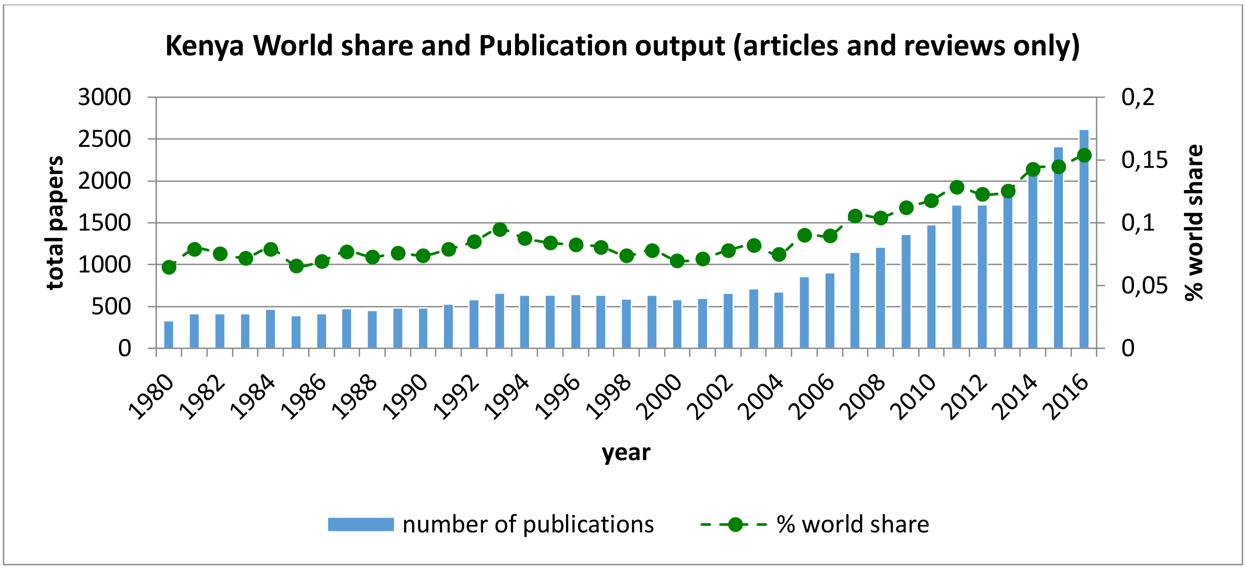

Figure 7-1: Kenya's scientific papers (whole counting) in all fields

Source: Clarivate Analytics Web of Science (n.d.).

Furthermore, this analysis also uses fractional counting which illustrates the perspective of contribution of the research unit to the scientific output. An analysis of the Kenyan authored articles using the fractional counting method indicates a three folds increase from 311 publications in 2000 to 966 publications in 2016.

A comparison of the results show that the publication output counted by full counting indicates a higher number of papers than the output counted by fractional counting.

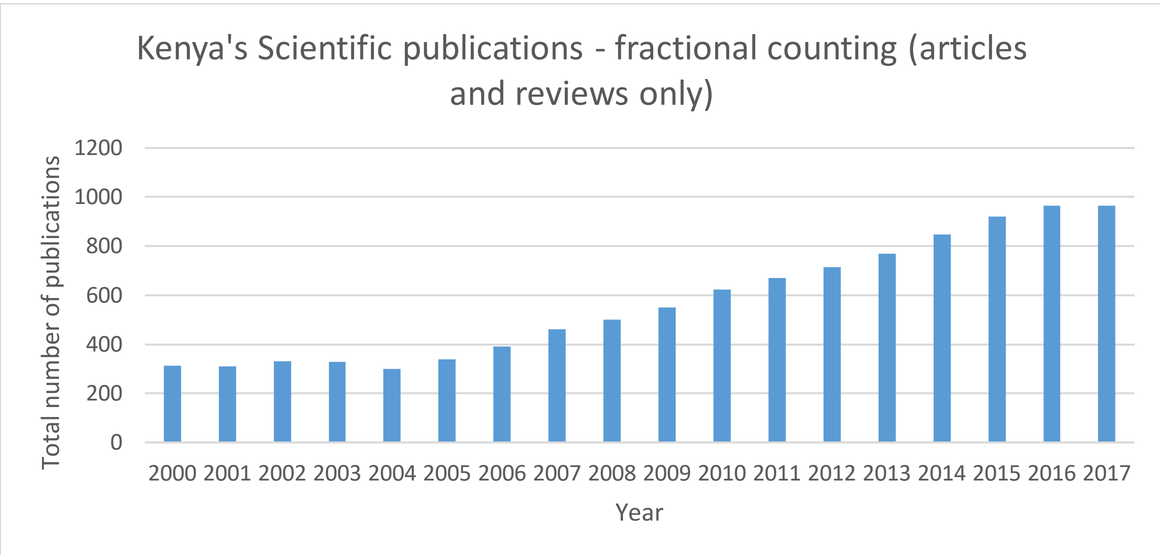

Figure 7-2.2: Kenya's scientific papers (fractional counting) in all fields

Source: Clarivate Analytics Web of Science (n.d.)

The Web of Science makes use of a field classification system where the journal (in which articles are published) is allocated to one or more of the subject categories. The Web of Science Clarivate Analytics comprises of 273 subject categories with more than 21, 000 journal titles allocated to them currently. The next figure provides a summary of Kenya's distribution of output across fields (articles and reviews) in relation to the largest scientific fields.

7.5.2 Scientific Output by Field

This section discusses scientific the research output for all scientific fields as well as the sub-fields.

7.5.2.1 Overview of Research output (full papers) by field: 1980 – 2016

The figure 7-2 below presents the results for Kenya's research output by scientific field at a high level of aggregation. The results show that, for the level 1 scientific fields, the Health Sciences and Natural and Agricultural Sciences dominate the production of Kenya's scientific output followed by the Social Sciences. However, in recent years, the Natural sciences have decreased in production, proportionately and not necessarily in the real numbers. For level 2 scientific fields, Clinical and Public health, Agricultural Sciences, Basic health sciences, Biological sciences dominate the production of Kenya's science.

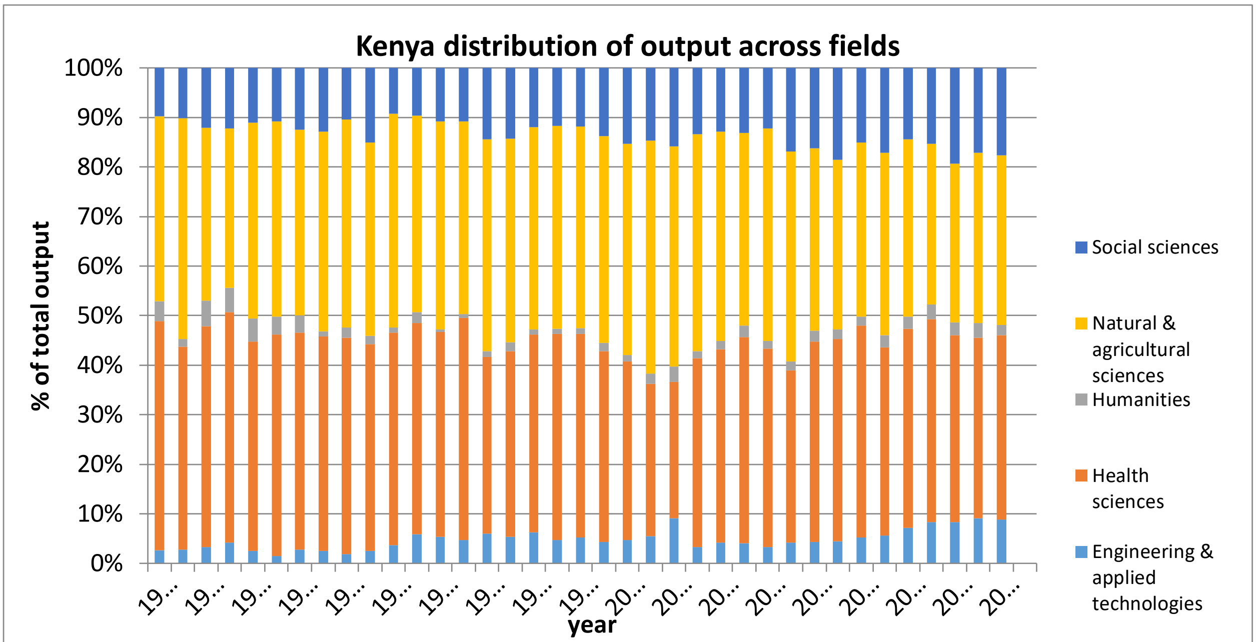

Figure 7-3: Kenya's distribution of output across fields (1980 – 2016).

Source: Clarivate Analytics Web of Science (n.d.)

In this section, we present a more detailed account of Kenya's scientific output by scientific field at a lower level of disaggregation. The table below includes the total number of publications in each field for the period of 1980 to 2016 and the percentage share of the total contribution to Kenya's output. The fields listed in the table below are those fields which are large in volume, with a threshold of at least 500 papers in total over the period and make a significant contribution to Kenya's scientific output for the period analysed. Some of the top fields with the highest numbers of papers (at least 2, 000 papers) include Public environment occupational health, Infectious Diseases, Immunology, Medicine General Medicine and Parasitology, Ecology and Environmental Sciences.

Table 7-1 Scientific fields with the highest contribution from Kenya (1980-2016)

Scientific Field	Total No. of publications (1980-2016)	% contribution to Kenya's total output
Public environmental occupational health	3, 622	10.802
Infectious diseases	3, 152	9.412
Tropical medicine	2,971	8.861
Immunology	2, 402	7.164
Medicine General Internal	2,362	7.044
Parasitology	2,177	6.493
Veterinary Medicine	1, 676	4.999
Ecology	1,654	4.933
Environmental sciences	1, 611	4.805
Entomology	1, 570	4.682
Agronomy	1,517	4.524
Multidisciplinary Sciences	1, 427	4.256
Plant sciences	1, 330	3.967
Microbiology	948	2.827
Zoology	858	2.559
Virology	847	2.526
Biochemistry Molecular Biology	819	2.443
Agriculture Dairy Animal Science	792	2.362
Agriculture Multidisciplinary	781	2.329
Food Science and Technology	653	1.948
Biotechnology Applied Microbiology	550	1.640
Pharmacology Pharmacy	548	1.634
Environmental Studies	539	1.608
Soil Science	538	1.605

Biodiversity Conservation	530	1.581
Economics	526	1.569
Genetics Heredity	526	1.569
Planning and Development	514	1.533
Nutrition Dietetics	509	1.518
Marine Freshwater Biology	503	1.500

7.5.2.2 Research publication distribution per field

In this section, I present the bibliometric results of publication for each of the main fields separately: health sciences, social sciences, agricultural sciences, natural sciences, humanities and engineering and applied technology.

Health Sciences

7.5.2.3 Publication Output and World Share in the Health Sciences: 2000 to 2016

Between 2000 and 2016, the scientists in the health sciences produced 8 333 articles in the Web of Science. The results show a notable increase in article output over this period, from 230 papers in 2000 to 934 papers in 2016, which translates to a compound annual growth rate of 8.6%. This increase` in the papers is seen in the increase in the world share, as it doubles from 0.07% in 2000 to 0.15% in 2016.

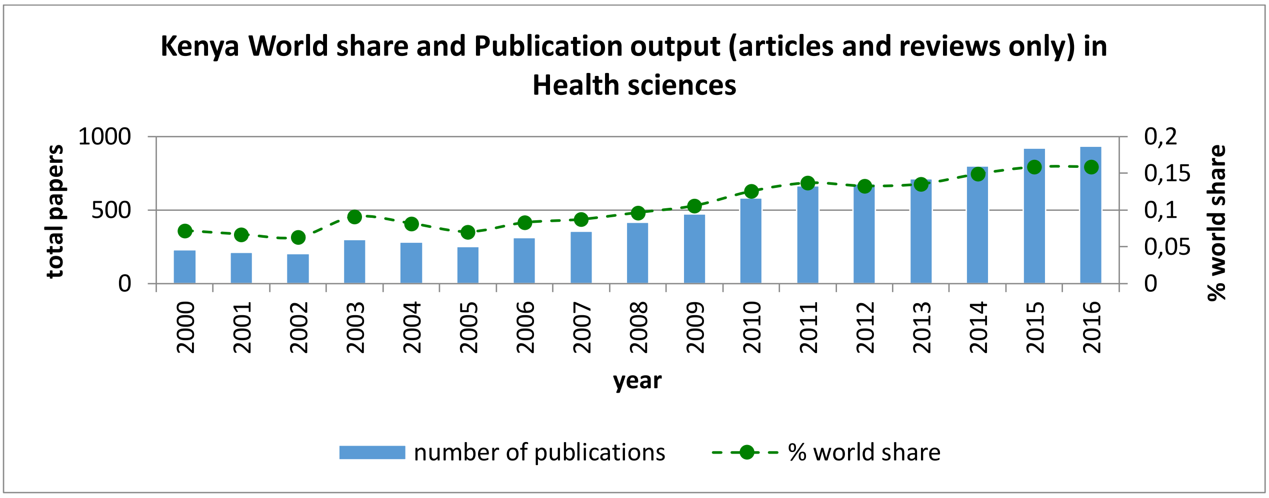

Figure 7-4: Health Sciences: Kenya's publication output (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.)

Despite the increase in the number of papers and the world share indicated above, there has been a slight decline in Kenya's rank in the world, dropping by two positions from 51 in 2000 to 53 in 2016.

Between 2005 and 2014, the results of my analysis show that two institutions, the Kenya Medical Research Institute (KEMRI) and the University of Nairobi (UON) are the largest producers of publications in the health sciences and are also prolific producers of the overall output. Apart from the above-mentioned institutions, other notable institutions that contribute to Kenya's health science are Moi University, Jomo Kenyatta University of Agriculture and Technology, Ministry of Health, Kenyatta University, Kenyatta National Hospital and the Centre for Geographic Medical Research – Coast. In general, apart from the medical research institute, the results suggest that higher education institutions are among the prolific producers of publications in the health sciences.

7.7.2.2.2 Scientific output by sub-fields of the health sciences

The broad field of the health sciences as used in this analysis comprises of a wide range of sub-fields. There are variations of the clinical and public sciences and basic health sciences. Our results show that the scientists in the clinical and public health sciences produced 6 501 papers followed by the basic health sciences which had 3 705 papers. The tree map below (figure 7-4) shows the dominance of sub-fields such as infectious diseases, public environmental occupational health, tropical medicine, immunology, parasitology virology, general and internal medicine and microbiology.

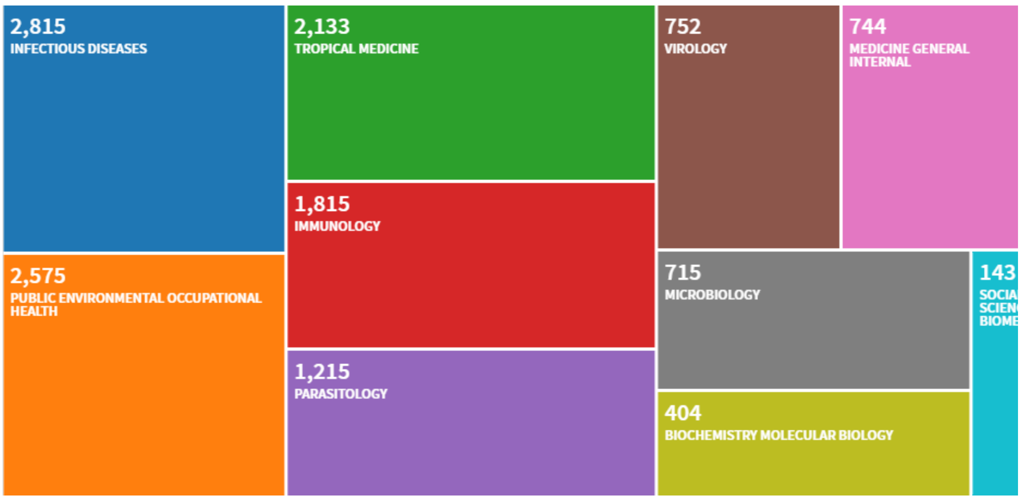

Figure 7-5: Health Sciences: Publication output by scientific field (WoS) (2000 -2016)

Source: Clarivate Analytics Web of Science (n.d.)

Agricultural Sciences

7.5.2.4 Publication Output and World Share in the Agricultural Sciences: 2000 to 2016

The results of the analysis show that between 2000 and 2016 Kenya's agricultural scientists published 3 574 articles in the web of science. The results show a substantial increase in article output over this period, from 120 papers in 2000 to 365 papers in 2016 at a CAGR of 7.0%. This translates into a twofold increase in the publication output. This slight increase resulted in a small but notable increase in the world share: from 0.24% in 2000 to 0.39% in 2016. Despite the slight increase in the publication output, Kenya's rank in agricultural sciences in the world declined from position 45 in 2000 to 48 in 2016.

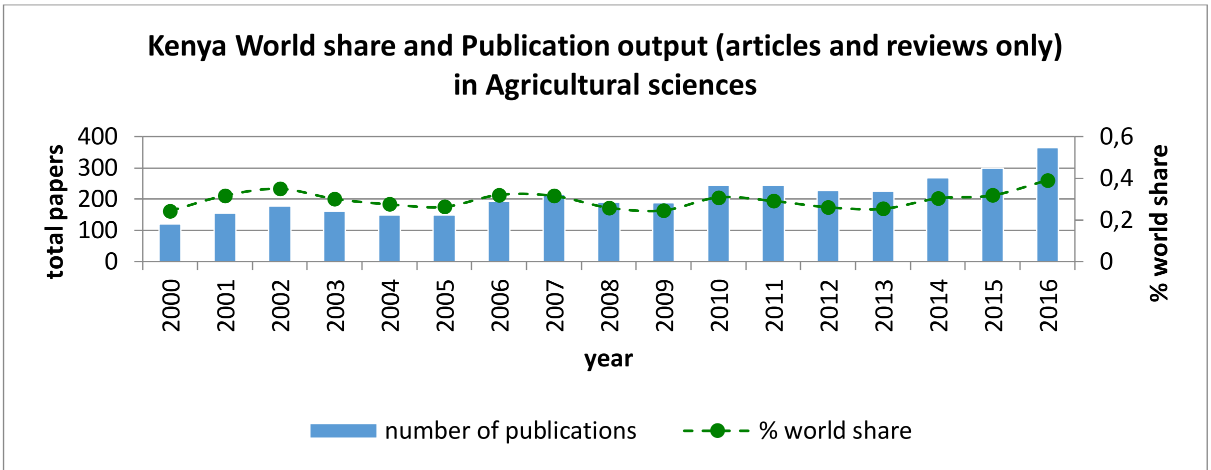

Figure 7-6: Agricultural Sciences: Kenya's publication output (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.)

The results show that for the period analysed the top producers of articles in the agricultural sciences are three institutions the University of Nairobi, Kenya Agricultural Research Institute (KARI) and Egerton University. The other institutions that also contributed notable numbers of articles were Jomo Kenyatta University of Agriculture and Technology, Kenyatta University Kenya Medical Research Institute, International Center for Tropical Agriculture, Kenya, National Museums of Kenya, Ministry of Livestock and Fisheries Development and Maseno University. These institutions comprise of higher education institutions, government ministries, research institutes and parastatals as well as international agricultural research institutes based in Kenya.

7.7.2.3.1 Scientific output by sub-fields of the agricultural sciences

The agricultural sciences are comprised of several sub-fields. The tree map below (figure 7.6) illustrates the proportion of each of the sub-fields of the overall publication output between 2000 and 2016. The results show that the following sub-fields dominate the agricultural sciences output: agronomy, plant sciences, veterinary sciences, food science technology, agricultural dairy animal science and soil science. The map also illustrates that there are small but notable outputs from the following sub-fields: horticulture, agriculture multidisciplinary, forestry and nutrition dietetics.

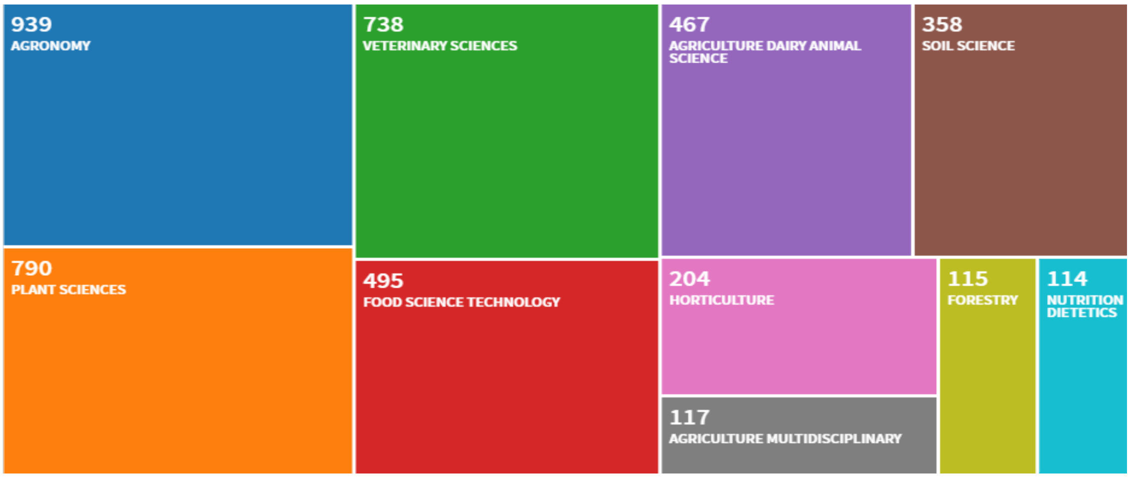

Figure 7-7: Agricultural Sciences: publication output by sub-fields (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

Natural Sciences

7.5.2.5 Publication Output and World Share in the natural sciences: 2000 to 2016

The results of my analysis show that between 2000 and 2016 Kenya's scientists had published 6 111 papers in the web of science in the field of natural sciences. My findings further illustrate a steady increase in the papers published from 188 articles in 2000 to 667 articles in 2016, at a CAGR of 7.9%. This increase in the articles was seen in the slight increase in the world share: from 0.05% in 2000 to 0.08% in 2016. Despite the increase in the number of publications and a slight increase in the world share, Kenya's rank in the world slightly declined from position 66 in 2000 to 68 in 2016.

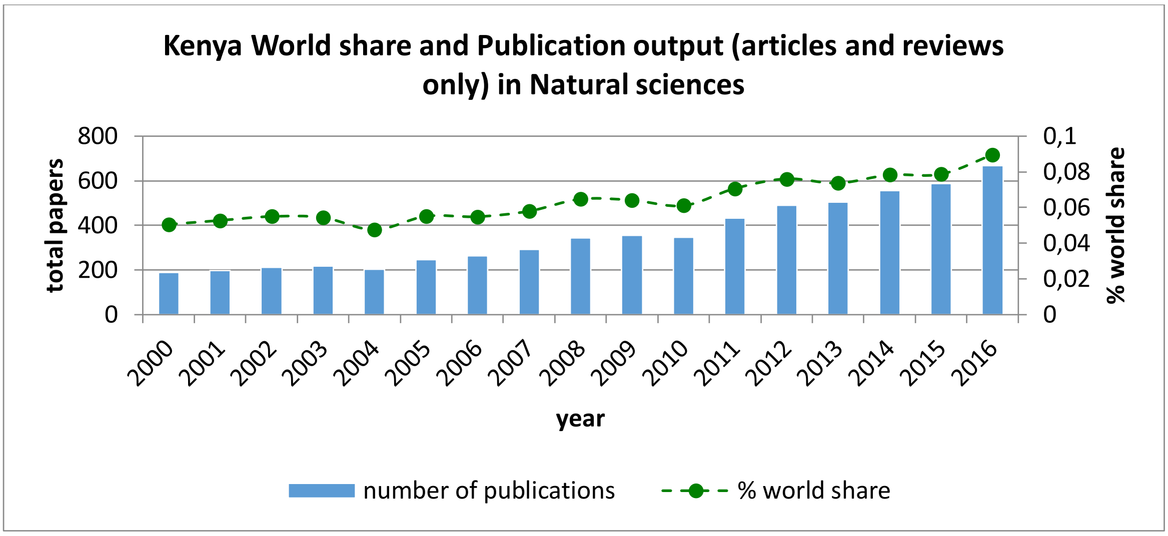

Figure 7-8: Natural Sciences: World share and publication output (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

7.5.2.5.1 Scientific output by sub-fields of the natural sciences

Natural sciences have an array of sub-fields that belong to five subfields: biological sciences, mathematical sciences, physical sciences, chemical sciences and earth sciences. The figure below illustrates the publication output of subfields in the natural sciences. The results show that the following subfields dominate Kenya's output in the natural sciences: environmental sciences ecology, entomology, zoology, biodiversity conservation, marine-freshwater biology, biochemistry molecular biology, and biotechnology applied microbiology, geology and water resources.

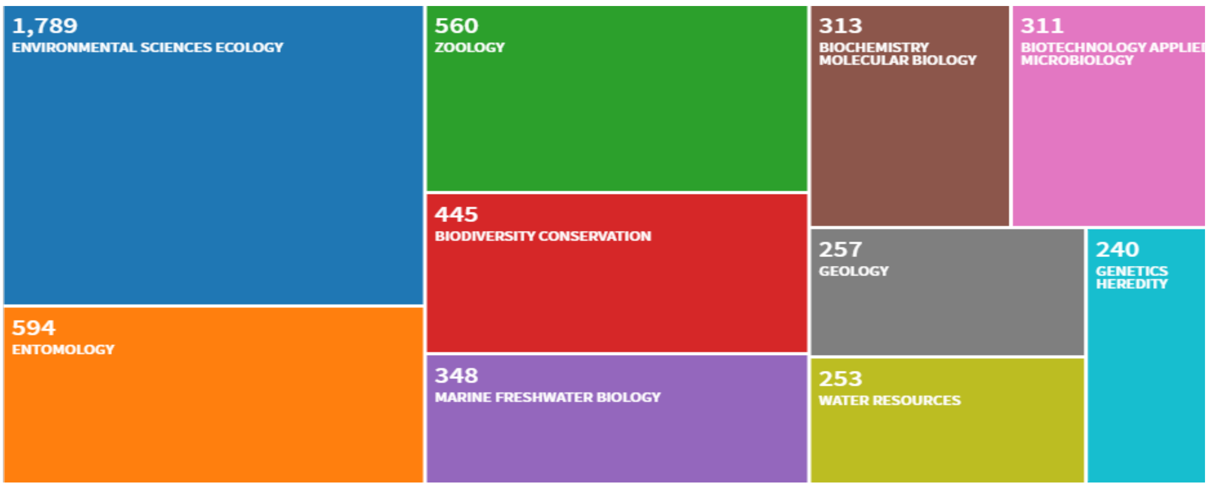

Figure 7-9: Natural Sciences: Publication output sub-fields (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

Social Sciences

7.5.2.6 Publication Output and World Share in the social sciences: 2000 to 2016

The results show that between 2000 and 2016, social scientists in Kenya produced 3 595 articles in the field of social sciences in the Web of Science. The results show a substantial increase in article output over this period, from 86 articles in 2000 to 485 papers in 2016 at a CAGR of 10.8%. This translates into a five-fold increase of the publication output in the social sciences. The increase in the publication output resulted in a doubling in world share: from 0.09% in 2000 to 0.18% in 2016. Despite the increase in the publication output and world share, Kenya's position in the social sciences in the world declined from position 47 in 2000 to 58 in 2016.

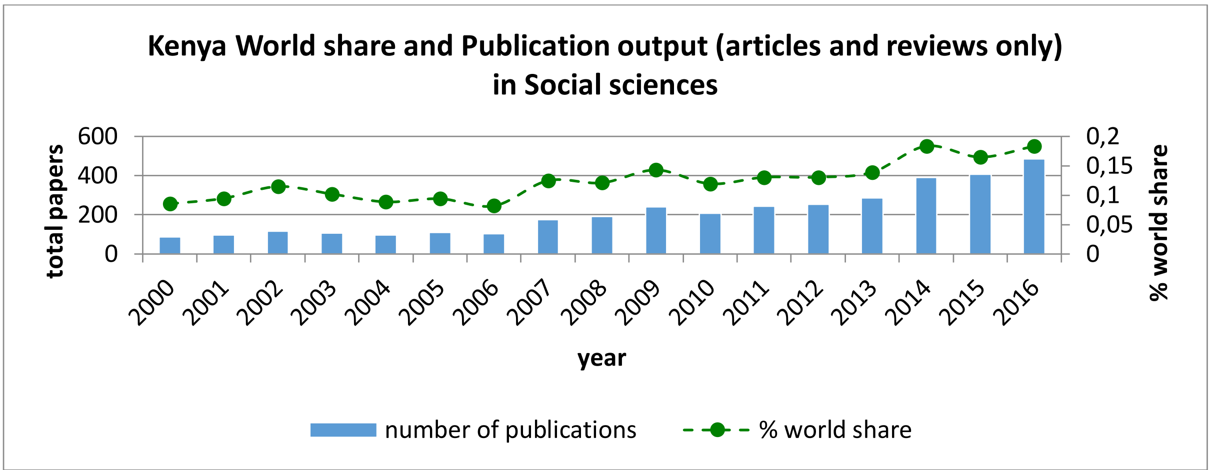

Figure 7-10: Social Sciences: World share and publication output (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

Furthermore, the results show that between 2000 and 2016 the top producers of publication output in the social sciences are three institutions: The University of Nairobi, the Kenya Medical Research Institute and the National Museums of Kenya. Other institutions with considerable output in the social sciences include Moi University, Kenyatta University and Jomo Kenyatta University of Agriculture and Technology, Egerton University and the Kenya Marine and Fisheries Research Institute. The results suggest that higher education institutions and the public research institutions were high producers of the papers in the social sciences. Other non-governmental or international research organisations with considerable output include the Mpala research centre and the International Centre for Tropical Agriculture

7.7.2.5.1 Scientific output by subfields of the social sciences

The broad field of the social sciences has a diverse group of subfields. Some of these fields include 'basic' fields such as economics political science, psychology, sociology, demography, economics, geography, economics and other professional fields (social work and education work, etc.).

The tree map below illustrates the subfields in the social sciences. The figure shows that economics, education or educational research, development studies, area studies, social sciences interdisciplinary and political science dominate the output in the social sciences. In addition, other sub-fields such as information science library science, international relations, social sciences biomedical and family studies also contributed to the output in the social sciences.

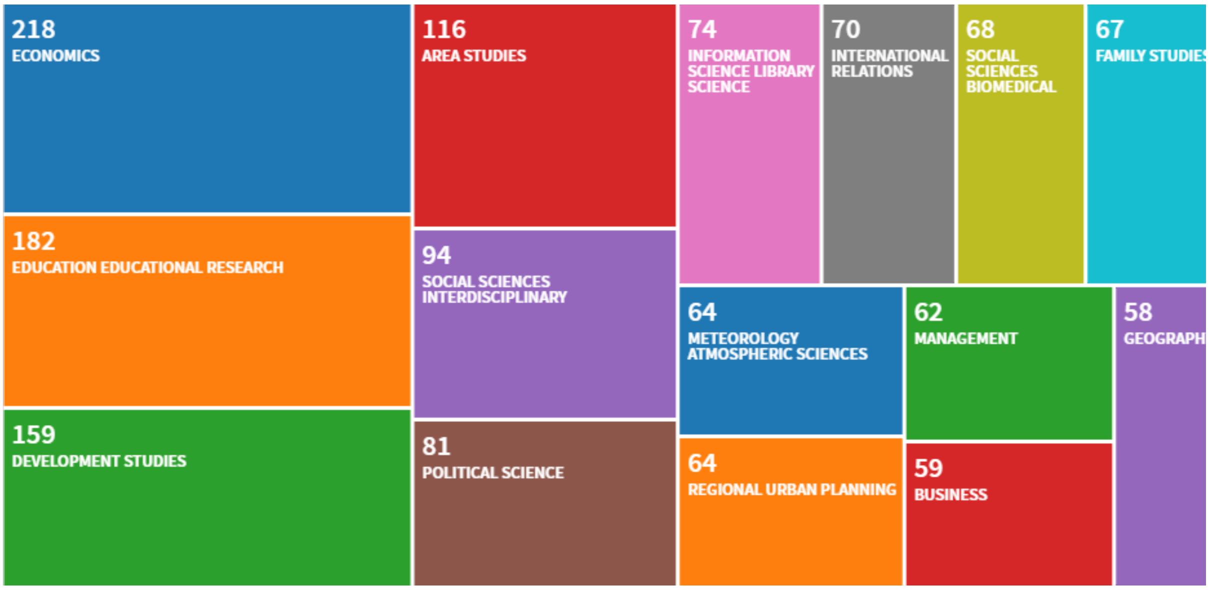

Figure 7-11: Social Sciences: Scientific output by sub-fields (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

Engineering and applied technology

7.5.2.7 Publication Output and World Share in engineering sciences: 2000 to 2016

Between 2000 and 2016, scientists in Kenya produced 1 596 papers in the field of engineering and applied technology. The results show a substantial increase in publication output over this period, from 29 papers in 2000 to 247 papers in 2016 at a CAGR of 13.4%. This translates to an eight-fold increase of the article output in engineering and applied technology. The slight increase in the publication output did not result in any substantial increase in the world share: which averaged at 0.03%, increasing from 0.02% in 2000 to 0.05% in 2016. In addition, Kenya's position in engineering and applied technology in the world was maintained at 76 in 2000 and 2016.

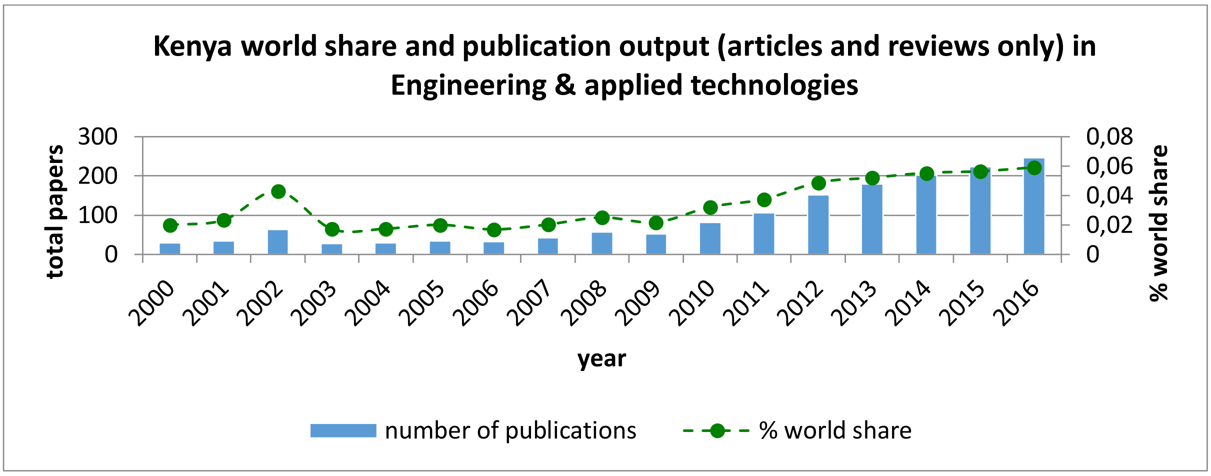

Figure 7-12: Engineering and applied technology: World share and publication output (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

7.7.2.6.1 Scientific output by subfields of engineering and applied technology

The broad field of engineering and applied technology has a diverse group of subfields. Some of these sub-fields include environmental engineering, mechanical engineering, civil engineering, electrical engineering, material science and nanoscience and nanotechnology, among others.

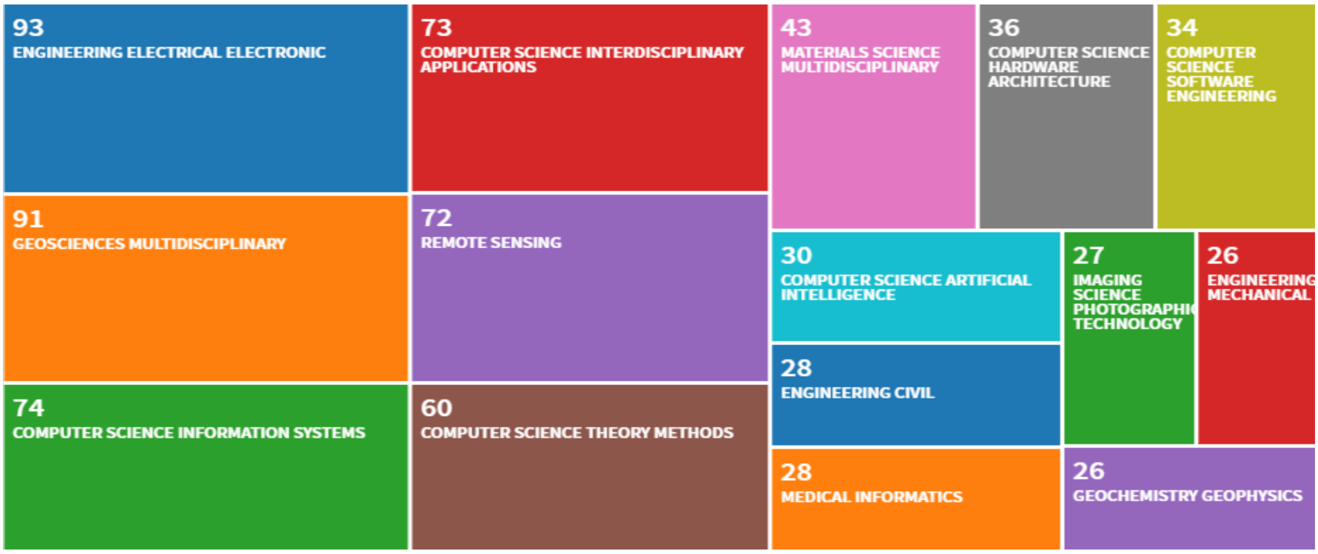

Figure 7-13: Engineering and applied technology: Publication output sub-fields (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

7.5.3 Kenya's rank among all countries across all research fields

Looking at Kenya's share of world output together with the publication output, our analysis shows that Kenya has improved its position relative to other countries. However, despite the above-illustrated results that show an increase in output and share of world output, there has been less improvement when ranking Kenya with other countries. Our analysis shows that, as far as country rank among all countries across all research fields is concerned, Kenya has declined in its ranking in the world relative to other countries (from position number 48 in 1980 to 63 in 2016).

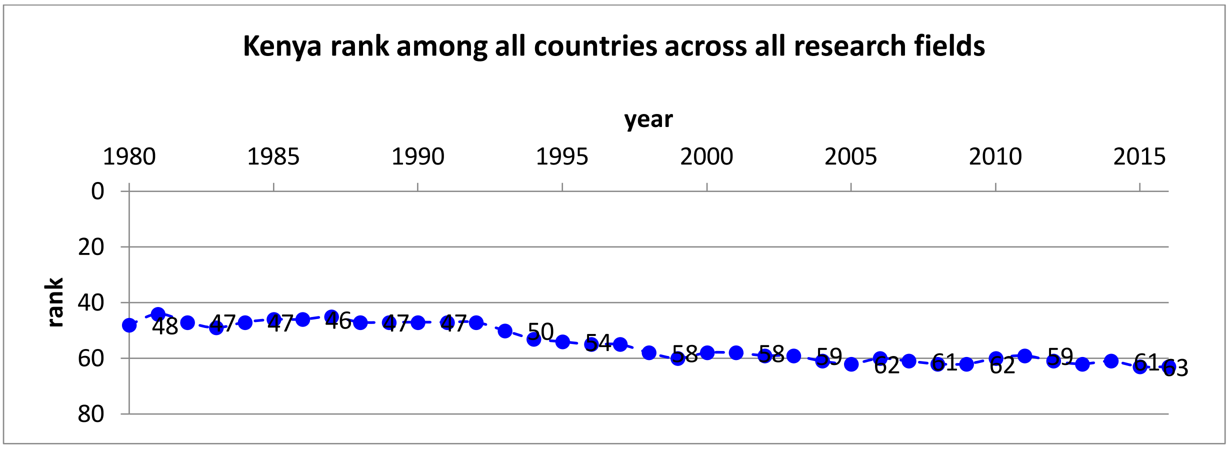

Figure 7-14: Kenya's rank amongst all countries (1980 – 2016)

Source: Clarivate Analytics Web of Science (n.d.).

7.5.4 Scientific output by research institutions

In this section, we present the volume of publication output of Kenya's top-performing research institutions for two periods: 2005to 2007 and 2012 to 2014. These results are presented in descending order from the largest to the smallest for the periods analysed. These results are similar to previous studies. They showed continued dominance of the Kenya Medical Research Institute and the University of Nairobi, followed by larger contributions from Jomo Kenyatta University of Agriculture and Technology, Moi University, International Livestock Research Institute, together with smaller but significant contributions from International Centre for Insect Physiology and Ecology, Kenyatta University, Ministry of Health, World Agroforestry Centre, National Museums of Kenya and African Population and Health Research Centre. It is noteworthy that the top research institutions include the medical institution, the public university universities and the international research organisation. This is consistent with the study by Tijssen (2007).

Some of the top institutions that Kenyan researchers dominantly collaborate within the two periods analysed include the University of Oxford, University of London, University of Washington, Seattle; followed by significant contributions from the Centres for Disease Control and Prevention, University of California System, University of Cape Town and the University of Witwatersrand.

Table 7-2: Kenya top-performing research institutions

2005 to 2007			2012 to 2014		
Research Institution	nPubs	Rank	Research Institution	nPubs	rank
Kenya Medical Research Institute	716	1	Kenya Medical Research Institute	1145	1
University of Nairobi	523	2	University of Nairobi	1142	2
International Centre for Insect Physiology and Ecology	220	3	University of Oxford	416	3
Kenyatta University	194	4	University of London	404	4
University of Oxford	192	5	University of Washington, Seattle	373	5
Jomo Kenyatta University of Agriculture and Technology	190	6	Jomo Kenyatta University of Agriculture and Technology	373	6
International Livestock Research Institute	170	7	Moi University	340	7
Kenya Agricultural Research Institute	152	8	International Livestock Research Institute	329	8
Moi University	152	9	International Centre for Insect Physiology and Ecology	291	9
Centers for Disease Control and Prevention	148	10	Kenyatta University	286	10
University of London	148	11	Centers for Disease Control and Prevention	271	11
National Museums of Kenya	144	12	Ministry of Health	263	12
Egerton University	115	13	University of California System	233	13
Ministry of Health	112	14	World Agroforestry Centre	214	14
World Agroforestry Centre	97	15	University of Washington Seattle	211	15
Association pour la Promotion de l'Education et de la Formation à l'Etranger	93	16	National Museums of Kenya	205	16
University of California System	75	17	University of Washington	197	17
Maseno University	75	18	African Population and Health Research Center	197	18
University of Washington Seattle	73	19	Makerere University	163	19

University of Washington	73	20	Egerton University	161	20
International Center for Tropical Agriculture	70	21	University of Cape Town	154	21
University College London	65	22	University of the Witwatersrand	149	22
Wageningen University & Research Center	65	23	Centre for Geographic Medical Research - Coast	147	23
United States Department of Defense	63	24	Centers for Disease Control & Prevention - USA	146	24
United States Army	61	25	Maseno University	146	25
University of Liverpool	61	26	Kenyatta National Hospital	142	26
Centers for Disease Control & Prevention - USA	55	27	Harvard University	139	27
Pennsylvania Commonwealth System of Higher Education (PCSHE)	54	28	Kenya Agricultural Research Institute	138	28
International Center for Tropical Agriculture, Kenya	52	29	Wageningen University & Research Center	121	29
World Agroforestry Centre, Kenya	49	30	Association pour la Promotion de l'Education et de la Formation à l'Etranger	120	30

7.6 Relative Field Strength Index

The specialisation index (SI) or Relative Field Strength Index (also known as the activity index) is one the standard indicators used to measure whether a country (or region or institution) is relatively active or strong in a specific scientific field. The specialisation Index can be defined as the research intensity or concentration of the country [or particular university] for a given research field relative to the average in the world [for the case of the country] or in a country, region, or group of countries [for the university]. The Activity Index focuses on the relative research efforts or resources allocated to a particular field relative to a national or group baseline. This concept was proposed by Frame (1977) and expounded on by Schubert and Braun (1986) to compare the performance of scientists, departments, research groups and centres, institutions or countries with the average (Chen & Guan, 2011, cited in Siripitakchai & Miyazaki, 2015). The SI indicator is calculated on the basis of the research publications.

$$\text{Specialisation index in field F} = \frac{\text{Publication world share of the country in field F}}{\text{Publication world share of the country for all fields}}.$$

Notably, an RFS value of 1 (which is shown by the bold line in the radar diagrams below) in a given scientific field implies that the unit (country or region or institution) has a world share for that field that is similar to its share in all the fields combined. When the RFS is greater than 1, the country is stronger in the field, as compared to other fields or disciplines which have an RFS index less than 1. The next sub-sections present the RFS index values for the various categories of scientific fields.

Firstly, we begin with an overview that presents a radar or spider diagram for Kenya in the five broad scientific fields comparing the Relative Field Strength for two periods: 2005 to 2007 (in blue) and 2012 to 2014 (in green). This overview enables us to identify some shifts in the relative strengths of Kenyan scientific fields.

7.6.1 Relative Field Strength across all scientific fields: Overview

Our analysis, as illustrated in the radar diagram below shows, Kenya's relative field strength Index (RFSI) is strong in the broad domain of health sciences and social sciences, the broad domains where the RFS index value is greater than 1. The RFSI of all the broad domains increased over time except for the Natural & Agricultural sciences which have weakened in the last five years analysed. Kenya is weakest in the broad domain of Engineering sciences and Applied technologies and Humanities.

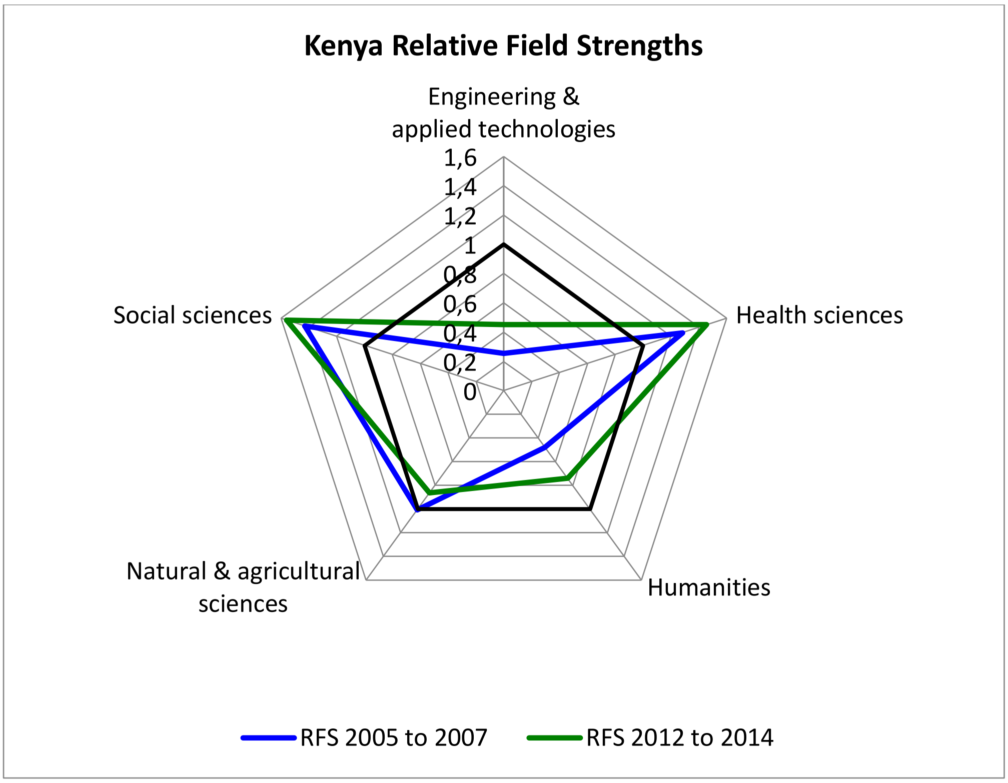

Figure 7-15: Kenya's Relative Field Strengths of Broad domains

Source: Clarivate Analytics Web of Science (n.d.).

Table 7-3: The Relative Field Strength Index (RFSI) of science domains

Field	Npubs(2005 - 2007)	RFSI (2005-2007)	Npubs (2012 – 2014)	RFSI (2012 – 2014)
Natural & Agricultural Sciences	1513	1.00702	2521	0.862908
Health Sciences	1408	1.28339	2988	1.45528
Social Sciences	521	1.4292	1249	1.55951
Engineering & Applied Technologies	140	0.255576	603	0.452335
Humanities	69	0.477157	200	0.738883

In the broad field of health sciences, Kenya is relatively strong and active in the clinical & public health and basic health sciences. The disaggregation of the broad field of Basic Health Sciences shows that Kenya is strong and active in the field of Infectious Diseases, Public, Environmental & Occupational Health, Tropical Medicine, and Immunology & Virology and General and Internal Medicine.

The disaggregation of the broad field of the Social sciences shows Kenya is active and strong in the fields of Environmental Sciences & Ecology, Environmental Sciences, Business & Economics and Environmental Studies.

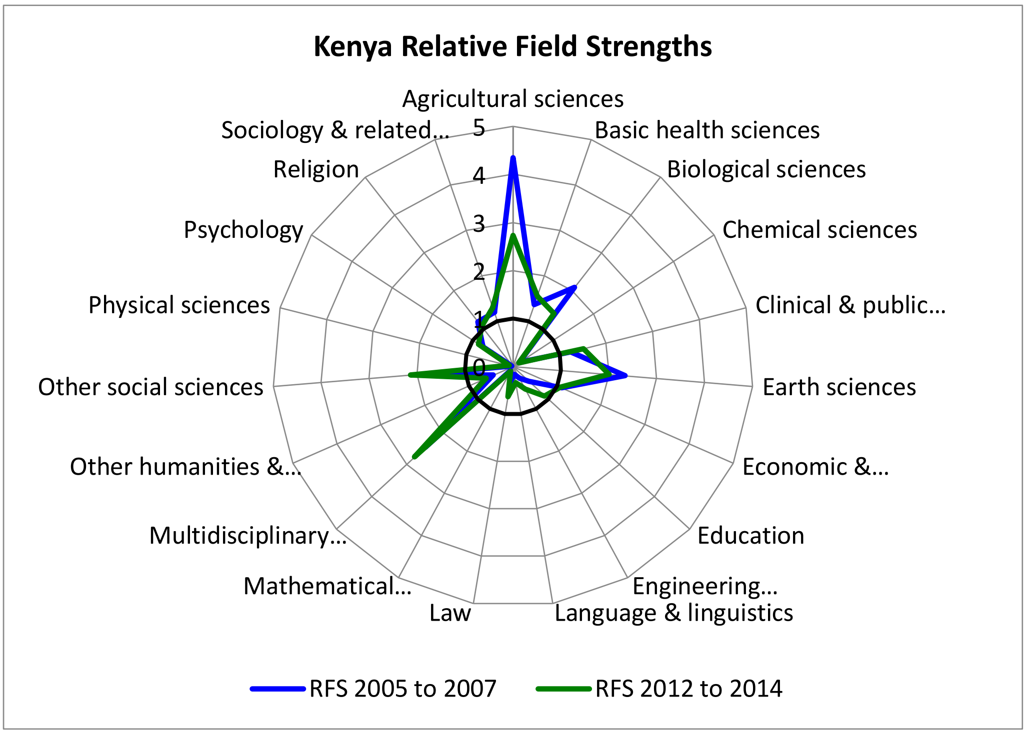

Figure 7-16: Relative Field Strengths of scientific fields

Source: Clarivate Analytics Web of Science (n.d.).

The figure above shows that, the relatively strongest fields in scientific production are: Agricultural Sciences, Biological Sciences, Basic health sciences, Earth sciences, Clinical and public health, Multidisciplinary sciences and other social sciences. Despite the overall stronger relative strength of Agricultural Sciences and Biological sciences weakened during the 2012 to 2014 period analysed.

7.6.2 Relative Field Strength of different fields

This section discusses and illustrates the relative field strength for the articles produced in different scientific fields in Kenya. The section will discuss the relative field strengths for the major first-level scientific fields and their respective subfields: health sciences, agricultural sciences, engineering and applied technology, natural sciences and humanities. N *7.6.2.1 Health Sciences: Relative Field Strengths and Mean normalised citation score*

Between 2000 and 2016, the results show that the relative field strength (RFS) and the mean normalised citation score (MNCS) in the health sciences were above the world average (that is above 1). This implies that Kenya is more active (stronger RFS) and has higher visibility (higher citation impact) in the health sciences as compared to other scientific fields. The results further show that the RFS increased slightly from 1.2 in 2000 to 1.4 in 2015 and slightly declined to 1.3 in 2016 as shown in figure 7.23 below. On the other end, Kenya's mean normalised citation score (MNCS) in the health sciences increased from 1.1 in 2000 and increased to 1.8 in 2015 before a slight decline to 1.4 in 2016 as illustrated in the figure 7.16 below.

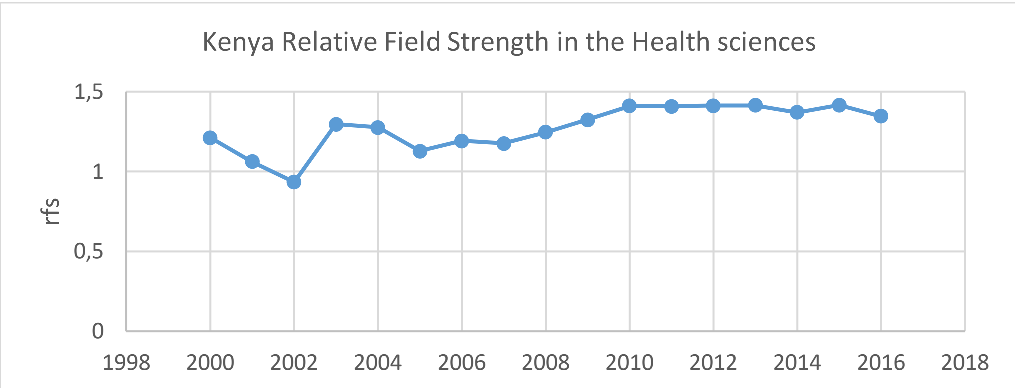

Figure 7-17: Health Sciences: Relative field strength (2000 -2016)

Source: Clarivate Analytics Web of Science (n.d.).

7.6.2.2 Agricultural Sciences: Relative Field Strengths and Mean normalised citation score

Between 2000 and 2016 the relative field strength (RFS) score in the agricultural sciences recorded high numbers above the world average (that is above 1). This implies that Kenya is more active (stronger RFS) in the agricultural sciences as compared to other scientific fields. A breakdown per year shows that further show that the RFS maintained an average of 4.5 between 2000 and 2007 and slightly declined to 3.3 in 2016 as illustrated in figure 7.31 below.

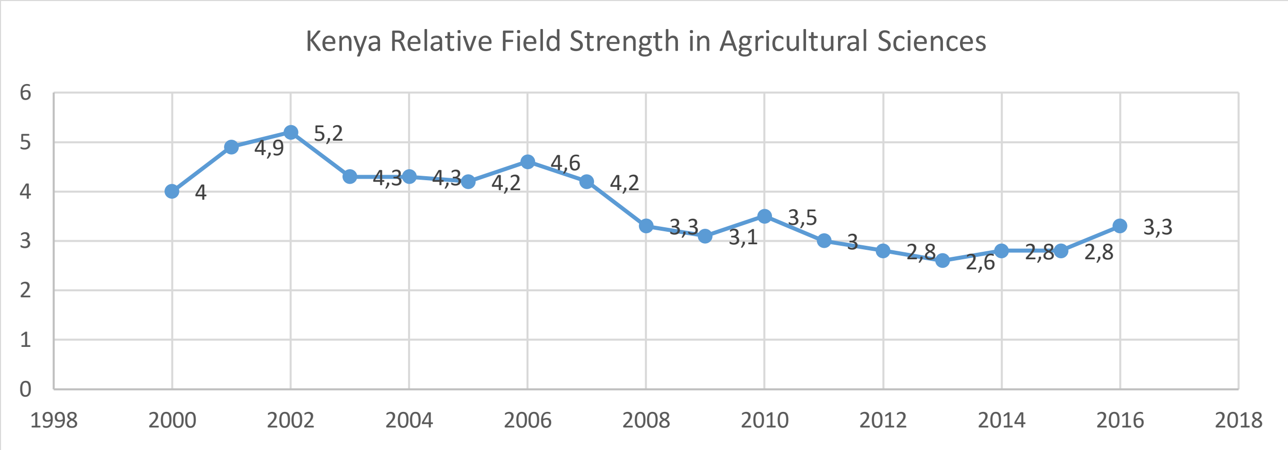

Figure 7-18: Agricultural Sciences: Relative field strength (2000 -2016)

Source: Clarivate Analytics Web of Science (n.d.).

7.6.2.3 Natural Sciences: Relative Field Strengths and Mean normalised citation score

Between 2000 and 2016, the results show that the relative field strength (RFS) in the natural sciences was between 0.7 and 0.8, numbers slightly below the world average. This implies that Kenya is less strong in the natural sciences as compared to other scientific fields. A breakdown per year further reveals that the RFS slightly declined from 0.84 in 2000 to 0.75 in 2016 as illustrated in the figure below. On the other end, Kenya's mean normalised citation score (MNCS) in the natural sciences increased from 1.05 in 2000 and increased to 1.4 in 2016 as illustrated in the figure below. These results show that Kenya is less specialised in the natural sciences; however, the papers in the natural sciences have maintained high visibility, especially in the last decade.

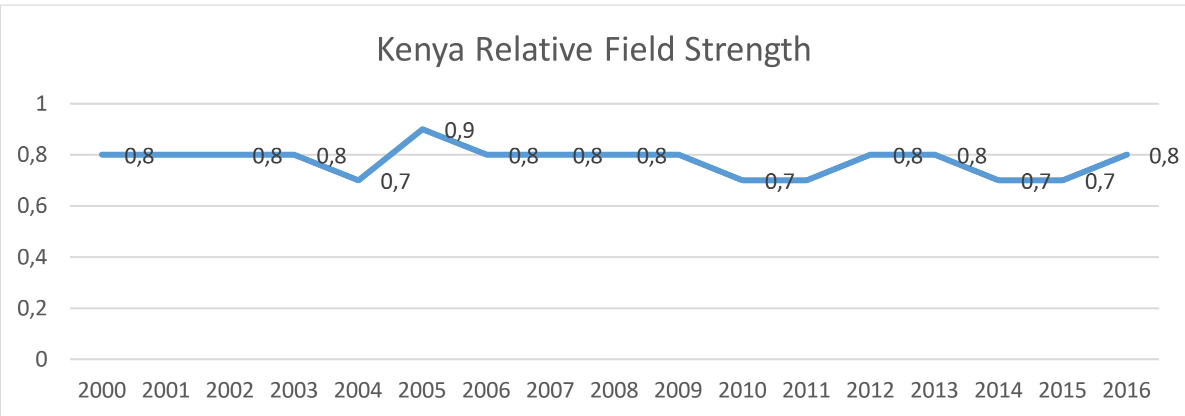

Figure 7-19: Natural Sciences: Kenya Relative Field Strength (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

7.6.2.4 Relative Field Strength and Mean Normalised Citation Score

The results show that between 2000 and 2016, Kenya's relative field strength in the social sciences recorded high numbers of the relative field strength above the world average. This implies that Kenya was more active in the social sciences compared to the world averages of this field (RFS>1). A breakdown per year suggests that the RFS for the social sciences increased from 1.4 in 2000 to 1.8 in 2009 and later slightly declined to 1.6 in 2016.

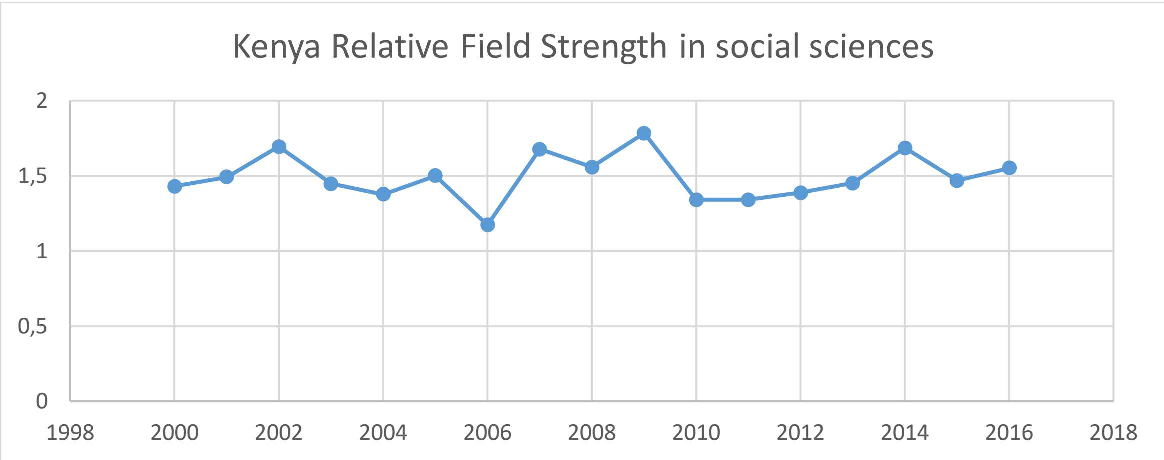

Figure 7-20: Social Sciences: Relative Field Strength (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

7.6.2.5 Engineering Sciences: Relative Field Strength and Mean Normalised Citation Score

Between 2000 and 2016, the results show that Kenya's relative field strength in the engineering and applied technology recorded very low numbers of the relative field strength below the world averages. This indicates that Kenya is less strong in engineering and applied technology compared to the world averages (where the world average is 1) of this field (RFS<1). A breakdown per year suggests that the RFS for engineering and applied technology slightly rose from 0.3% in 2000 to 0.5% in 2016. In the past half-decade, the average of RFS in the engineering sciences was 0.5%.

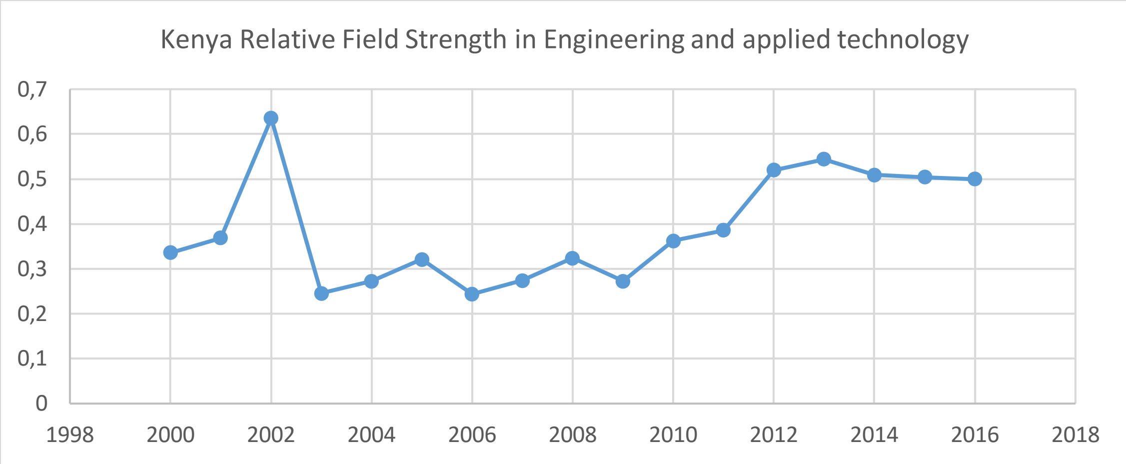

Figure 7-21: Engineering and applied technology: Kenya Relative Field Strength (2000 -2016).

Source: Clarivate Analytics Web of Science (n.d.).

7.7 Discussion

This section of the thesis discusses the results presented on research production in the above sub-sections. In this section I will try to provide reasons that explain the performance of the different bibliometric indicators measured above: publication output and relative field strength.

7.7.1 Increased publication output

The analysis of Kenya's research output between 1980 and 2016 reveals several observations. First, a steady increase in the publication output during the analysed period is recorded. My analysis found slow growth in the 1980s and steep growth rates in the 2000s. Second, a higher increase in the output is observed over the past decade, from 858 papers in 2005 to 2619 papers in 2016. Third, the share of world output more than doubled from 0.06% in 1980 to 0.15% in 2016. These findings are congruent with studies in the literature, which found that research publications authored by African scientists were slightly on the increase (NPCA, 2010; Mouton & Boshoff, 2010; Mouton & Blanckenberg, 2018).

Several factors in the literature could explain the increased growth of publication output for Kenya. The amount a country invests in research and development (R&D) has an influence on the country's output among others. In 1980, there were calls by the heads of governments to increase the investment into science and technology by 1 % of the gross domestic product (GDP), a call that was repeated by the African Union in 2005 (Reference, XX). Despite these calls, R&D investment in the 1980s and even in the 2000s remained below 1% of GDP. By 2007, the gross expenditure for research and development (GERD) was at 0.36% doubling to about 0.76 in 2010. Similarly, during this period, 2007 to 2010, higher education, government and foreign sources experienced the largest growth of R&D investment. Inasmuch as the R&D investment remains below the set target, I argue that the amounts invested have to some extent contributed to the steady growth of Kenya's publication output.

Apart from the investment in R&D, research capacity available for research could explain the growth rate of Kenya's publication output. Research and development are dependent on well-trained, skilled and experienced researchers across the different sectors. In 2010, Kenya recorded 1,489 researchers and research support staff (i.e. headcounts) per million inhabitants. In contrast to the mere headcount, Kenya reported 1,029 researchers per million inhabitants as full-time equivalents (FTE), indicating the amount of time available for conducting research beside administrative and teaching requirements (UIS). Compared to the countries in the East African region, Kenya reported the highest number of research and development FTE personnel per million inhabitants in comparison to Uganda (59.2) and Tanzania (63.5). These high numbers of researchers could also explain the growth rates in the publication output for Kenya, especially in the last decade.

In addition to the increase in the number of researchers over the years, Kenya has also seen an increase in the number of PhD graduates over the years. Although these numbers are still below the target of producing 1000 PhD graduates per annum, the slight increase is seen in the higher education and agricultural sectors.

Similarly, our data shows that collaboration rates have increased steadily over the years. In the 1980s, the collaboration rates (for both national and international levels) were lower compared to the higher collaboration rates demonstrated in the 2000s. In the literature reviewed, scholars argue that collaboration may result in an increase in publication output. Therefore, based on our results in the collaboration rates and previous literature, it is plausible to conclude that the increase in the collaboration rates (especially the national and international levels) have also contributed to the increase in the publication output during the different periods.

My findings show that the health sciences and natural and agricultural Sciences dominate the production of Kenya's scientific output. These findings are congruent with previous studies, various scholars found that the health and natural sciences and agricultural sciences have the highest number of publications in most African countries including Kenya (Pouris & Pouris, 2009; Uthman & Uthman, 2007). My findings are also in support of previous findings that found that at lower levels of disaggregation, African countries including Kenya, produce a higher number of papers in public environment occupational health, infectious diseases, immunology, medicine general medicine and parasitology, ecology and environmental sciences (Pouris & Pouris, 2009). These sub-fields with a higher number of publications belong to the health sciences, agricultural sciences and natural sciences broad fields.

The theoretical and empirical scholarship reviewed found a higher positive effect of public funding on publication output (Beaudry & Allaoui, 2012; Beaudry & Clerk-lamalice, 2010; Shapira & Wang, 2010). The GERD data from UNESCO statistics show that as of 2010, the agricultural and health sciences received the largest share of R&D investment – 44.82 per cent and 27.47 per cent respectively – from both the government and international sources. In as much as the natural sciences recorded a higher article output, this can be linked to the field differences in the publication forms and collaboration rates. The literature reviewed shows that scientists in the natural and health sciences tend to publish articles (which are analysed in this study) compared to scientists in the social sciences and humanities who publish more books and book chapters. Similarly, scientists in engineering and applied technology tend to publish conference papers in proceedings. These field differences in publication forms explain why the natural sciences, agricultural sciences and health sciences recorded a higher number of article output. Similarly, previous studies showed that scientists who indicated they received greater funds have more collaborators (Bozeman & Corley, 2004). The literature reviewed showed that scientists in the natural sciences and medical sciences tend to engage in more collaborative work, which might influence their publication productivity. Previous studies found that collaboration has a positive impact on publication output (Beaudry & Allaoi, 2012; Beaudry & Clerk-lamalice, 2010) especially the full count (total number) of research publications (Lee & Bozeman, 2005).

As far as country rank among all countries across all research fields is concerned, Kenya declined in its ranking in the world, relative to other countries (from position number 48 in 1980 to 63 in 2016). This decline in ranking occurs despite Kenya's increase in the publication output and world share contribution demonstrated above.

My findings are congruent with previous empirical studies, which found that higher education institutions and public research institutes in Kenya were the highest producers of Kenya's science (Tijssen, 2007). For the two periods analysed, that is, 2005 and 2007 and 2012 and 2014, the Kenya Medical Research Institute and the University of Nairobi recorded the highest number of publications. The high publication output at the University of Nairobi could be explained by several factors. The historical analysis conducted on the Kenyan science system (chapter 2) shows that the University of Nairobi was the first fully-fledged university to be established in Kenya in 1971, with its history traced back to 1949 with the establishment of the Royal Technical College. Given its long history, it can be argued that the University of

Nairobi to some extent has an established research culture that will influence its publication output, compared to the recently established institutions. The historical analysis (Chapter 2) shows that the University of Nairobi has the highest number of research centres, especially in the health sciences and natural sciences, which contributes to its publication output. Compared to the other Kenyan universities, the University of Nairobi record the highest number of academics, over 30 per cent holding doctoral degrees, arguably these human resources contribute to the University's scientific output. Universities that were established after the University of Nairobi, as discussed in the historical analysis (chapter 2), are also big contributors to Kenya's scientific output. As discussed in chapter 2 and shown in my findings (section 7.1.4), these universities include Kenyatta University (1985), Moi University (1984), Egerton University (1987) and Jomo Kenyatta University of Technology (1994). It is clear that the oldest and largest universities in Kenya have a cumulative advantage, in terms of a research culture, collaborative networks, research capacity and research resources, which positively impacts on their scientific output, compared to the recently established universities.

Similarly, my historical analysis (chapter 2) shows that the Kenya Medical Research Institute (KEMRI) has a long history in medical research. Although KEMRI was only established in 1979, medical research dates in Kenya dates back to 1949 when Foy and Kondi with the support of the Wellcome Trust set up a laboratory in Nairobi. Since its establishment, KEMRI has continued to collaborate with and receive funding from the Wellcome Trust and other international institutions. Following the argument that collaboration and funding has a positive effect on publication output, the continued collaborative research and funding from the Wellcome Trust and other international institutions has contributed to KEMRI's higher output

Kenya is also host to several international research organisations and agencies that also contribute to its science base. The historical analysis (chapter 2) shows that there are multiple international; organisations involved in agricultural, ecological and environmental research: International Livestock Research Institute, International Centre for Insect and Physiology and Ecology, the World Agroforestry Centre (ICRAF), the International Potato Centre, International Crops Research Institute for the Semi-Arid Tropics, Kenya. The other international organisations are involved in health research: The Centre for Disease Control (Kenya) and CARE international centre. A further breakdown of the national collaboration shows that these international research collaborations collaborate with the local universities and public research institutes in Kenya.

7.7.2 Relative field Strength

The results presented here show that in terms of the relative field strength (RFS) Kenya performs well in relation to the world average in agricultural sciences, followed by the social sciences and the health sciences. These results are consistent with previous studies which revealed that African countries are relatively strong or active in the agricultural sciences and the health sciences (Mouton & Blanckenberg, 2018; NPCA, 2014;). The plausible explanation for the activity or specialisation in the agricultural, health and social sciences could be several factors. First, the specialisation in these fields could be linked to both government and international funding that is invested in these fields. The R&D data presented above shows that the agricultural sciences and health sciences received the highest proportions of government and international funding. Previous studies have shown a positive effect of both public and private funding on research production (Beaudry & Allaoui, 2012; Payne & Siow, 2003). Secondly, the fields that Kenya is strong could be influenced by the natural resources of the country (plant sciences, forestry etc.), the local needs of the country (food security) the health challenges (such as malaria and infectious diseases) and probably international interests. Thirdly, the historical analysis (chapter 2) I conducted shows that agricultural research and medical research in Kenya has a long history that dates back to the late 19th to the early 20th century. Therefore, there are strong scientific institutions with a strong research culture that enables Kenya to be strong in the agricultural and health sciences.

The results show that Kenya is less strong or active in the engineering sciences and humanities with a RFS-score of only 0.2. This analysis confirms a similar trend that found that African countries including Kenya are likely to be less active in the engineering sciences and humanities (Mouton and Blanckenberg, 2018). Despite less activity in engineering and applied technology, there are several initiatives that show an emphasis on research in the engineering sciences and applied technologies in Kenya. In its developmental plan, Vision 2030, Kenya acknowledges that science, innovation and technology are key for the country's economic growth and target to become a middle-income country by 2030. This has resulted in a push for increased funding and resources that are needed for science, technology, engineering and mathematics (STEM), especially in training more young engineers and other researchers (Republic of Kenya, 2007, 2013). Recently, Kenya joined the Square Kilometre Array Observatory as a partner country which shows its emphasis on technological research. There are other international initiatives to increase engineering and technological research, for instance, Microsoft selected Kenya to host one of its development centres that will help training young engineers and develop technologies needed locally (Reuters, 2019).

7.8 Factors affecting scientific production

As signalled earlier, studies have identified several factors such as individual factors (age, gender, and academic rank), disciplinary factors (scientific field), institutional policies and strategies, and structural factors (funding, mobility) to have an association with research production. In the next section, I discuss studies that analyse the relationship between age (chronological and career) and scientific output.

7.8.1 Hypothesis 1: Age and research production

The relationship between the age of scientists and their research production has been a subject of inquiry for some time now. Inasmuch as the results are not consistent, previous studies observed a "curvilinear" relationship between age and research production. In other words, on average, scientific production increases with age reaches a peak at some point during the career and later decreases (Cole, 1979; Kyvik, 1990a). Several studies below observe this pattern between age and scientific output in several fields and countries.

The classical study by Lehman (1953) on the relationship between age and achievement was the first to show that creativity in science is higher among young scientists. Lehman showed that younger scientists are more likely to make significant discoveries compared to older scientists. Lehman used histories of science as the main source of data in identifying examples of excellent achievements and then established the scientist's age at the time of making the discovery. Lehman illustrated that, from the age distributions, for many of the scientists, major discoveries or contributions occurred when they are in their late 30's and early 40's, but mainly under the age of 40, and thereafter declines.

Later, Cole (1979:959) criticised the findings by Lehman's study based on the methodology used, indicating that the study did not "take into consideration the number of scientists alive in each age group in the population". The assumption was that over time science had grown exponentially, hence the scientists' population is likely to comprise mostly of young individuals. Rather, the study used data that was of a small proportion of the population of scientists – only those who made key discoveries. According to Cole (1979:959), the study by Lehman needed to inquire on the "proportion of scientists in different age groups make discoveries", instead of the question on the key discoveries produced by researchers at different ages. Cole (1979) argued that data used by Lehman provided information that is linked more to the social system of science than to how scientific production of scientists shifts over a lifespan. Since the influential work by Lehman, many economists, psychologists and sociologists of science have extensively studied the relationship between age and scientific production and impact. Some studies have illustrated that scientists make much of their scientific contributions while young, whereas other studies have claimed that scientists make more discoveries when older.

The first set of studies argue that younger scientists tend to be more productive and are likely to have more citations compared to their older colleagues (Lehman, 1956; 1960; Over, 1988; Stephan & Levin, 1993; Weiss & Lillard, 1982). In addition, scientists tend to make significant contributions before the age of 40 (Simonton, 1984; Stern, 1978; Zuckerman & Merton, 1973; Zuckerman, 1977). There is a general assumption that that science is a "young person's game" in that the best work is produced at a relatively young age (Zuckerman & Merton, 1973). These findings resonate with Kuhn's (1962) claims, (see section 7.8.1.1.1 below for a detailed discussion) that younger scientists have 'a fresher perspective' to science, can learn the paradigms first and easily and make their significant contributions. These studies are also in support of Simonton's model (Simonton, 1984) of creativity, which demonstrates that scientists have an initial "creative potential" that declines over time. In addition, these studies follow the utility-maximising theory argument, according to which as scientists age, they tend to invest their time in other activities at the universities (e.g. administration, government secondments etc.) as a way to increase their prestige and/or income (Simonton, 1984:39). Thus, lower productivity as compared to younger scientists.

In contrast, the second group of studies demonstrates that the mid-career and older scientists are more productive and more cited compared to their younger peers (Allison & Steward, 1974; Cole & Cole 1973; Cole, 1979; Dennis, 1956; Kyvik & Olsen, 2008). These findings tend to resonate with Mertonian "Matthew effect"[17] (Merton 1968; 1973) the argument, according to which, older scientists have cumulative advantages. The cumulative advantage theory concludes that renowned researchers who receive recognition for their past significant works are likely to be more productive compared to those with no recognition (Cole, 1979). Secondly, as scientists rise in the science hierarchy, they are more likely to gain more "scientific capital", which allows them to be more productive. According to Archer *et al.*, (2015:928), "scientific capital" "is not a separate type of capital […] but derive from colliding various types of economic, social and cultural capital that specifically relates to science […] and those that have the potential […] to support and enhance the attainment, engagement or participation in science." Therefore, older scientists are more likely to have increased access to more resources research funding, graduate students, competent research assistants and more

[17] "Matthew effect" in science: "the accruing of greater increments of recognition for particular scientific contribution to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark" (Allison & Stewart:597).

international research networks, which eventually may result in higher scientific production and impact (Allison & Stewart, 1974; Cole, 1979).

For the theories discussed above, Gingras *et al.* (2008) demonstrated that both theories are of worth. Gingras *et al.* (2008) studied the effects of age on scientific productivity and impact for all Quebec professors. Gingras *et al.* found that: older professors were more productive (have access to more research funding, resources and are leaders of own research groups), whereas the younger scientists recorded higher scientific impact (measured by citations).

Studies reviewed found field differences in the relationship between age and scientific output and impact. A group of studies showed that scientists in the basic fields reach the creativity or productivity peak in their younger age, whereas scientists in the empirically based fields reach the peak later. The question then is, does the age of Kenyan scientists influence their research production?

Null Hypothesis (H_0): There is no positive association between age and the frequency of collaboration
Alternate Hypothesis (H_a): There is a positive association between age and the frequency of collaboration
Method of analysis: Three-way Analysis of Variance

7.8.1.1 Field differences in the peak age for scientific output

Several studies demonstrated field differences in the scientists' productivity peak (Cole 1979; Dennis 1966; Gonzalez-Brambila & Veloso 2007; Kyvik 1990; Levin & Stephan 1991; Weiss & Lillard 1982). These studies show that, for the natural sciences, the young scientists tend to be more productive and creative as compared to the older scientists (Cole, 1979; David, 1986; Dennis, 1966; Kyvik 1990; Lehman, 1960; Levin & Stephan 1991). Studies showed that for the basic sciences (i.e. chemistry, physics, geology, biology, material sciences, and earth sciences) the scientists' productivity peak is reached when scientists are young or middle-aged (Dennis 1966; Lehman 1960; Levin & Stephan 1991; Stephan & Levin 1993). For instance, chemistry scientists' output peaks between 26-30 ages (Lehman, 1960); for atomic physics the productivity peak is at 39 (Levin & Stephan, 1991); physics and geology output declines by age 35; for physiology output peaks in the late 30s and early 40s and by age 55 they have lower output compared to those under 35 (Cole 1979; Dennis, 1966;). Furthermore, Levin and Stephan (1991) demonstrated that for fields of solid-state physics and condensed matter physics, the scientists' output increases and then reaches the peak at age 45, and later decreases; and for geophysics publication activity peaks late in the career at age 59, and later decreases. Turner and Mairesse (2003) found that for matter physicists productivity increases and peaks at age 50, then declines. The results with citations are almost similar to those with publications.

For the natural sciences, there were exceptions for botany and mathematics (Dennis, 1966; Cole 1979). Cole (1979:958) illustrated that "age has a slight curvilinear relationship[18] with both quality and quantity of scientific output for other fields like physics with the exception of the scientists in mathematics. This implies that productivity did not decline with the increase in age for the mathematicians. Using longitudinal data for the scientists in mathematics Cole (1979) distinguished between "age and cohort effects" on productivity, thus confirming that for mathematicians' older scientists are also productive. However, David (1986) contradicts this observation as the study found that the publication activity of the mathematicians at Berkley University decreases with age. The study by David (1986) does not control for age and cohort effects as well as other individual factors that influence the scientists' productivity.

In a recent study, Costas, Van Leeuwen and Bordons, (2010) studied full-time scientists in Spain in three scientific areas (Biology & Biomedicine, Material Sciences and Natural Sciences). Costas *et al.* (2010) found that, for Biology and Biomedicine and Materials Science, the distribution of a number of research papers per scientist by age takes an inverted U-shaped curve. These results are similar to what (Gingras *et al.*, 2008) observed for the Canadian researchers. For the Natural Sciences, they observed a downward pattern in productivity by age. Material Science and Biology and Biomedicine scientists reach their highest productivity between 50 and 54, while in the Natural Sciences the scientists reach their peak between the age of 40 and 44 years (Gingras et al.:1575).

Similarly, a recent macro study of about 12, 400 Norwegian university researchers analysed five fields (humanities, social sciences, natural sciences, engineering and technology and medicine) (Aksnes, Rørstad, Piro, & Sivertsen, 2011). For the fields analysed, the study found that productivity measured by the number of publications per annum increases by age, usually to the age of 40-50, reaches a peak later in the career, and then declines. The highest scientific productivity is observed for scientists in the 50-54 and 55-59 age bracket. For the fields analysed, the study showed an increase and decline pattern in the publication rate by age, which is most distinct for engineering and technology.

The studies reviewed found contradicting results for humanities and social sciences in relation to the scientists' productivity peak. Denis (1966) showed that in fields such as history and

[18] A **Curvilinear Relationship** is a type of **relationship** between two variables whereas one variable increases, so does the other variable, but only up to a certain point, after which, as one variable continues to increase, the other decreases.

philosophy, there was no decline in output with the increase in age. These results are similar to those of Aksnes *et al.* (2011) who found that the publication rate for the older scientists in the humanities does not decline. Kyvik (1990) observes that in the social sciences the productivity of the scientists “remains more or less at the same level in all age groups”. A unique pattern is observed in the humanities, where publication activity decreases between 55-59 years old, but a new peak occurs in the 60 years old and above age group. They were exceptions for fields like psychology and sociology where the older scientists were less productive than the young researchers (Cole, 1979).

The next section expounds on factors that explain these field differences identified in the relationship between age and scientific production.

7.8.1.1.1 Factors that explain the field differences

From the above discussion, two key aspects clearly emerge. First, the huge field differences in the effect of age on scientific production. Age is more significant in some fields than others. Some authors have looked into these field differences. Several factors are linked to the field differences in the relationship between age and research production identified above. Scholars argue that "the cognitive structures” or epistemological structures of scientific fields vary (Kuhn, 1962). Kuhn notes that, for instance, fields such as physics have well developed "paradigms" whereas some fields in the social sciences are still in the "pre-paradigmatic phase" or competing paradigms (Kuhn, 1962, cited in Cole 1979:972). Other fields are likely to be highly descriptive, while others are more mathematical and theoretical. Zuckerman and Merton, (1973) describe scientific fields based on how extensive its "knowledge is codified". According to Zuckerman and Merton (1973: 507), "codification refers to the consolidation of empirical knowledge into succinct and interdependent theoretical formulations". Furthermore, Zuckerman and Merton (1973) argue that more codified fields have its knowledge “compacted” into few theories, which can be easily communicated in “mathematical language”. Following this definition, fields that are highly codified include physics and chemistry; the less codified fields comprise of botany and zoology and the least codified fields are the social sciences.

Based on the above characterisation, Zuckerman and Merton (1973) suggested that in fields like physics and chemistry where knowledge is more codified, young scientists should be able to easily make significant scientific contributions as compared to the young scientists in fields like sociology that are least codified. Zuckerman and Merton (1973) identified two main reasons for this suggestion. Firstly, knowledge in highly codified fields is more compact, thus graduate students can learn the state of the field fast and start working on their research fronts. Whereas for less codified fields, knowledge is less compacted, thus scientists need more experience to be competent. Secondly, young researchers in the more codified fields can easily make important scientific contributions in their fields, as there seems to be a general agreement on identifying which discoveries are significant or non-significant. Conversely, in the less codified fields, identifying new scientific contributions largely depends on the scientists' reputation. As the authors emphasise, "in these less codified disciplines, the personal and social attributes of scientists are more likely to influence the visibility of their ideas and the reception accorded them. As a result, work by younger scientists who, on the average, are less known in the field, will have less chance of being noticed in the less codified sciences" (Zuckerman & Merton, 1973:516). The authors conclude that, based on these two reasons, larger proportions the younger researchers in highly codified fields should be more likely to contribute scientifically as compared to the young researchers in the less codified fields.

In addition, the obsolescence theory also explains the field differences. The obsolescence theory assumes, there are expectations of "greater differences between older and younger researchers in fields where technical developments occur at a rapid pace", that is, in the natural and medical sciences as compared to the humanities and social sciences (see Kyvik, 1990a:47).

In summary, of the studies reviewed, the first set of studies argue that young scientists tend to be more productive and are likely to have more citations compared to their older colleagues. In addition, Researchers tend to make significant contributions before the age of 40. In contrast, the second set of studies argue that it is the mid-career and older scientists who are more productive and more cited compared to the younger scientists.

Field differences emerge in the age and productivity patterns. In fields like physics and chemistry which are highly codified, younger scientists tend to learn the state of knowledge fast and start working on their research fronts, thus easily make scientific discoveries than their peers in fields like sociology which are least codified. A later section discusses in detail how the extent of codification of different fields affects research production of the younger researchers.

7.8.2 Hypothesis 2: Gender and research production

Studies have investigated the relationship between gender and scientific productivity (Cole & Zuckerman 1984; Fox 2005; Long 1992; Kyvik & Teigen 1996; Turner & Mairesse 2003; Xie & Shauman 1998). Scientists' gender is a key determinant of the differences in scientific production (Cole & Zuckerman, 1984; Long, 1992). Various studies have shown that female scientists tend to publish less as compared to male scientists. These patterns emerge across different fields and countries. Cole and Zuckerman (1984:217) determined gender differences in scientific production using publication and citation data for doctoral graduates between 1969 and 1970. Cole and Zuckerman found that "women published slightly more than half (57%) as many papers as men" with the proportion declining slightly over time (Cole & Zuckerman, 1984:217). Another study analysed a sample of American biochemists and found that gender differences in the number of publications and citations are larger during the first decade of the career but the pattern later reverses (Long, 1992). Gender differences in research production need to control other factors that will influence the scientists' output.

Kyvik and Teigen, (1996:54) further analysed childcare, research collaboration and gender differences in scientific production. Their study found that childcare and lack of research collaboration are the two main factors that result in major gender differences in scientific production. Particularly, they observed, "women with young children and women who do not collaborate in research with other scientists are clearly less productive than both their male and female colleagues". The study reports, on average, male scientists produced 6.9 article equivalents during the three-year period analysed, while the female scientists published 5.6, that is about 20 per cent fewer articles.

In an in-depth study, Xie and Shauman (1998:847) examined a sample of American scientists analysing datasets from four large cross-sectional surveys spanning a 24 year period (1969, 1973, 1988 and 1993). The authors found that gender differences in scientific productivity decreased over the period analysed, "with the female-to-male ratio increasing from about 60 per cent in the late 1960s to 75-80 per cent in the late 1980s and early 1990s". According to Xie and Shauman (1998:863), "women scientists publish fewer papers than men because women are less likely than men to have personal characteristics, structural positions, and facilitating resources that are conducive to publication". Overall, the authors note that there is minimal "direct effect" of gender on scientific output (Xie & Shauman (1998:863). In addition, a study by Turner and Mairesse (2003) analysing the French condensed matter physicists observed that on average women scientists publish almost 0.9 papers less than the men scientists per year. This study supports the claim male scientists are more productive than females.

Another study also controlled for other factors that may result in gender differences in research production. Fox (2005:131) looked at the "relationship between marriage, parental status and publication productivity for women in academic science, with comparisons to men". Fox found differences in scientific output between men and women. In the analysis, Fox observed that women had 8.9 papers accepted or published in the 3-year period analysed, compared to the

11.4 papers for men. The differences in the publication rates for men and women are observed at both productivity extremes (i.e., both high and low). Fox further shows that, women are more likely as twice as men to produce zero or one publication during the period (18.8% in comparison to 10.5%); men are more likely as twice as women to produce 20 or more publications during the period analysed (15.8% for men in comparison to 8.4% for women).

Another study of Italian academics in technological scientific fields confirmed significant differences in scientific production between male and female scientists (Abramo, D'Angelo and Caprasecca, 2009:517). Abramo *et al.* (2009) observed that "males do demonstrate higher average productivity with respect to that of females for all the performance indicators considered". However, the major performance gap between the genders is in the quantitative indicators of output (i.e. number of publications), whereas for the quality indicators (i.e. citations) and contribution intensity the performance gap that exists is less pronounced. However, they noted the differences are smaller than the ones indicated in the other previous studies. Inasmuch as men generally perform better, in some scientific fields women tend to perform better. A recent study analysing longitudinal data of individual scientists and engineers demonstrated that gender is not significant to scientific production (Ponomariov & Boardman, 2010).

A large-scale study by Aksnes *et al.* (2011) of scientists and publications in all scientific fields found variations in research production between men and women, which explain the gender differences in citations observed in the study. They claim there is a cumulative advantage effect of increased scientific output on citation rates. For instance, in this study, the women produced significantly fewer papers, that is, between 20-40 per cent fewer publications compared to their male colleagues, hence minimally benefited from the cumulative advantage effect. From these studies, gender impacts the research productivity of scientists. Therefore, this study hypothesises that gender is associated with the scientific production of Kenyan scientists.

Null Hypothesis (H_0): There is no positive relationship between gender and research production

Alternate Hypothesis (H_a): There is a positive association between gender and research production

Method of analysis: Cross-tabulation, chi-square statistic

7.8.2.1 Reasons why women publish less

Given the claims that women are more likely to publish less compared to men, several studies have attempted to explain why women publish less. Long (1992) observed that the gender differences in relation to scientific production begin with their experiences of collaborating with their post-graduate mentors. For instance, through specialisation, men are more likely to be more specialised compared to women. The specialised skills might make them participate in collaborations and co-author more hence increased productivity (see Gaughan and Bozeman, 2016:539). Apart from the post-graduate experience, studies have also looked at the family status and their influence in scientific production.

Studies have shown that there are claims that, the presence of young children have a huge negative impact on the production of the female scientists as compared to that of the male scientists (Kyvik, 1990b). Apart from the family status, Aksnes and Rørstad (2015: 318) also showed that, "women occupy fewer of the highest academic posts and also are less integrated in the scientific community, for example, by positions/membership in scientific associations and on the editorial boards of journals, hence the gender differences in productivity." Authors have claimed that men are more likely to occupy these high academic posts, which might enable them to be more productive. Equally, existing variations in "personal characteristics such as ability, motivation and dedication, or in educational background" also explain the gender differences (Long, 1992:159).

The studies that show that women publish less tend to follow the "Matilda effect" studied by Margaret Rossiter. According to Rossiter (1993: 330), the "Matilda effect" refers to a case where women receive less recognition for their scientific discoveries or contributions. In some instances, women get unequal credit for their co-discoveries or co-authorships with male colleagues. Rossiter also observed that unmarried female collaborators may be under-recognised, however, "the pattern is even more pervasive among collaborative married couples" (Rossiter, 1993:330). Notably, this under-recognition of the contributions occurs "either deliberately for strategic reasons or unconsciously through traditional stereotyping" (Rossiter, 1993:330). Rossiter (1993:330) links the "Matilda effect" to the Mertonian "Matthew effect" (Merton, 1968) hence the "Matthew Matilda effect". As discussed above (section 7.5.1), given the processes of the cumulative advantage as the prominent researchers receive more recognition, they are motivated to be more productive, and for those under-recognised in this case, may not be motivated to publish more or make more scientific discoveries. That is, those with less capital are likely to get poorer, hence the Matilda effect (See Cole, 1967; Cole and Zuckerman, 1984; Merton, 1988; Rossiter, 1993).

In summary, gender is a key determinant of the differences in scientific production. Several studies reviewed show that female scientists are more productive compared to male scientists. However, some studies observed that in some instance women scientists can be more productive compared to men. Other studies have demonstrated that gender has no significant effect on scientific production. Several reasons have been identified in the literature to explain these gender differences: variations in personal characteristics, family obligations, having young children, less integration in the scientific community, less frequency of collaboration and the effects of the processes of accumulative advantage (recognition from past contributions). Apart from the scientists' gender, the scientists' academic rank is claimed to be a determinant of scientific output. The next section discusses how academic rank influences scientific production.

7.8.3 Hypothesis 3: Academic Rank and research production

Several studies have shown that an individual level, scientific production increases with the academic rank. Professors are the most productive personnel compared to scientists in the lower academic ranks (Abramo, D'Angelo, & Di Costa, 2011; Allison & Stewart, 1974; Aksnes *et al.,* 2011; Blackburn, Behymer & Hall 1978; Bordons, M., Morillo, Fernández & Gómez, 2003; Knorr-Cetina, Mittermeir, Aichholzer & Waller, 1979; Kyvik, 1991; Tien and Blackburn 1996; Trow & Fulton, 1974). These studies are expounded on below. Trow and Fulton, (1974) surveyed a sample of American college and university teachers and showed that the overall scientists' research activity does not change much after they attain the tenured rank of associate professor. The results also show that within the three top academic positions research activity tends to increase as scientists' rise the academic rank. The authors claim that, just like age as discussed above, as the scientists arise in science hierarchy, they attract more funding, resources, and increase in experience, hence, increase in productivity and impact.

Studying in the Norwegian context, Kyvik, (1991) identified four factors that are likely to explain differences in the academic ranks in relation to scientific production. Kyvik noted the factors that are unique to the higher ranks as compared to the lower ranks: the ability to conduct more research, more time is allocated to research, easy to access funding and assistance for research, and closer communication networks in science. Furthermore, cumulative advantages in science are said to explain why academics in higher ranks are likely to be more productive (Allison & Stewart, 1974). As signalled earlier, scientists in higher academic ranks are like to: receive more recognition for their past research, access funding, be leaders of large research groups (i.e. comprise of many PhD students, postdocs and other researchers). These resources and opportunities enable professors to increase their productivity and impact. Unlike the professors, who are involved in the leadership and planning of the research, the postdocs and PhD students conduct much of the research work. Professors as the leaders of the research are likely to have their names on all the papers produced in the group, unlike the PhD students who are only authors to publications they are involved indirectly (Aksnes, 2012). This shows the effects of cumulative advantage, such that the professors have more comparative advantages over academics in the lower ranks that help them be more productive.

A study studied the differences in the production of scientist in different academic ranks while considering their gender and scientific field. Bordons *et al.* (2003:160) studying Spanish researchers analysed "the differences in productivity and impact between scientists in different professional categories". Overall, the study found that scientific productivity increases as scientists rise the professional hierarchy in the two scientific fields. Particularly, in natural resources, professors produced more publications compared to the tenured scientists. Equally, the study found that the average impact factor tends to increase for both men and women as they went up to the academic rank in natural resources. In contrast, in relation to scientific impact, the study found no significant differences between genders within each academic rank in chemistry (Bordons *et al.,* 2003:165).

A large-scale study of Norwegian scientists confirmed that professors are the most productive personnel (Aksnes *et al*., 2011). A further disaggregation shows that, on average, male professors produced 9.5 publications, whereas the female professors produced 7.2 publications in the four-year period analysed. They were followed by associate professors (4.8 publications), post-doctoral fellows (4.5 publications) whereas PhD students recorded the lowest productivity (2.9 and 2.4 publications for males and females respectively). The pattern is similar for female scientists. However, the average publication activity is much lower for the female scientist (Aksnes *et al*., 2011).

In addition, a study by Rørstad and Aksnes (2015) using regression analysis (OLS) investigated 12, 400 Norwegian university researchers, in six fields, humanities, social sciences, natural sciences, medicine and engineering and technology. The study demonstrated that the academic position to be a key factor in productivity as compared to age and gender. Overall, professors are more productive in all the fields investigated and across the genders. The associate professors follow, though their productivity is somewhat lower than that of the professors by 20-30 per cent (ranging from 19 per cent in the social sciences to 30 per cent in engineering and technology). Postdoctoral students were found to have much lower productivity levels compared to the associate professors in the three fields examined, while the publication rate was somewhat higher in the other two fields. Unsurprisingly, PhD students recorded the lowest publication rates in all the fields investigated. This study identified field differences in the publication rate of different academic positions. On average, in the natural sciences and engineering and technology, professors produced the highest proportion of output (at least 50%), followed by associate professors, post-doctoral and PhD students. In medicine, the female professors and associate professors were more productive compared to their male colleagues. In contrast to the other major fields analysed, in the social sciences postdocs produce more publications as compared to the associate professors, with 1.53 and 1.44 article equivalents, respectively. In the humanities, the male PhD students were found to be more productive than their female colleagues, however, no gender differences were observed for the associate professors and postdocs (see Rørstad and Aksnes, 2015). This study asks the question, is academic rank associated with the scientific production of Kenyan scientists?

Null Hypothesis (H_0): There is no positive association between academic rank and research production

Alternate Hypothesis (H_a): There is a positive association between academic rank and research production

Method of analysis: Cross-tabulation, chi-square statistic

From the above discussion, the reviews show that senior professors are more productive compared to their colleagues in the lower ranks, that is, associate professors, lecturers, postdocs and PhD graduates. The studies observe field differences in the academic rank and publication rates. For instance, although professors were the most productive in the natural sciences and engineering and technology, the postdocs were more productive in the social sciences as compared to the associate professors. Nevertheless, it has been observed that in general, as it is the case for older scientists, senior professors are likely to have the accumulative advantage (Merton, 1968) over the scientists in the lower academic ranks, like associate and assistant professors, which hence lead to their higher levels of scientific productivity. As already signalled in the previous discussions, scientific production varies by scientific field. The next section discusses in detail how the scientific field influences research production.

7.8.4 Hypothesis 3: Scientific field and research production

The literature identifies the scientific field as a key determinant in publication patterns and rates. An analysis at Norwegian universities demonstrated uniform publication patterns within each field analysed; however, there were noteworthy exceptions (Piro *et al.*, 2013). Piro *et al.*

(2013) used a detailed and complete publication dataset for all the scientists at Norwegian universities over a period of 4 years. They compared the scientific production in five broad scientific fields and sub-fields (i.e. natural sciences, medicine, humanities, social sciences, engineering and applied technology), with age, gender and academic positions. The study found that, "researchers from medicine, natural sciences, and technology are most productive when whole counts of publications are used, while researchers from the humanities and social sciences are most productive when article counts are fractionalised according to the total number of authors" (Piro *et al.*, 2013:307). The variations in the scientific field production are dependent on the counting methods[19] used in measuring publications.

In their study, Aksnes and Rørstad, (2015) established field differences in the publication activity of scientists. The study showed that scientists in engineering and technology produced somewhat more publications compared to their colleagues in the natural sciences. In addition, the scientists in the social sciences recorded higher publication rates as compared to the scientists in the natural sciences, engineering and technology. On average, the scientists in the social sciences published 1.5 articles per year, whereas scientists in the 'hard' sciences published between 0.6 and 1.0 articles per annum. The different publication patterns in the social sciences explain the differences in the publication rates as compared to the other fields investigated. For instance, in the social sciences, an article consists of fewer authors unlike for the articles published within medicine, natural sciences and engineering and technology (Moed, Glänzel & Schmoch, 2004). Additionally, scientists in the social sciences mostly produce monographs. The study also found that scientists in the humanities have higher publication rates than the other major fields with 2.02 article equivalents per year. As is the case in the social sciences, the different publication patterns, coupled with a higher number of monographs produced explain these field differences (Moed *et al.,* 2004.). These studies show huge field differences in publication patterns and rates. Several reasons in the literature attempt to explain these differences including knowledge codification, collaboration patterns, funding patterns and availability of resources.

As discussed above, these huge field differences in the publication patterns and rates have links to the differences in the "codification of knowledge" among fields, which then influences moving forward to the research fronts as well as identification of significant scientific contributions (see Merton & Zuckerman, 1973). In this case, another possible explanation is the differences in the collaboration patterns and forms across the scientific fields (see Katz and Martin, 1997; Ponomariov and Boardman, 2016; Smith and Katz, 2000;). For instance, in

[19] There are two main methods of measuring research production: full or whole counting method and fractional counting methods. The full counting method attributes full credits or counts to the collaborating individual, institution or country. Whereas, in fractional counting, all the collaborators share one credit (Huang *et al.*, 2011).

medical sciences, scientists tend to work in large teams and collaborate more, as compared to the humanities and social sciences where scientists tend to work as individuals and collaborate less. AS it will be discussed in detail in the next chapter (chapter 8), studies have shown that higher collaboration may result in higher publication rates. However, given the huge field differences in the patterns and forms of publication and co-authorship, as observed in the study by Piro *et al*. (2013), scholars have questioned the use of publication indicators to compare scientific production across scientific disciplines (see Costas & Bordons, 2007; Hirsch, 2005; Moed *et a*l., 2004;).

In addition, studies show that publication behaviours vary across disciplines (Moed *et al*., 2004). For instance, in fields like Social sciences scientists tend to produce books, whereas scientists produce more conference papers in engineering and technology. Therefore, these differences have to be accounted for when comparing the outputs of different fields. Given the huge field differences, when one is making comparisons of production levels across disciplines, normalisation by field is crucial in the analysis (Sugimoto and Larivière, 2018). Based on the findings of previous studies, the current study hypothesises that the scientific field is associated with the scientific production of Kenyan scientists.

Null Hypothesis (H_0): There is no positive association between the scientific field and research production Alternate Hypothesis (H_a): There is a positive association between the scientific field and research production Method of analysis: Cross-tabulation, chi-square statistic

Studies reviewed in this section have identified field differences in the publication patterns and rates. For instance, the studies show that there is higher productivity in the natural sciences when the whole counting is used, compared to the social sciences and humanities that have higher output when fractional counting used. Some studies also showed higher productivity in the social sciences as compared to the natural sciences and engineering and technology. Several reasons explain these field differences including knowledge codification in the different fields, access to funding and resources in the different fields and the different collaboration patterns.

7.9 Summary of the literature review

Furthermore, the literature reviewed shows that there are different factors that influence scientists' productivity: individual factors such as, age, gender, and scientific field and academic position. The relationship between age and research output found mixed results. The first group of studies claimed that younger scientists are more productive than older scientists are. On the other end, the second group of students argued that older scientists are more productive compared to young scientists. The first group of studies are in support of the Simonton model, which argues that creative potential is higher in young scientists. The second group are in support of the Mertonian recognition theory, where older scientist tends to access more funding and resources that enable them to be productive. Just as is the case of age, the studies showed that as academic rise up the academic ranks, they tend to be more productive as compared to scientists in the lower ranks.

Furthermore, studies showed, women are more likely to publish less as compared to men. These observations are in support of Rossitter's Matilda effect (recognition) which claims that women are likely not to receive recognition for their work, which might make them less productive. The gender difference in research production is also explained by differences in the personal characteristics, family obligations and having young children and less collaboration among women scientists. The field differences in relation to scientific output have been explained knowledge codification whereby in fields that are highly codified like natural sciences, scientists are more likely to start working early on their research fronts, which allows them to be more productive. The different collaborative patterns that exist between fields also explain why fields like the medical sciences are more likely to have more publications as compared to the humanities.

Based on the findings observed in the previous studies, the current study hypothesises that individual and disciplinary factors (age, gender, academic rank and scientific) have a relationship with scientific production. The next section(s) reports on the volume of research publications as well as the relationship between these individual factors and scientific output

7.10 Reported volume of research publications

In the African Young Scientists Survey conducted in 2016, respondents were asked to report on the volume of research output they had produced for the past three years prior to data collection. Respondents reported on six categories of output (i.e. articles, books, book chapters, conference papers, policy documents and popular articles), as illustrated on the table below (Table 7.5). I conducted a secondary analysis of the survey. In this section, I present results on 'reported' volume of publications. However, there are claims that 'self-reported' publications can result to some biases (under- and over-estimation of the volume of publications); we argue that the size of our sample reduces some of the major biases in our results.

7.10.1 Mean and median scientific outputs by scientific field

Table 7-4: Mean and median scientific outputs by scientific field

Field		Articles	Books	Book chapters	Conference papers	Policy documents	Popular articles
Natural sciences	N	50	41	36	48	40	38
	Mean	23.76	12.78	6.56	7.54	9.08	6.87
	Median	6.50	0.00	1.00	3.00	1.50	1.00
Agricultural sciences	N	39	26	31	38	30	28
	Mean	12.46	4.58	7.81	5.74	4.97	1.75
	Median	5.00	0.00	1.00	2.50	1.00	2.00
Engineering and applied technologies	N	18	12	14	16	16	14
	Mean	10.67	25.08	15.57	16.06	15.69	15.43
	Median	3.50	0.00	1.50	3.00	3.00	1.50
Health Sciences	N	47	34	34	42	37	37
	Mean	16.40	15.12	12.09	9.00	9.76	7,49
	Median	5.00	0.00	0.00	2.50	2.00	2.00
Humanities	N	10	9	9	8	9	9
	Mean	15.70	24.56	4.89	4.75	2.78	5.11
	Median	4.50	4.00	4.00	4.00	3.00	5.00
Social sciences	N	44	35	40	38	38	36
	Mean	18.32	18.06	6.80	11.71	13.84	19.64
	Median	4.50	1.00	2.00	3.00	3.00	2.00
Total	N	208	157	164	190	170	162
	Mean	17.31	14.72	8.68	8.94	9.85	9.60
	Median	5.00	0.00	1.00	3.00	2.00	2.00

Table 7-4 above shows the results of the reported research output disaggregated by the scientific field. The medians and means of the reported number of show small but noteworthy variations of output by field – with the median and mean of the natural sciences highest, at 6.5 and 23.76 respectively. Respondents in the natural sciences reported the highest number of articles. Respondents in the agricultural sciences and engineering and applied technologies reported lower numbers of articles, illustrated by means of 12.46 and 10.67 respectively. As expected, respondents in the engineering sciences, humanities and social sciences reported notable numbers of published books (with a median of 4). The results also show that the respondents in the engineering sciences recorded the highest number of book chapters. In addition, the medians show that noteworthy numbers of conference papers published in proceedings were reported in engineering sciences and humanities. Respondents reported high numbers of policy documents with the exception of natural and agricultural sciences. Lastly, respondents in all fields reported having written popular articles, as engineering and social sciences reported the highest numbers, while scientists in the agricultural sciences and humanities recorded the lowest numbers. A notable number of popular articles in some fields illustrates that scientists are keen on popularising their research.

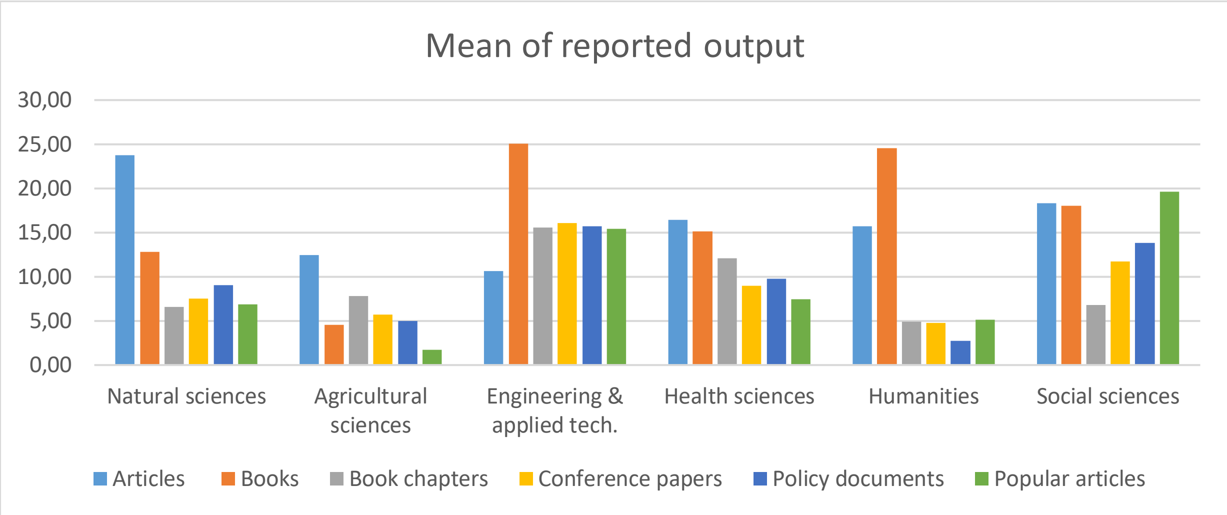

Figure 7-22: Mean reported article output by scientific field

7.10.2 Discussion

My findings indicate that scientists in the natural sciences reported the highest number of articles of the six fields analysed, while agricultural and engineering sciences recorded the lowest number of articles compared to the natural sciences. In general, this finding is congruent with the findings in the literature, which found a higher number of articles, or output in the natural sciences (Kuhn, 1962; Kyvik, 1990; Kyvik & Olsen, 2003; Levin & Stephan, 1991; Piro *et al.*, 2013). In relation to lower numbers of articles in the engineering and agricultural sciences, compared to the natural sciences, my results are in contrast to the findings of previous studies, which found higher numbers of articles in engineering and technology (Kyvik & Olsen, 2003; Piro *et al.,* 2013). In Norway, however, one study found that scientists in the engineering sciences published a higher number of articles compared to those in the natural sciences. This study also found that scientists in the social sciences recorded a higher number of articles compared to scientists in the natural sciences and engineering and technology (Piro *et al.,* 2013).

The results, thus, partially support the hypothesis that scientific fields (natural sciences, social sciences, agricultural sciences, health sciences, humanities and engineering and technology) have a positive association with scientific production. In chapter 8 and 9, I discussed the literature, which suggests that the many theoretical frameworks, the competing paradigms and difficulties in identifying the scientific discoveries in the social sciences and humanities, make mastering of concepts and identification of research problems difficult compared to the natural sciences (Kuhn, 1962; Zuckerman & Merton, 1973). Scholarship illustrates that the natural sciences have developed paradigms and it is easy to identify scientific discoveries or contributions, which as a result eases identification (Kuhn, 1962). These characteristics of scientific fields thus influence scientists' output.

The literature reviewed in chapters 8 and 9 argues that scientific fields, and the way in which they are practised, represent particular characteristics. Several scholars suggested that these characteristics affect publication rates and patterns in different scientific fields (Fry & Talja, 2007; Whitley, 2000; Zuckerman & Merton, 1973). These include cognitive or epistemological structures of scientific fields, the methods in use in empirical research, the levels of methodological and theoretical agreement, the modes of reporting and the objectives of scientific research, among others (Fry & Talja, 2007; Kuhn, 1962; Whitley, 2000; Zuckerman & Merton, 1973). This has resulted to a number of scholars arguing scientists in the natural sciences are more like to be productive as compared to the scientists in the social sciences or humanities (Lehman, 1960; Levin & Stephan 1991).

My findings demonstrate field differences in publication behaviour. The results indicate that scientists in engineering sciences humanities and social sciences reported the highest number of books, as compared to the natural and agricultural sciences where books play a minor role. This finding is congruent with the findings in the literature, which found a higher proportion (60%) of books in humanities (Kyvik & Olsen, 2003). Similarly, in relation to high numbers of book chapters in engineering, my results support those found in studies by Kyvik and Olsen (2003). Scholars argue that book chapters are more common in engineering because of many conference papers published in proceedings in the field (Kyvik & Olsen, 2003). Following the argument, conference proceedings are the preferred publication outlet in engineering sciences, similarly, in my analysis, scientists in engineering and applied technology reported they had the largest number of conference papers published in proceedings, hence a large number of book chapters. My findings also showed that scientist in the humanities recorded the highest number of popular articles. This result is in support of a previous study, which found that academics in humanities and social sciences are more engaged in the writing of popular articles, compared to the natural and medical sciences (Kyvik & Olsen, 2003). The results above suggest that while the different scientific fields can be compared in terms of their publication activity, the analysis has to account for the field differences in the publication forms.

For instance, while the medical and natural sciences can be compared as they mostly produce articles, a comparison with the social sciences and humanities will only be adequate and impartial, when monographs and book chapters are incorporated as measures of production (Piro *et al*., 2013).

The results, therefore, partially support the hypothesis that scientific fields have a relationship with research production. This relationship is illustrated in the field differences in the output and publication forms. Scientists in some fields such as the natural sciences reported the highest number of articles, compared to the scientists in the humanities and engineering sciences who recorded a higher number of book and book chapters.

In the next sub-sections, I analyse the main categories of research publications and their relationship with age, gender and scientific field using the three-way analyses of variance. In particular, I report the results on how the research output correlate with other variables such as scientific field, age and gender.

7.10.2 Reported article output: Age, scientific field and gender

My first set of analysis focused on the reported scientific articles in peer-reviewed journals. My main finding is congruent with the literature, indicating that younger scientists reported to have produced a lower number of scientific articles in the preceding three years, median and mean (4.0, 9.54) as compared to the older scientists (5.0, 22.62). Findings in the literature showed as publication output tend to be influenced gender and scientific field, in my analysis, I controlled for these variables. I conducted a three-way between-group analysis of variance to test the relationship between age, gender and scientific field with article output.

The three-way between-group ANOVA results showed a statistically significant interaction effect between the three independent variables, age, scientific field and gender, $F(2, 2904) = 2.926$, $p = 0.05$. The results in table 9.2 showed that the interaction effects (age and output; scientific field and output; gender and output) were all statistically significant at $p<0.05$. The largest effect was found between age, scientific field and article output.

Table 7-5: Reported article output by age, field and gender

		39 or younger			40-50			Older than 50		
Field		N	Mean	Median	N	Mean	Median	N	Mean	Median
Natural sciences	Male	11	15.18	6,00	17	30,47	10,00	10	35,30	10,00
	Female	3	2,00	2,00	2	5,00	5,00	6	21,67	4,00
	Total	14	12,36	5,00	19	27,79	10,00	16	30,19	9,00

Agricultural sciences	Male	12	4,42	3,50	9	28,00	8,00	7	19,14	5,00
	Female	4	2,00	1,50	5	5,40	5,00	1	10,00	10,00
	Total	16	3,81	3,00	14	19,93	6,00	8	18,00	6,50
Engineering and applied technologies	Male	4	5,25	3,50	7	20,29	9,00	5	5,20	3,00
	Female	1	2,00	2,00	0	0,00	0,00	1	1,00	1,00
	Total	5	4,60	3,00	7	20,29	9,00	6	4,50	2,50
Health Sciences	Male	9	4,78	3,00	12	14,67	5,00	9	29,89	13,00
	Female	9	15,22	3,00	4	30,50	10,00	4	6,00	4,00
	Total	18	10,00	3,00	16	18,63	5,50	13	22,54	10,00
Humanities	Male				4	6,25	4,00	4	29,25	6,00
	Female							2	7,50	7,50
	Total				4	6,25	4,00	6	22,00	6,00
Social sciences	Male	2	4,00	4,00	23	18,13	6,00	6	20,83	3,00
	Female	6	22,83	7,00	3	2,33	3,00	3	36,00	4,00
	Total	8	18,13	6,00	26	16,31	5,00	9	25,89	3,00
Total	Male	38	7,68	4,00	72	21,25	6,00	41	24,98	8,00
	Female	23	12,61	2,00	14	11,86	5,00	17	16,94	4,00
	Total	61	9,54	4,00	86	19,72	6,00	58	22,62	5,00

Older respondents in our sample regardless of their gender and scientific field reported having produced a higher number of articles in the preceding years. The results show that respondents older than 50 years reported having produced a mean and median of 22.62 and 5 articles compared a mean and median of 19.72 and 6 articles for those between 40 and 50 years and a mean and median of 9.54 and 4 articles for those 39 years or younger. These results are in support of the findings in the literature which found that the mid-career and older scientists are more productive compared to their younger counterparts (Allison & Steward, 1984; Cole 1979; Cole & Cole 1973; Dennis, 1966; Gingras *et al*., 2008; Kyvik & Olsen, 2008).

In section 7.5.1, I discussed the theoretical and empirical scholarship, which argues that, as scientists rise in the science hierarchy, they access more funding, lead large research groups, have more research assistants, access more research resources and supervise more graduate students, thus, increase their scientific output and impact (Allison & Steward, 1984; Cole, 1979; Kyvik & Olsen, 2008; Merton 1968; 1973).

Figure 7-22 below illustrates the means of the reported articles by the scientific field, age and gender.

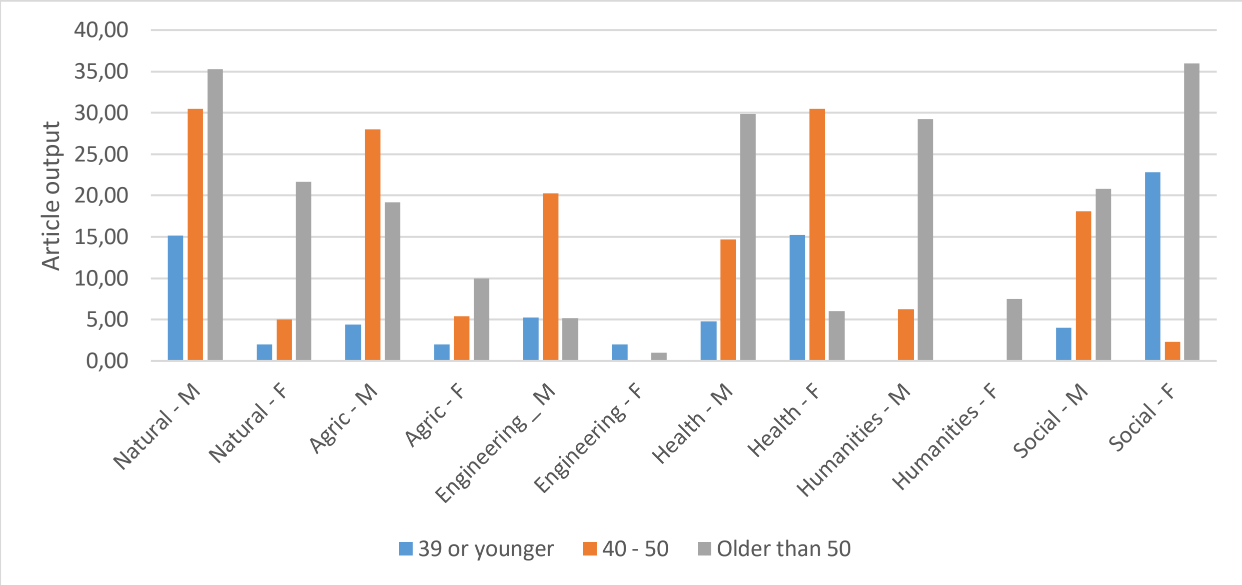

Figure 7-23: means of reported articles by age, scientific field and gender

When controlling for the field and gender, our results show that male respondents (with the exception of the young and middle-aged researchers in the health sciences) reported higher numbers of articles compared to their female counterparts. My results show that, in the field of engineering, female scientists who were 40-50 years at the time of the survey reported to have published zero articles. In the health sciences, more women who were 39 years or younger and 40-to 50 years reported having published a higher number of articles. Those female scientists who were 39 years or younger and 40-to 50 years, at the time of the survey, on average reported having published a median of 15.2 articles and 10 articles respectively, in the preceding three years, compared to a median of 4.8 articles and 5 articles for the male scientists in the same age categories. In the social sciences, women scientists who were 39 years or younger and older than 50 years, reported to have published more articles, a median of 7 articles and 4 articles respectively, compared to a median of 4 articles and 3 articles for the male scientists is in the same age categories. These results are partly in support of the findings in the literature, which found gender differences in scientific productivity, arguing that women scientists tend to publish fewer papers compared to the male scientists (Aksnes *et al*., 2011; Cole and Zuckerman, 1984; Kyvik & Teigen, 1996; Piro *et al*., 2013; Xie and Shauman, 1998). My results partially support a study that found a similar pattern, where male scientists were more productive for almost all age categories and scientific fields, with few exceptions (Aksnes *et al.,* 2011). However, it is important to look at the gender balance in the fields, given the claims that, a higher proportion of women are associated with lower publication output. A total of 25.5% (N=57) of our sample are women, and the highest proportions of women are found in the health sciences (29.8%) and social sciences (24.6%). The proportion of women is much lower in the agricultural sciences (19.3%), natural sciences (19.3%), humanities (3.5%), and engineering and applied technology (3.5%). These results do not support gender as an explanatory factor of the scientific field differences in publication output, given that female scientists are well represented in the two scientific fields where their publication output is highest, in terms of a number of articles.

7.10.3 Reported book output: Age, gender and scientific field

Table 7-6 below presents results on the reported number of books disaggregated by age, scientific field and gender. The means of engineering and applied technologies and health sciences show significant numbers (for the 39 or younger) reported that in the other fields. In particular, older respondents, in engineering and applied technologies and humanities reported significant numbers of books. The ANOVA results do not show statistically significant results between the young and older scientists (when controlling gender and the scientific field), F (2, 1316.56) = 1.096, P=0.33.

Table 7-6: Reported book output, by age, scientific field and gender

Field		39 or younger			40 - 50			Older than 50		
		N	Mean	Median	N	Mean	Median	N	Mean	Median
Natural sciences	Male	10	20,30	0,50	13	16,46	0,00	9	0,56	0,00
	Female	2	0,00	0,00	2	50,00	50,00	5	0,40	0,00
	Total	12	16,92	0,00	15	20,93	0,00	14	0,50	0,00
Agricultural sciences	Male	9	11,44	0,00	8	0,50	0,00	4	2,75	2,00
	Female	2	0,50	0,50	3	0,00	0,00			
	Total	11	9,45	0,00	11	0,36	0,00	4	2,75	2,00
Engineering and applied technologies	Male	3	33,33	0,00	5	0,00	0,00	3	66,67	100,00
	Female							1	1,00	1,00
	Total	3	33,33	0,00	5	0,00	0,00	4	50,25	50,50
Health sciences	Male	7	28,57	0,00	7	0,14	0,00	7	1,71	0,00
	Female	7	28,57	0,00	4	25,00	0,00	2	0,50	0,50
	Total	14	28,57	0,00	11	9,18	0,00	9	1,44	0,00
Humanities	Male							4	27,75	5,00
	Female							1	2,00	2,00
	Total							5	22,60	4,00
Social sciences	Male	2	0,50	0,50	19	27,32	1,00	4	1,50	1,50
	Female	6	17,00	0,50	1	0,00	0,00	2	0,50	0,50
	Total	8	12,88	0,50	20	25,95	1,00	6	1,17	1,00

Total	Male	31	19,58	0,00	56	15,11	0,00	31	11,13	1,00
	Female	17	17,82	0,00	10	20,00	0,00	11	0,64	0,00
	Total	48	18,96	0,00	66	15,85	0,00	42	8,38	1,00

The figure 7-23 below present the detailed interaction between age, scientific field and gender. Respondents between 40 and 50 (female) in the natural sciences reported high numbers of books.

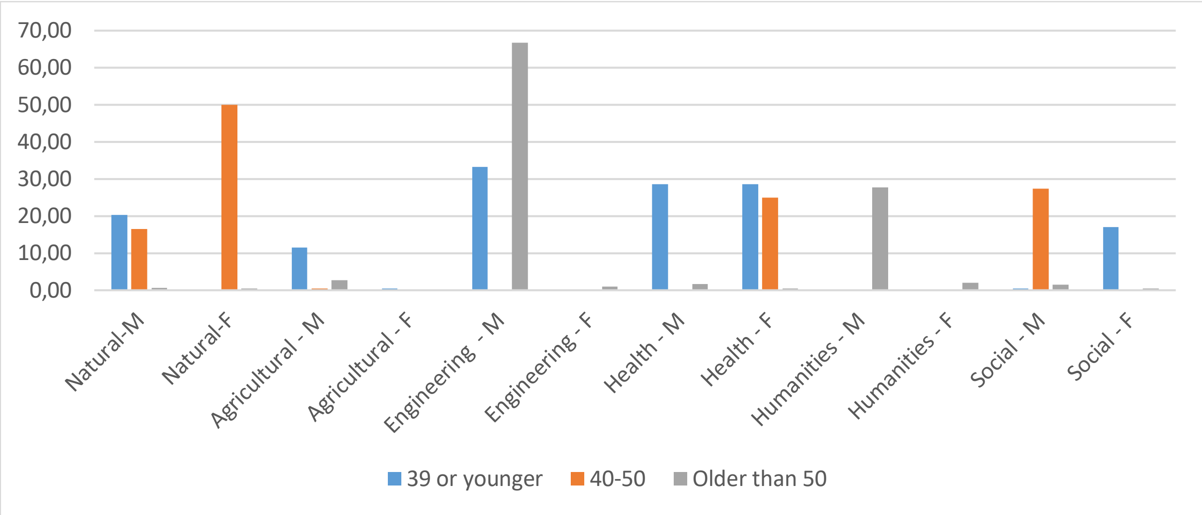

Figure 7-24: means of reported book output by age, scientific field and gender

When controlling for field and gender, both young and older respondents reported low numbers of books.

7.10.4 Reported Conference papers published in proceedings: Age, scientific field and gender

The table 7-7 illustrates the reported conference output disaggregated by gender, age and scientific field.

Table 7-7: Reported conference output by age, gender and scientific output

		39 or younger			40-50			Older than 50		
		Mean	Median	N	Mean	Median	N	Mean	Median	N
Natural sciences	Male	12,82	4,00	11	3,50	2,50	16	14,56	4,00	9
	Female	1,33	1,00	3	3,00	3,00	2	3,17	2,50	6
	Total	10,36	2,50	14	3,44	3,00	18	10,00	3,00	15
	Male	3,18	2,00	11	2,70	2,00	10	18,86	6,00	7

Agricultural sciences	Female	1,50	1,50	2	2,50	3,00	6	5,00	5,00	1
	Total	2,92	2,00	13	2,63	2,50	16	17,13	5,50	8
Engineering and applied technologies	Male	5,00	2,50	4	17,29	4,00	7	35,00	3,00	3
	Female	10,00	10,00	1				1,00	1,00	1
	Total	6,00	3,00	5	17,29	4,00	7	26,50	2,00	4
Health Sciences	Male	2,88	2,00	8	5,27	2,00	11	6,57	3,00	7
	Female	16,25	3,00	8	27,75	4,50	4	2,50	2,50	4
	Total	9,56	2,00	16	11,27	4,00	15	5,09	3,00	11
Humanities	Male				4,33	5,00	3	4,33	3,00	3
	Female							6,00	6,00	2
	Total				4,33	5,00	3	5,00	3,00	5
Social sciences	Male	0,00	0,00	13,65	3,00	20	3	26,00	7,00	5
	Female	3,50	2,00	2,50	2,50	2		4,67	1,00	3
	Total	3,00	2,00	12,64	3,00	22	3	18,00	5,50	8
Total	Male	6,26	2,00	8,18	3,00	67	67	16,38	4,00	34
	Female	8,40	2,00	9,79	3,00	14	14	3,59	2,00	17
	Total	7,04	2,00	8,46	3,00	81	81	12,12	3,00	51

Notably, conference papers are popular publication modes in some disciplines such as engineering, mathematics and computer science (Goodrum, McCain, Lawrence, & Giles, 2001; Glänzel, Schlemmer, & Schubert, 2006; Montesi & Owen, 2008; Zhang & Glänzel, 2012). Our results show that respondents in the engineering and applied technologies field, especially older respondents, reported the highest average number of conference papers, compared to the respondents in other scientific fields. The average reported output for the scientists who were 39 years or younger is 6.0 papers, while for those who were between 40 and 50 years is 17.29 papers and for those who were older than 50 years is 26.50 papers. ANOVA results show no statistically significant interaction effect between age, scientific field and gender. The results show that older respondents produced more conference papers. Although, the results show no statistically significant interaction effect between gender and any of the scientific fields. Older women in the field of engineering and applied technologies reported the highest averages (35.00) of conference papers followed by the older male respondents in the social sciences (26.00).

Mean reported conference papers in proceedings by age, gender and scientific field

Figure 7-24 reports on the conference papers in proceeding disaggregated by age, gender and scientific field. When controlling for the field and gender, our analysis shows that older than 50 male respondents with the exception of health sciences, reported a high number of conference papers as compared to their female peers. For the health sciences, females between 40 and 50 years, reported the highest number of conference papers. These results are consistent with the findings of the studies reviewed here, as over 50 years older researchers were found to have the highest research output.

Means of reported conference papers by age, gender and scientific filed

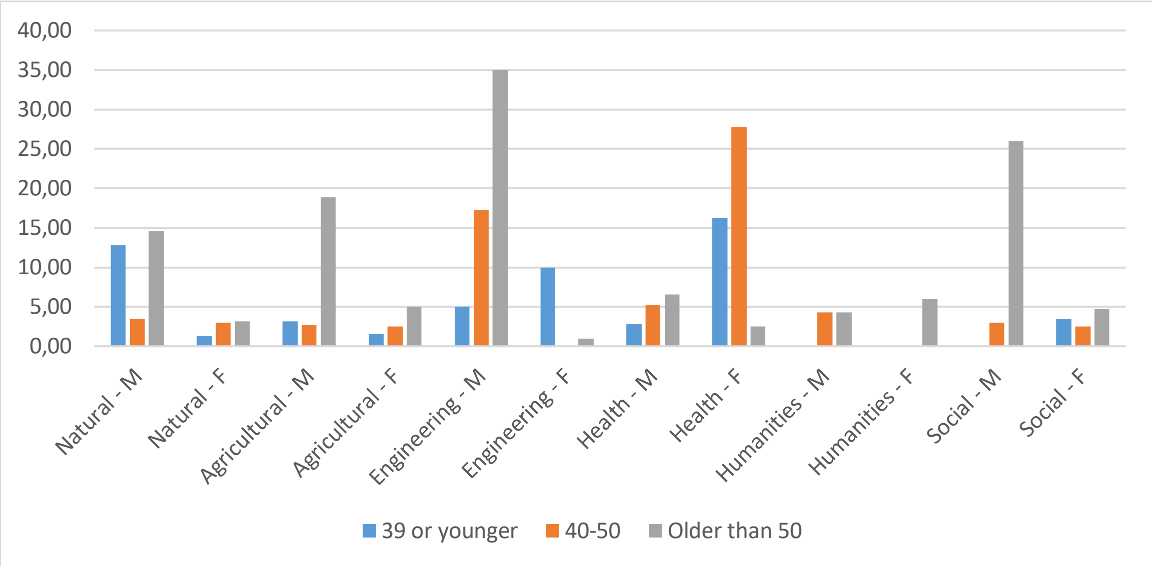

Figure 7-25: means of reported conference papers output by age, scientific field and gender

7.10.5 Discussion

My results are in support of the scholarship, which showed that older scientists are more productive compared to the younger researchers (Cole, 1979; Gingras *et al.,* 2008; Merton, 1968; Kyvik, 1990). In relation high numbers of conference papers reported by older scientists (irrespective of gender and scientific field) in engineering, my results support a previous study that found higher publication output amongst researchers older than 50 years in the field of engineering sciences.

The literature reviewed suggest that conference papers published in proceedings are regarded as a substitute for journal publications in the engineering sciences (Glänzel *et al.,* 2006; Goodrum *et al.,* 2001; Montesi & Owen, 2008; Zhang & Glänzel, 2012). My results are congruent with the findings in the literature, in relation to a high number of conference papers in engineering and applied technology. A number of scholars observed that, in software engineering and computing fields conference papers published in proceedings are regarded as a final scientific output, which is counted in evaluations of scientific productivity of scientists, hence they see no need to republish the results in journals (Goodrum *et al.,* 2001; Montesi & Owen, 2008). Similarly, with regard to scientists in the social sciences and humanities recording the highest number of conference papers, my results support those found in a previous analysis of proceedings in the social sciences and humanities (Glänzel *et al.,* 2006). According to Glänzel *et al.* (2006), conference proceedings are considered as a supplement to the journal publications. Importantly, inasmuch as conference proceedings are considered a final scientific output and a supplement to journal publication, scholars claim that a journal article deriving from a conference indicates its high quality (Zhang & Glänzel, 2012).

7.11 Enablers and constraints of scientific publishing

During the interviews, respondents expounded on several matters associated with scientific publishing: 1) the increasing demand for the scientists to publish; 2) the consequences of the demand for publication; 3) the constraints to publishing scientific research as perceived by the young Kenyan scientists; and 4) suggestions by the young scientists in areas that they need support, training and mentoring. I will start by discussing the themes that emerged during the interviews that are linked to the increasing demand for scientists.

7.11.1 The consequences of the demand for publication

This section discusses the consequences of the increased demand for researchers at universities and other scientific institutions to publish. The demand to publish

Given the demand for scientists in Kenya to conduct research and publish, researchers have devised several strategies to enable them to publish more articles amidst several constraints. One of the strategies reported by the respondents is publishing from their research as final year undergraduate students (fourth or fifth year) or from their PhD research. In Kenya, as a measure to improve the quality of teaching, supervision and research in universities, the Commission of University Education (CUE) requires masters and PhD students to publish at least an article or two in a refereed journal before they graduate (CUE, 2016). During the interviews, some participants who had been productive in the preceding three years before the survey reported that the increase in their publications was as a result of publishing their work as final year students and publishing with the postgraduate students they supervise.

> It also eludes the few I published when I was a fifth-year student … But most of the papers you know I get a lot of submissions that I do. So, it's easy to get papers applications from students' work that I supervise, actually. (40-year-old male respondent from Kenya, R_078)

Given the demand to publish, especially in the context of heavy workloads, respondents, especially those in the field of engineering reported they focused on publishing papers in conference proceedings compared to journal articles, citing the time it takes to prepare and publish a journal article.

> … why I have focussed specifically on the proceedings for conferences, rather than articles … I think it's time to take that paper to the maturity it needs for a journal. That's the main problem since I came back, now since I came back to Kenya. (33-year-old male respondent from Kenya, R_072)

7.11.2 The constraints to publishing scientific research as perceived by the young Kenyan scientists

In this section I discuss the constraints to publishing scientific research as based on the perceptions of the young scientists in Kenya. Lack of conducive environment

Respondents felt that despite having the interest in engaging in research and publish, they are faced with the challenges of poor remuneration, weak incentive structures and weak institutional policies or structures from the university and government. Research is assumed not to have additional monetary value to salaries, therefore, scientists opt to engage in additional teaching at different local universities to augment their meagre pay. Given the additional teaching and heavy workloads, scientists have limited time to engage in research and publish.

> And, another challenge is that even though I have interests in doing research, since doing research, it doesn't add any monetary value. You always tend not to spend much time on it, because your salary will not change, and you find that, like, specific to my country, that salary is really very limited also because the university's taken as a government institution. So, what's happened is that we're ending putting more time on teaching from one institution to another. And the time left for research is also very limited because even if we're getting funding from outside, the funding will not allow salaries just for research, yes. So, there is another challenge … because the challenge in some countries is that you know lecturers are paid very little. And from what they are paid, they cannot survive, so they end up doing other things apart of… You know, the hours they're allocated, and yes. (32-year-old male respondent from Kenya, R_192)

7.11.2.1 No recognition

In addition, apart from the poor remuneration, participants reported that they received little or no recognition and incentives for publishing their research.

> It's not paid, there's not an incentive or there's compensation or any … recognition, we just like publishing the paper, there is no extra recognition for… Because they've published a paper, something like that. (32-year-old male respondent from Kenya, R_192)

Respondents felt that neither published research or training/supervising postgraduate students determine the success of their promotion from one rank to the other. Respondents reported that even after publishing and producing a good number of PhD students, their promotion applications have been unsuccessful, resulting in them staying longer in one rank.

> Well, to some extent you may find that at least you have mentored students, but sometimes you don't move as you expect to move. You start late when you are published like right now I think when I want to talk, try next year if I can get [unclear] professor because I have supervised about 11 PhDs. So, I want to see, but sometimes you apply, and you don't get moved, so that is the challenge. (40-year-old male respondent from Kenya, R_078).

In general, some interviewees are of the perception that universities in Kenya lack incentives to encourage scientists to publish their research.

> I can't say there are any incentives [for publishing], there are really no incentives. (33-year-old male respondent from Kenya, R_072).

However, amidst the claims that there no incentives for research, some respondents reported that there are some recent initiatives from African institutions to incentivise research and improve the salaries.

> The incentives, yes. But I… Recently I saw something very, very, very interesting. I think it was coming from the African Union or the African Academy of Science. Yes. Like, yes, I think they open a call for those who are coming from a government institution in Africa, and that's complete their PhD, and they are planning to do research. That they do research and they will avail 50% more of their salary. And I believe this will be…a start and bring change. (32-year-old male respondent from Kenya, R_192).

7.11.2.2 Limited time resources and heavy workload

As signalled earlier, participants in the interview reported they spend much time on teaching and supervising postgraduate students (masters and PhDs), thus, given these roles together with administrative duties, respondents indicated that they have limited time dedicated to research and publishing.

> Time for my own research is an issue because I spend most of my time reading students' theses and giving feedback and teaching many undergraduate students. In Kenya, we have so many undergraduates in one class. Like currently I am teaching an undergraduate class, fourth-year groups, that is about over 800 students. I am one lecturer. And there are no tutorials, there are

> no marking assistants. So, the workload doesn't allow me to do any research on my own … It is very minimal because of that workload. (40-year-old male respondent from Kenya, R_078)

7.11.2.3 Academic freedom and freedom to publish

Some respondents feel that, inasmuch as they have academic freedom in general, they are faced with some limitations on publishing their research: what they have to publish and where they have to publish. Scientists have to be within specified 'boundaries' when they are publishing their work in articles, reports or newspapers.

> Well, academic freedom we do have. We do have to some extent we have academic freedom, but of course with limitations. You know the context of where we did, or maybe not having to publish something that will attack the government, very open or attacking the administration very openly you know. ….. The thing is that when you want to publish you have to check fast otherwise you might get a second letter. Yes, you might not just write something or it without getting this. [Unclear] from the university administration, so freedom is there, but it has text … because the boundaries are drawn properly. The thing is if you want to go to university, they will not allow that. If you want to even write to a newspaper, you get the consent of the university if you want to add something that touches their interests. (40-year-old male respondent from Kenya, R_078)

7.11.2.4 Research support or funding

Some interviewees felt that the payment needed for publishing in high-impact journals could be an impediment for young scientists to publish their work.

> […] it might not mean that young people don't do research … as a resident [graduate student] I published the work that I did as a resident last month. But I tried three or four journals, they asked me to pay something … you see I wouldn't have minded paying, but that could be an impediment to other many young people who would want to publish their work. (35-year-old male respondent from Kenya, R_189)

In the next section, I present results on the suggestions provided by respondents on the support and mentoring that can be provided by governments or universities to increase productivity.

7.11.3 Suggestions by the young scientists in areas that they need support, training and mentoring

During the interview, a participant in the health sciences suggested that young scientists should be offered opportunities to publish, as well as, the financial support needed for publishing in some journals that require payment.

> Just opportunists to publish. Like in our setting here we have, you know, residents doing their work based …. and you find that every year there are about ten or 20 people who have done some form of research, that is done locally. And what they lack is the opportunity to publish. Most journals will need money, you know, to publish, they need you to pay this or do this to publish. And even some time, even that opportunity to publish is missing (35-year-old male respondent from Kenya, R_189)

Related to the above suggestion, some interviewees were of the perception that encouraging and financially supporting young scientists to publish, and not necessarily focussing on the established researchers, will have a 'ripple effect' on the fellow younger researchers who will be encouraged to publish more in the future.

> So, I think, one other thing is, to encourage young people to publish, is to see other younger people publish. So that when you open the Annals journal of medicine the people you see there are professors, people who are established in their careers … (35-year-old male respondent from Kenya, R_189)

In the next section, I discuss these results in detail as well as integrate the related literature.

7.12 Discussion

This section discusses the results presented on the consequences of the demand to publish, as well the young scientists perceptions on the constraints of publishing. Consequences of the demand to publish

The results in this chapter show that given the demand to publish at Kenyan institutions, researchers have come up with several strategies to publish. They include publishing from their final year undergraduate research or postgraduate research (masters and PhD). These results are consistent with a recent study (Mouton and Prozesky, 2018) which found that African (young) researchers tend to publish from their PhD research either as a requirement by their universities before they graduate or as an agreement between the student and supervisor to publish their work. The pressure to publish, particularly from the doctoral thesis is seen in the light of the advancement of the career of young researchers. Inasmuch as the demand to publish from the doctoral thesis can be beneficial to the career of the (young) scientists, some authors have pointed to the possibilities of the unintended consequences that result from this pressure. The results in this chapter corroborate a previous study which showed that the unintended consequences may entail the decline in the quality of scientific articles as scientists are more likely to focus on producing publications for promotion or tenure (Mouton and Prozesky, 2018: 137).

The results in this chapter are in support of previous studies which showed that supervisors often publish with their students (Bozeman and Corley, 2004; Mouton and Prozesky, 2018). Supervisors provide mentoring and support in research and publishing, but at the same time, they increase the number of articles they submit and publish with their students. Specifically, the recent study showed that apart from the role of encouraging or motivating their students to publish, they also offer support in making choices on the best journals for their students to publish in (Mouton and Prozesky, 2018).

The results show that scientists in engineering focus on publishing papers in conference proceedings compared to articles in journals. According to the interview data, respondents cited the time to prepare and publish a journal article, especially in the midst of heavy workloads. Studies have shown that scientists in the field of engineering tend to use conference proceedings as their mode of publication (Moed *et al*., 2005). Several reasons have been cited in the literature and my findings as to why researchers in the fields such as engineering, mathematics and computer science opt to publish more papers in conference proceedings: ease and faster mode of disseminating the research results; requires minimal time to write and publish, compared to journal articles.

7.12.1 Enablers or constraints of publishing

The results presented above are consistent with previous studies (Lutomiah, 2014; Mouton and Prozesky, 2018; Wangenge-Ouma, Lutomiah & Langa, 2015) that identified several factors that constraint publishing research in Kenyan scientific institutions in particular and, in Africa in general. These constraints for research include poor remuneration/salaries, lack of incentive structures for research, lack of recognition, limited time resources and heavy workloads, lack of financial support to publish in journals, and limited academic freedom/freedom to publish.

Consistent with previous studies (Lutomiah, 2014; Wangenge-Ouma *et al.,* 2015) this study reveals that poor remuneration or salaries are a huge constraint for scientific publishing. In this study and the previous studies, findings show that in Kenya, academics are civil servants, which implies that they earn similar salaries with other civil servants, regardless of the academic qualification (i.e. PhD as the highest qualification), or in some instances, some civil servants (i.e. permanent secretaries, with a similar qualification, PhD) earn higher salaries compared to the professors. Comparing the salaries for professors and permanent secretaries, Lutomiah (2014) showed that in the last decade, permanent secretaries earn more than professors who have a similar highest qualification (i.e. PhD).

Furthermore, apart from the poor remuneration, the findings of this study corroborate previous studies which showed that, although the government and institutions attempt to provide research incentives, that is, monetary incentives attached to publications or student supervision, the incentives available are inadequate (less than 50 US dollars), not transparent and inconsistent (Wangenge-Ouma *et al.*, 2015). Apart from the monetary incentives, the results in this study support previous studies which showed that lack of recognition (non-monetary incentives such as citations) also constraint research publishing.

Given the poor remuneration and weak research incentives, the current study also confirm previous studies (Wangenge-Ouma *et al.*, 2015) which have shown that academics engage in 'moonlighting', consultancy and business to supplement their meagre pay. Applying the principal-agent model, Wangenge-Ouma *et al*. (2015) showed that academics have multiple principals, that is, the government, research council, NGOs and universities who offer "competing incentives", that is, they reward different outputs, that is research, extra teaching, consultancy and business. Given the availability of "competing incentives" scientists may not focus on the research activities that will enhance research behaviour and subsequently result in increased scientific output. Competing incentives tend to be easy to earn compared to research incentives (such as promotions, that may take long), as scientists will focus on teaching on Module II programmes and engaging in research consultancy. Therefore, in the context of poor salaries and lack of research incentives, scientists make 'trade-off" in relation to the incentives to respond to, thus are likely to choose the competing incentives that will increase their income. In addition, scientists lack sufficient time resources available for research as they have heavy teaching loads, accompanied by a lack of teaching and research assistants to support them. The survey result in this study reveals that scientists across fields spend over 40 per cent of their time on teaching. The survey results also show that scientists in the field of health sciences and agricultural sciences spend the highest proportion (at least 40%) of their time on research consultancy.

Apart from weak incentive structures, this study found that lack of financial support constraints Kenyan scientists to publish their work. Respondents in this study indicated that they lack funds to pay for the journals that require payments before publishing. Some respondents indicated that following the need for payments and lack of financial support delayed the publications of their PhD research. Previous studies (Mouton and Prozesky, 2018) show that a lack of financial support constraints research as well as scientific publishing. In general, as highlighted on in the funding chapter (chapter 5) respondents indicated that research funding is one of their major constraint for research. Similar to suggestions made earlier (funding chapter) this study provides several suggestions on the support needed for publishing, which includes, opportunities to publish and the financial support for publishing and research.

7.13 Summary and Conclusion

The results presented and discussed above are generally consistent with previous studies reviewed. In relation to scientific output, the above results show that the scientific production for Kenya has been on the increase over the recent past. The increase in the scientific output translates into the increase of Kenya's world share, which exceeded the world average, especially in the past five years. However, Kenya's world rank or the position has declined over the years. In relation to scientific output disaggregated by the scientific field, its shown that the health sciences, agricultural sciences and natural sciences recorded the highest number of papers. The majority of the papers were produced by the oldest and largest universities (University of Nairobi, Kenyatta University, Jomo Kenyatta University of Agriculture and Technology, Maseno University and Egerton University), the public research universities (KEMRI, KALRO) and the international research organisations (ILRI, ICIPE, ICRAF, ICRISAT, CDC-Kenya and CIMMYT).

In relation to research activity index or relative field strength (RFS), Kenya is relatively strong and active in the health sciences and social sciences. This implies Kenya specialises in producing papers in these fields. Kenya's activity index in the natural sciences has weakened in the past decade. Conversely, Kenya is weak and less active in the engineering sciences and humanities.

In this chapter, I investigated whether factors such as age, gender, and scientific field have significant influences on research production. In general, my findings show that age, gender and scientific field are key predictors of reported scientific output. Statistically significant differences between age categories, although small, and research production were found as older scientists reported higher publication output in some fields and publication forms as compared to the younger scientists. The literature on age and productivity, although varied, suggests that scientific output increases with age, since the older respondents are likely to access funding, access research resources and lead research groups, hence increase in their productivity. Gender differences in scientific output were also observed, as male scientists, irrespective of age and scientific field, with a few exceptions, recorded the highest number of reported scientific output in the preceding three years. In some fields such as the health sciences and social sciences, female scientists reported the highest number of publication output. In my analysis, based on the gender balance between fields, I argue that gender is not the biggest explanatory factor since female scientists were well represented in these fields that they had higher output. In relation to the publication categories, respondents reported the highest number in the articles, books, book chapters and conference papers respectively. My findings demonstrate statistically significant field differences in the publication output and forms, with scientists in the natural sciences publishing more journal articles, compared to the scientists in the humanities, social sciences and engineering sciences who reported a high number of conference proceeding, books and book chapters.

Based on these results, I could reject the null hypothesis that age has no positive association with scientific production. In relation to gender, I could not conclusively reject the null hypothesis that gender has no positive association with scientific output, in that, female scientists publish less. Looking at the characteristics of scientific fields, I could only partially reject the null hypothesis that there is no positive association between the scientific field and scientific output. That is, scientists in the natural sciences are more productive compared to the social sciences and humanities. In as much as this holds true for the article output, scientists in the social sciences are more productive in the book output.

The data presented and discussed above shows that in the context of increased demand to publish, scientists have devised several structures to enable them to publish. This includes: publishing their work as final-year undergraduate students, publishing from their PhD work, supervisors/mentors publishing with their post-graduate students. Similarly, given the heavy workloads, scientists in the field of engineering prefer publishing conference papers which are likely to take minimal time to publish as compared to a journal article.

This study also shows that in the context of the increased need to publish, they lack a conducive environment to publish. Respondents indicated that they are poorly remunerated, lack recognition and incentives for research thus, they choose competing incentives such as extra teaching and research consultancy to supplement their income. In the context of weak incentive structures and the presence of competing incentives, scientists are likely not to engage in research activities that will increase their scientific output. With the extra teaching loads and consultancy work, scientists also have minimal time resources to devote to research. As discussed in an earlier chapter on funding (chapter 5), respondents indicated that in general, they lack funding to support research and publishing. Given the different constraints for research, respondents suggested opportunities to publish and financial support for research as the support they need to increase their productivity.

Chapter 8 Research Collaboration

8.1 Introduction

In this chapter, I address the following research objective: to describe and assess the trends in research collaboration of Kenyan scholars and scientists. I address the following research questions:

6. What are the types of research collaboration?
7. What are the motives for research collaboration?
8. What are the strategies for research collaboration?
9. What are the factors that enable or constraint research collaboration?

To address the following research questions, this chapter starts with a literature review on research collaboration: the importance of collaboration, definition and measuring of collaboration, motives, strategies, and types of collaboration. I later present bibliometric data on research collaboration. I also hypothesise that several factors identified in the literature such as age, gender, academic rank, scientific field, and funding and mobility enable or constraint research collaboration. Subsequently, I present the survey results that analyse the relationship between collaboration and these factors. The interview data presented in this chapter addresses the question on the reasons why researchers collaborate, reasons for no collaboration, the strategies for collaboration, whom the scientists collaborate with, and the enablers and constraints of research collaboration. Finally, I discuss the results on research collaboration and later provide a summary and conclusion of the main findings.

8.2 The importance of research collaboration in science policy

Scientific collaboration as a social process has received interest from both scientists and governments locally and internationally (Yeung *et al.,* 2005, cited in Pouris & Ho 2014). To expound, Pouris and Ho (2014: 2169) note:

> Researchers are investigating the effects, modes, dynamics and motives of collaboration, while governments utilise research collaboration as a policy instrument for technology transfer from universities and research councils to industry (intra-collaboration); for knowledge transfer from abroad (inter-collaboration); as a means to improve diplomatic relations with other countries by creating goodwill; and gain political capital.

From the above excerpt, we observe that, on the one hand, researchers are concerned with the following aspects of collaboration: what collaboration is, why and how collaboration occurs. On the other hand, the governments are concerned with the science policy aspects, that is, how research collaboration can contribute to science, technology and innovation. Scientific collaboration is considered to be a key element of science, technology and innovation policy, hence, governments support the objective through huge investments (Pouris & Ho, 2014; Wagner, 2005). The participation of governments in research collaboration is based on the acknowledgement that science is part of a competitive ecosystem of research development and commerce (Arnold, 2004; 2012). Therefore, governments are more actively involved in supporting and institutionalising research collaboration programmes. For instance, in the mid-1990s, the US government was estimated to have spent about US$3.3 billion on international collaboration. Particularly, the US government is estimated to have spent an average of US$322 million between 1994 and 1999 for collaboration with Russia, an amount that peaked in 1996 at US$380 million and later decreased to about US$275 million in 1999 (Wagner, 2005: 11).

In general, the significance of collaboration rests on the channelling of knowledge flows amongst scientists. Research collaborations have a central role in knowledge creation and innovation. Innovation and creativity are reliant on notions which can create new knowledge, and collaboration is a key platform to harness and develop these important ideas (Katz & Martin, 1997; Lee & Bozeman, 2005). Toivanen and Ponomariov (2011) argue that "this dynamic is particularly important for developing countries, such as many in Africa, with limited national knowledge stocks, infrastructure/instrumentation, and human capital" (p.473). In this case, collaborative research offers important channels for building up research capacity locally (Lee & Bozeman, 2005). Collaborating both internationally and nationally with renowned scientists is claimed to be of great necessity for the enhancement of scientific quality (Narin, Stevens & Whitlow, 1999) and scientific output (see Borghei, Qorbani, Rezapour, Majdzadeh, Nedjat, Asayesh, Mansourian, Noroozi & Jahahgir, 2013). In addition, collaborative work is claimed to result in quicker knowledge diffusion (Ponds, 2009).

In his review, Beaver (2001) comprehensively investigated research collaboration. In his examination, Beaver considered "synergy, feedback, dissemination, recognition and visibility" as advantages of research collaboration (Beaver, 2001). This view is based on the assumption that each actor in the collaborative activity comes with a 'network' of fellow scientists who are keen on the research; each actor of the collaboration is a visible team member; and that each individual comes with 'favourable reputation' to the collaborative research.

Scientific collaboration enhances the reliability of research results as several scientists engaged in the projects. Furthermore, it is argued, collaborative work might "reduce competition, increase trust, facilitate the exchange of complex knowledge, support the adaptation of a piece of knowledge, and help to speed up knowledge creation and innovation"

(Gazni & Thelwall, 2014: 261). It is evident that research collaboration supports knowledge flows. Collaboration may enable knowledge exchange, transfer, use and sharing because of the scientists' needs, goals, language, activities and understanding through their interactions (Gazni & Thelwall, 2014: 261).

Studies have identified various advantages of collaborative research between researchers and practitioners. The advantages include facilitating access to data and the process of collecting data, the researchers and practitioners familiarise with each other's' environment. In addition, research collaboration may improve skills, practices and competency of the practitioners and researchers, practitioners identify with the researchers' viewpoints, the research findings are put into use and the practitioners easily ensure availability of research grants (Denis, Lehoux, Hivon & Champagne, 2003; Jean-Louis & Loma, 2003). Given the importance of collaboration in the science policy context, the next section attempts to provide a definition and understanding of research collaboration.

8.3 Understanding Research Collaboration

8.3.1 Definition of research collaboration and collaborators

According to Subramanyam (1983), scientists do not engage in scientific work in isolation (Subramanyam, 1983:33). Scientific work, thus, has become more collaborative. Worldwide, the scientific community is working together with the aim of enhancing knowledge levels. Inasmuch as technological developments which are the applications of scientific research are always determined by the political and socio-economic structures of a given country, science is (or ideally should be) supra-national in nature (Subramanyam, 1983:33-34). Therefore, given that science is universal, complex, interdisciplinary and supra-national in nature, the scientific community tend to engage in collaborative activities more.

Inasmuch as there are extensive literature and study on research collaboration, scholars like Katz and Martin (1997) argue that literature lacks a clear and unambiguous definition of research collaboration. They argue that the concept of collaboration is neither understood well nor consistently applied (Katz and Martin, 1997; Smith and Katz, 2000). Katz and Martin (1997: 7) indicate that the dictionary definitions of research collaboration emphasise on two features: "the working together of individuals to achieve a common goal". From this definition, collaboration should entail two or more individuals with a common goal and work jointly to achieve it. According to Subramanyam (1983: 34), "research collaboration takes place when two or more scientists work together on a joint project and share intellectual, physical and financial resources with the objective of creating new scientific knowledge." In support of this definition, scholars maintain that collaboration is a social process that entails people pooling human and scientific capital to create knowledge (Bozeman, Fay & Slade, 2013; Ponds, 2009; Thakur, Wang & Cozzens, 2011). These definitions emphasise the role of people, a specific objective/goal and available resources. Subramanyam (1983) and Katz and Martin (1997), however, cautioned that inasmuch as these definitions seem straightforward, the definitions do not indicate how closely individual scientists should work or what roles they should play, in order for their work to be considered collaborative.

Katz and Martin (1997) argued that defining collaboration is almost impossible given that collaboration has “fuzzy” or “ill-defined” borders. Furthermore, given that collaboration is intrinsically a social process, scholars have faced difficulties in establishing what constitutes research collaboration and what does not: On the one extreme, any individual that provides input into a piece of research can be seen a collaborator. While on the other extreme, only the scientists that contribute directly to all the main research tasks over the duration of the project are considered collaborators (Katz and Martin, 1997). Inasmuch as there are problems with these extremes, it is suggested that research collaboration lies between these two extremes.

Several scholars have concluded that, what constitutes research collaboration is a matter of social convention in the scientific community (Katz and Martin, 1997; Ponds, 2009; Subramanyam, 1983). Notably, it is difficult to reach a consensus on where the informal links between researchers end and where collaborative work commences. Katz and Martin (1997) notes that, what other individuals see as collaboration may be termed as “loose groupings” or informal links. Based on the difficulties of defining research collaboration, alternatively, Katz and Martin (1997: 7) offered a “checklist” to distinguish between collaborators and researchers. Collaborators might then include the following:

i. Those who work together on the research project throughout its duration or for a large part of it, or who make frequent or substantial contributions.

ii. Those whose names or positions appear on the original research proposal.

iii. Those responsible for one or more of the main elements of the research (e.g., the experimental design, construction of research equipment, execution of the experiment, analysis and interpretation of the data [and] writing up the results in a paper).

iv. Those responsible for a key step in (e.g., the original idea hypothesis or hypothesis, the theoretical interpretation).

v. The original project proposer and/or fundraiser even if his or her main contribution subsequently is to the management of the research (e.g., as team leader) rather than research per se.

From the above description, it is clear that collaborations mainly involve people, although, in some instances, it might involve institutions or laboratories and equipment. Furthermore, apart from describing whom collaborators are, Katz and Martin (1997: 8) suggested that research collaborators exclude:

i. "Those who make only an occasional or relatively minor contribution to a piece of research;

ii. Those not seen as, or treated as, 'proper' researchers (e.g., technicians, research assistants)".

Furthermore, taking a narrower view than what is proposed by Katz and Martin (2007), Laudel (2002: 5) notes that "a research collaboration is defined as a system of research activities by several actors related in a functional way and coordinated to attain a research goal corresponding with these actors' research goals or interests". From this definition, Laudel makes several propositions: first, a common research goal is not necessarily a premise for collaborative work. Secondly, what defines collaboration is the "activities" and not necessarily the participating "actors". Hence, the efforts of Katz and Martin (1997) to provide a "checklist" above on who qualifies to be a collaborator. Lastly, the notion of research collaboration is "strictly reserved for research that includes personal interactions" (Katz and Martin, 1997). Based on the above definition, Laudel (2002) provides six variations of research collaboration:

- collaboration relating to a division of labour;
- providing of access to research equipment;
- service collaboration;
- mutual stimulation;
- transmission of knowledge; and
- trusted assessorship.

Laudel (2002) further expounds on the above variations of research collaboration. Laudel observes that collaboration that involves the division of labour mainly leads to co-authored publications. This is because collaborative work that involves the division of labour is known for its characteristics of "shared research goal and a division of creative labour between collaborators" (Laudel, 2002:7). On the other end, service collaboration entails a case where the setting of the research goals is done by one researcher alone, and they carry out all the creative work. The provision of access to research experiment is claimed to be a weaker type of collaboration. This claim is attributed to the fact that the collaborator is not engaged in the research work, but rather allows accessibility to the research equipment. Unlike the other types of collaboration that are linked to the process of knowledge production, "trusted assessorship refers to the process of publishing results." Specifically, this describes "those colleagues who act as accepted and friendly critics" (Laudel, 2002:8). In other words, trusted assessorship entails the review process that leads to a publication. Importantly many of these collaboration variations overlap or accompany each other. The figure below illustrates the different collaboration variations.

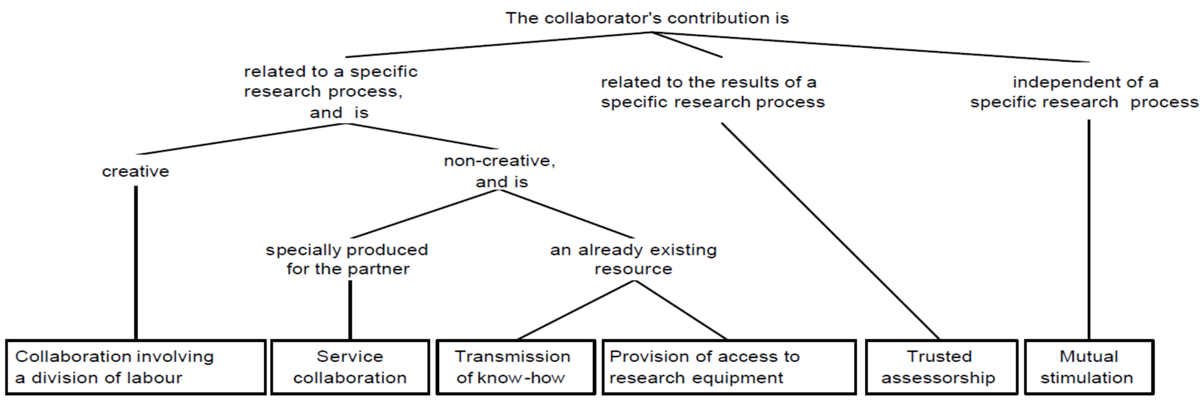

Figure 8-1: Construction of types according to horizontal specialisation and non-specialised contributions

Source: Laudel, 2002: 7.

Lewis, Ross and Holden (2012: 696) argue that scientists across all scientific fields participate in collaborative activities, though not all collaborations have equal levels of visibility. To address the problems that result in the analysis having more bias towards the more visible (and easy to measure) modes of collaboration, Lewis and colleagues distinguish between **C**ollaboration (capital C) and **c**ollaboration (small c). According to Lewis *et al.* (2012), **C**ollaboration entails scientists working on a project together, designing it and/or undertake the project together and publish together with the research findings. Collaboration is a solid mode to the network that is more noticeable to research funding and performance systems. On the other hand, **c**ollaboration consists of discussing research and ideas, feedback and comments on the project and the working papers.

Given the above description of research collaboration and a collaborator, the key question often raised in the literature is: how close should scientists work together to constitute a collaboration? In one sense, "the international research community is one big collaboration", where basic research is a global activity, and all the researchers are working together in advancing scientific knowledge. The researchers share ideas on the experiments to be done, the hypotheses to be tested, the instruments needed, to make relationships between their results and theoretical models, etc. Importantly, collaborations need constant effort for bringing and holding together the various interdependent actors, including, "the local and international scientists, and their respective institutions, local scientists and their local collaborators, and research employees and trial participants" in an effort to produce knowledge (Thakur *et al.,* 2011). Having presented an understanding of collaboration and collaborators, the next section focuses its discussion on understanding the motives for collaboration.

8.3.2 Motives for collaboration

Research collaboration, as a complex social phenomenon in science, has been on the rise in different scientific fields and countries, hence the systematic and extensive studies on research collaboration by various authors as from the 1960s (Katz & Martin, 1997; Glänzel & Schubert, 2005; Ponds, 2009). Collaboration, like any other human phenomenon, is essential for the progress of science. Consequently, policymakers in various countries and at international levels progressively encourage collaboration by providing funding for creating and sustaining scientific networks (Ponds, 2009; Gazni and Thelwall, 2014).

Several reasons have been put forward to explain the growth in research collaboration over the last years (de Solla Price, 1963; Katz and Martin, 1997; Glänzel and Schubert, 2005; Thakur *et al.*, 2011). These reasons are micro (i.e. individual) and macro (i.e. structural). In his study, de Solla Price (1963) argues that huge funding, as well as 'teamwork', characterises 'big science'. Subsequently, teamwork requires massive human capacity that largely relies on the availability of funding. In the context of increased funding of science, that is, direct or indirect economic factors, there has been an increase in teams and research networks dominating knowledge production (Adams, 2012; Katz & Martin, 1997; Wuchty, Jones & Uzzi, 2007).

Apart from increased funding of science, other individual factors have contributed to the rise in collaboration. First, the reduced costs in travel and communication together with the impact of electronic media have facilitated networking which has then enhanced collaborative research efforts. Secondly, accessibility of data, skills and equipment that enable researchers in the exploration and exploitation of complex ideas mostly not available outside the collaboration context, thus encouraging collaboration (Beaver & Rosen, 1978, 1979; ; 1993; Katz & Martin, 1997; Luukkonen, Persson & Siverstsen, 1992; Tijssen, 2006).

Structural or macro-level factors or "intra-scientific" factors have also been cited as resulting in an increase in collaboration. First, the increased costs of conducting scientific research (e.g. construction of large laboratory facilities, purchase of equipment) calls for pooling resources together, hence collaboration is deemed to increase efficiency in the production of science (de Solla Price, 1963). Therefore, scientists from these organisations extensively participate in the collaboration. Second, the increased need "for specialization within certain scientific fields" [field specialisation], which has resulted from the growing number of scientific fields and subfields encourage collaboration (Katz & Martin, 1997: 8; also see de Solla Price, 1963). The division of labour that comes with field specialisation stimulates collaboration since no single individual can perform the specialised tasks of a research project, which requires a teamwork approach. Third, and related to the above, is the rise in complex instrumentation that has resulted in the increase of specialised experts within scientific fields. These factors have motivated co-operation in experimental fields/research but also in the theoretical fields like social sciences and pure mathematics. Fourth, Ponds (2009) notes that the growing interdisciplinary research in fields like biotechnology requires collaborative research efforts. In general, there is a move towards cross-fertilisation between discipline, thus, as an awareness of the complexity and the need for different perspective grows, it increases collaborative work (Ponds, 2009). Fifth, policy and market-driven demands of science to which collaboration (particularly multidisciplinary collaboration) are deemed a key response. Thus, given these factors governments and other funders are expected to support collaboration (Lee & Bozeman, 2005).

Apart from the structural factors, political factors have also been identified in the literature to motivate collaborations. Scholars note that some research collaborations develop to build strategic links between nations, for instance, those between the nations of Western Europe countries post World War, and between the East and the West Europe nations after the collapse of the Berlin wall. Specifically, important for the African nations are collaboration initiatives by countries looking for African partners especially as a requirement for funders (Katz & Martin, 1997; Wagner, 2005).

Furthermore, Melin (2000), using questionnaires and interviews, conducted a study to find out why scientists collaborate. The results of the study showed that, apart from the need to gain knowledge and skills and accessing equipment and methods, as indicated above, "social reasons such as long-time friendships" were indicated by several respondents as their sole reason for collaborating. Similarly, the "supervisor-student relation" was indicated as another reason for engaging in collaborative work. Melin notes in her conclusion that "science is a socio-cognitive practice" given the dominance of the cognitive, technical and social reasons for collaboration reported in the study (Melin, 2001: 34).

Another study by Beaver (2001) identified and summarised eighteen motives why scientists tend to collaborate. Beaver notes that these motives include: accessing expertise, accessing funding, accessing equipment and resources, obtaining prestige or visibility, for career advancement, time and labour efficiency, make rapid progress, tackling "bigger" problems, increase productivity, satisfying curiosity and intellectual interest. Other motives identified by

Beaver are: learning new skills or techniques, advancing knowledge and learning, to train researchers, to sponsor a *protégée,* reducing [intellectual] isolation and recharging one's energy, knowing people and creating networks, recognition, multiplying proficiencies, avoiding competition, but also for fun, amusement and pleasure (Beaver, 2001: 373; also see Beaver and Rosen, 1978; Melin, 2000). In the later discussions (8.3.3 and 8.3.4), we will look at the effects of these motives to collaborate on research production. In the next section, we look at different levels of collaboration.

8.3.3 Collaboration levels

The basic unit of research collaboration is deemed to be between two or more scientists. The basic unit of collaboration is when two or more scientists cooperate on a research project (Smith & Katz, 2000). However, research collaboration can be seen at various levels, that is, "between research groups within a department, between departments within the same institution, between institutions, between sectors, and between geographical regions and countries" (Smith and Katz, 2000:33). Importantly, collaborations mainly occur between individuals. It is the people who participate in collaborative activities and not institutions (Smith and Katz, 2000). Inasmuch as the interpersonal collaborations are considered important, given that it is the people who collaborate at the several levels, Smith and Katz (2000:33) observe that many of the policies aim to foster collaboration at the "higher levels rather than inter-individual collaboration".

Smith and Katz (2000) identify the main differences between several levels of collaboration, and these include the purpose for existence, the group composition, the structure, ownership and benefits. However, the boundaries between interpersonal and team collaborations remain unclear, particularly when it entails groups of individuals across institutions. Smith and Katz (2000) emphasise that, it is crucial to distinguish the different collaboration levels, since, "an inter-institutional or international collaboration may not necessarily entail an inter-individual collaboration" (Katz, 2000:10). Equally, collaborative research "varies across institutions, fields, sectors and countries, and changes with time" (Katz, 2000: 10). The next section expounds on research collaboration at the individual level. This is given the fact that individuals often initiate collaborations.

Importantly, as indicated earlier, the fundamental unit of scientific collaboration is the individual. Collaboration happens between individuals and not institutions (Katz & Martin, 1997; Smith & Katz, 2000). In their study, Bozeman and Corley (2004: 600) observe that "many of the factors governing individual scientist's collaboration choices remain very much within the control of the individual, especially when the researcher works in an academic institution". In scientific networks, individual researchers are deemed as the key actors, whereas the institutions play a secondary role. Furthermore, even in cases where the scientific networks are institutionally-initiated, the individual researchers are the main actors whereas the institutions offer the resources needed for the collaboration (Sooryamoorthy, 2013). Following the definitions of collaboration described herein, individuals are seen as "collaborators if they conduct research activities". Therefore, a collaborator is mainly described as an individual who inputs to a specific research project (Moyi Okwaro & Geissler, 2015:495).

8.3.4 Collaboration strategies used by scientists

Beaver (2001:373) identified various ways of how research collaborations between individuals commence.

> [Research collaborations start] by chance, at a colloquium or lecture, or at a conference, because of a presentation, or because of working sessions or, on leave at another institution, to learn new skills, or catch up with the field; by intention, by letter or phone call solicitation; by recommendation or referral by trusted colleagues; because it's part of one's job mentor, to educate.

From the above discussion, we observe that several modes can lead to the start of a collaboration. According to Sooryamoorthy (2013), individual scientists mostly initiate collaborations which often begin spontaneously. Importantly, previous work or personal relationships are key to the success of scientists' cooperation. Sooryamoorthy (2013) argues that actors in a collaboration individuals or institutions with previous connections easily agree in collaborations, since these connections offer a sense of solidarity in the collaboration, given their collective aim. However, when collaborations emerge from informal contacts, there lacks clarity in responsibilities and in instances of uncertainty in commitment, the collaboration may turn stressful.

From the above discussion, it is evident that the personal and structural elements of collaboration have to be well aligned to ensure the success of the collaborative activities. Melin (2000:36) notes that "[p]ersonal chemistry, respect, trust and joy" and, friendship is deemed an important prerequisite for collaborative activities. For instance, collaborators have to be trusted with data and results that are not to be shared with competing teams before credit is granted. In Birnholtz's study, a researcher remarked, "collaborations are investigator-initiated and investigators aren't going to collaborate with people they think are going to stab them in the back" (Birnholtz, 2007: 2231). The structural elements ensure the access of resources; whereas personal elements determine whom an individual collaborates with a friend, colleague or a long-established contact which largely depends on previous knowledge or working experience and trust (Sooryamoorthy, 2013).

8.4 Measuring Research Collaboration

As discussed above, collaboration remains difficult to define. Equally, the challenge of analysing collaboration lies in measuring research collaboration. Most studies have used co-authorships as a proxy for research collaboration. Smith was among the first researchers to show a rise in co-authored papers and suggested that co-authorship could be used in measuring research collaboration (Smith, 1958). Co-authorships have been used in collaboration analysis since the early studies on collaboration in the 1960s (De Solla Price, 1963; De Solla Price and Beaver, 1966). De Solla Price (1963) presented data from chemistry abstracts early on supported the use of co-authored papers in measuring the changes in collaboration. In e Solla Price's study (1963), cited in Katz & Martin, 1997), he showed a trend where the number of papers with three co-authors was increasing faster than papers with two co-authors, and the papers with four co-authors faster than for three co-authors, etc. This trend led to the observation that, over time, the single-authored papers will largely decline. However, some studies show that the increase in the co-authored papers varies significantly by scientific field, and in some fields like biomedicine seems to exhibit insignificant growth (see Katz & Martin, 1997). Co-authored papers have since then been widely used in most studies as a proxy for research collaboration (Adams *et al.,* 2005; Katz & Martin, 1997; Ponomariov & Boardman, 2010; Subramanyam, 1983).

Co-authorships have largely been used because of: the availability of the bibliometric data (Glänzel & Schubert, 2005; Melin & Persson, 1996), and the assumption that a collaboration normally results in a publication (see Beaver & Rosen, 1978; Katz & Martin, 1997; Laudel, 2002). Melin and Persson (1996: 365) conclude, "there is hardly a tendency for collaboration to be underrepresented when studying co-authorships". Co-authorship is the most "tangible and documented indicator" of collaboration (Glänzel and Schubert, 2005:257). The authors further argue that a bibliometric analysis of co-authorship identifies nearly all aspects of collaboration. Despite the above arguments, Ponomariov and Boardman (2016:1944) note that, collaboration does not always result in co-authored publications, as it can result to "other outputs or nothing tangible at all". Ponomariov and Boardman (2010) further remark that research collaboration 'is a fluid and multi-dimensional process [that is, has various aspects of collaborative relationship], of which co-authorship is only one potential dimension'. Therefore, inasmuch as co-authorship is a strong indicator of collaboration, it does not necessarily represent all aspects of collaboration.

The general practice of using co-authorship in measuring collaboration is based on two main assumptions: Firstly, all the individuals listed on a research publication as co-authors, in reality, participated in the research collaboration (Katz & Martin, 1997). Similarly, Katz and Martin (1997: 3) like Ponomariov and Boardman (2010) criticise this assumption as they argue that, some co-authorships are not as a result of actual collaborations, rather there are honorary co-authorships. Fields like biomedicine often use honorary co-authorships. In support of this argument, Smith and Katz (2000) note that caution needs to be taken when co-authorships are used to measure research collaboration, as:

> [t]here are many cases of collaboration that are not consummated in a co-authored paper and which are consequently undetectable with this approach. Conversely, there are other cases of, at best, only very peripheral or indirect forms of interaction between scientists which nonetheless yield co-authored publications (Smith and Katz, 2000: 37).

From the above, Smith and Katz (2000) show that co-authorship on their own might not make the excellent measure of research collaboration. Although the assumption that all co-authors on a paper were engaged in the research is frequently violated, it is argued that the resulting errors from these problems could be addressed statistically (Melin and Persson, 1996; Laudel, 2002).

Secondly, there is the assumption that all the scientists who participate in a research collaboration become co-authors (Laudel, 2002). The second assumption is largely criticised and deemed more problematic since co-authorships do not exhibit all the relationships in collaboration but a fraction (Katz & Martin, 1997: 2–3; Laudel, 2002; Melin & Persson, 1996). Furthermore, Melin and Persson (1996: 365) emphasise that "when we infer co-authorships to collaboration, we are running the risk of neglecting some collaborations as well as being insecure about the actual reasons behind co-authorships". However, there normally exists no substantial information on what is not covered. Most bibliometric studies analysing research collaboration focus on using co-authorship as a measure of collaboration and fail to account for many of these "methodological warnings" (Laudel, 2002).

A study by Laudel (2001) revealed through interviews with scientists that a larger fraction of collaboration is not acknowledged through formal acknowledgements or through co-authored papers. A large proportion of individuals who are involved with the preparation of publications are not listed as co-authors or as a sub-author of the research publications. Therefore, Laudel (2001) raises the question as to what extent co-authorship and sub-authorship are a suitable proxy of research collaboration. Glänzel and Schubert (2005: 258) note:

> the relationship between contributors, co-authors (and sub-authors) and co-writers can thus be interpreted as a chain of subsets where co-authors form just a subset of contributors and those scientists who are actually writing the publication are, in turn, a set of contributors acknowledged as co-authors and sub-authors.

Co-authorship is seen as 'a partial indicator' of research collaboration (Katz and Martin, 1997). However, Bozeman *et al*. (2013:3) propose, "co-authorship is not so much a partial indicator of collaboration as just one of many possible outcomes of the social processes encompassed by collaboration". As illustrated in various studies, increased collaboration is related to growth in co-authorship and sub-authorship. Glänzel and Schubert (2005:258) deduced that "collaboration and co-authorship and sub-authorship" are positively correlated especially at the individual level.

Although co-authorship is acknowledged not to be a "perfect" measure of collaboration, many of the previous studies on collaboration focus on co-authorship. Katz and Martin (1997:3) identified several advantages of using co-authorship in the measurement of collaboration. They include:

> First, it is invariant and verifiable; given access to the same data-set, other investigators should be able to reproduce the results. Secondly, it is a relatively inexpensive and practical method for quantifying collaboration. Furthermore, the size of the sample that it is possible to analyse using this technique can be very large and the results should, therefore, be statistically more significant than those from case studies. Finally, some would argue that bibliometric studies are un-intrusive and indeed non-reactive that is, the measurement does not affect the collaboration process.

Despite the above argument on bibliometric studies, in the long-run, it's argued that the bibliometric results may have an effect on the collaboration processes (Thakur *et al.*, 2011).

Subramanyam (1983) further proposes that a holistic viewpoint is needed when analysing collaboration. The author argues, it is not easy to determine "the precise nature and magnitude of collaboration" using the standard methods of "observation, interviews or questionnaire" given the complexity of human interactions, that centres collaborations over time. Equally, the nature and magnitude of what the collaborators contribute often changes throughout the research project (Subramanyam, 1983: 35). Therefore, bibliometric methods have been preferred in analysing collaboration given that bibliometric data is accessible and advantageous (Ponomariov and Boardman, 2016:1939). However, Ponomariov and Boardman (2016) suggest that researchers using "co-authorship as a proxy for collaboration" to consider the collection of more information apart from that available from bibliometric resources, as this data allows better-informed analysis and both policy and management decision making.

Using bibliometric analysis of co-authorships to measure research collaboration for years, Beaver and Rosen (1979) highlighted a challenge of this method that relies on the use of core journals, thus the visibility of the research of a few ‘elite’. This may be related to research in the developing regions which mainly focused on the local issues such as food security, poverty alleviation and disease, hence may end up being published in the local journals and not international journals, hence affecting their international visibility (Duque *et al.*, 2005; Ynalvez & Shrum 2011). It is observed that the international databases such as the Web of Science often used in the bibliometric analysis of co-authorships have a bias against the local journals (Pendlebury, 2008; Pendlebury and Adams, 2012).

Qualitative assessment of what the collaborators contribute is very complex, to some extent impossible, given the “indeterminate relationship between quantifiable activities and intangible contribution” (Subramanyam, 1983:35). Therefore, qualitative methods such as semi and unstructured interviews as well as case studies should augment the quantitative bibliometric methods in co-authorship analysis. As noted earlier, individuals are the key actors in a collaboration, therefore, to understand human behaviour and interactions often needs quality assessments. Qualitative assessments offer modes to explore and understand the meaning individuals or groups attribute to a social or human problem (see Bryman, 2012; Sooryamoorthy, 2013).

Melin (2000) identified various reasons for using both interviews and questionnaires to get the general views of scientists on collaboration. Melin further states, “personal or emotional details can be revealed through interviews while patterns of a more general kind may appear when analysing the questionnaires” (Melin, 2000: 33). Furthermore, interviews offer a specific understanding of the scientists’ thoughts regarding collaboration, interactions in collaboration and the practice of collaboration. Equally, through interviews, scientists are able to report details and opinions on collaboration from their personal experiences in collaborative activities, instead of giving general views on collaboration. Although, reliance on interviews is insufficient as information and evidence on where the collaboration took place will be needed to supplement the interview data. In addition to the interviews, case studies can be used to supplement and complement the quantitative methods in the analysis of research collaboration. Yin (2014) notes, case studies are aimed at understanding a contemporary phenomenon within its real-life context, particularly when the boundaries between the said phenomenon and its context are not apparent. Yin maintains that the case studies are used when researchers want to unravel the contextual conditions where this may be of importance to the phenomenon being studied.

From the above discussion, no single method is sufficient in analysing research collaboration. In spite of the criticisms levelled against the use of bibliometrics, Katz and Martin (1997) are of the view that co-authorship cannot be entirely dismissed as a proxy for research collaboration, especially based on the advantages aforementioned like verifiability, inexpensive and availability of the data.

8.4.1 Co-authorship and Collaboration

The challenges that arise from collaboration being "fuzzy" are also seen in the issue of co-authorship as an indicator of research collaboration. Although co-authorship may be a valid indicator of research collaboration "in some instances, co-authorship may have numerous other meanings besides collaboration" (Ponomariov and Boardman, 2016: 1940). Inasmuch as co-authorship is often used as a measure of collaboration, it cannot be assumed that multi-/co-authorship is synonymous to collaboration. Therefore, it is important to identify the difference between co-authorship and collaboration.

Based on the 'fuzziness' linked to co-authorship, several scholars (Bozeman *et al*., 2013; Katz and Martin, 1997; Narin *et al*., 1991) have identified some factors that have to be considered in the bibliometric analysis, when co-authorship is an indicator of collaboration. These factors include:

i. The precise activities of all persons need to be known in order to establish the respective contributions
ii. Given the complex nature of human interactions over time, the nature and extent of collaborative activity is difficult to access
iii. Not all aspects of collaborative work can be quantified, and sometimes, qualitative assessment can be difficult.
iv. Co-authorship is not always as a result of research collaboration. Collaborators from different scientific fields may decide to publish separately.
v. On the other extreme, co-authored papers may simply represent a pooling of individual research findings that do not result from the research collaboration.

Based on the above factors, Katz and Martin (1997) cited examples that can distinguish between collaboration and co-authorship. Katz and Martin (1997) used two illustrations to make this distinction. In the first scenario, two scientists who have been working together later decide to publish the findings independently. The differences in their scientific fields might influence this decision. Hence, the collaborators individually publish single-authored papers for their specific scientific fields. On the other end, the collaborators may disagree on how to interpret the findings hence publishing single-authored papers. In this first scenario, Katz and Martin noted that the scientists collaborated on all the other activities of the research project except for writing up and publishing the findings. Bozeman *et al.* (2013: 3) assert that collaboration can occur without a co-authored paper ever being produced. The second scenario illustrates a case where scientists working on different research projects, decide on jointly writing up their results. According to Katz and Martin (1997), in bibliometric analysis, the second scenario where two scientists cooperate in writing up results and publishing a co-authored paper is considered a collaboration and not the first scenario where the researchers collaborate on a research project but do not co-publish (Katz & Martin, 1997: 11-13). Therefore, bibliometric studies, as is the case for this study, are required to consider the above-mentioned factors in their analysis. This allows for the validity of the results. The next section discusses the bibliometric studies conducted on African countries.

8.5 Research Collaboration in Africa

Studies on research collaboration show that African researchers collaborate with scientists across the globe especially from Europe and America (Adams *et al*., 2010; Wagner & Leydesdorf, 2005;). The largest producers of African science comprise of Egypt to the North, South Africa to the South, Kenya to the East and Nigeria to the West (Adams *et al.*, 2014; Mêgnigbêto, 2013). These four countries form the core of a scientific collaboration network as they strongly link the different African countries and/or regions as well as Africa to the global research networks (Adams *et al.,* 2014). These collaboration links vary across the African countries and regions.

A study by Boshoff (2009) observed stronger cross-regional links between South Africa, Kenya and Nigeria and not between South Africa and The Southern African Development Community (SADC) countries. Nigeria has stronger collaboration links with the fellow anglophone countries in East Africa compared to the weaker links with the other West African countries (Adams *et al*. 2010). Studies show that South Africa is a major collaborating partner for various African countries, specifically Kenya, Uganda, Tanzania, Ethiopia, Cameroon and Nigeria (Toivanen & Ponomariov, 2011). However, South Africa has only about 1% of its co-authored publications with researchers from other African countries (Sooryamoorthy, 2010). In addition to South Africa, studies show that key countries like Algeria, Egypt, Tunisia, Kenya and Nigeria, directly link African scientists in the geographically defined regions northern, southern, eastern and central (Adams *et al.,* 2010). Looking at the differences in the collaboration links between these African countries, Onyancha and Maluleka (2011) show that collaboration within Africa is evidently regional. Adams and colleagues also revealed that the collaboration patterns for African countries are not universal. The authors remark that collaboration patterns in Africa "exhibits layers of internal clusters and external links" that can be explained by regional geography, history, culture and language (Adams 2012; Adams *et al.*, 2014: 547). The observation above explains why the countries within the large North, South, East and West African regions tend to collaborate with each other. Language as a determining factor of collaboration has resulted in Anglophone countries collaborating with each other and the same applies to the Francophone countries.

As signalled above, colonial ties determine collaboration partners. The main collaborating partners for African countries are the United States of America (USA), France, the United Kingdom (UK), Germany and Canada (Adams 2014; Adams *et al.,* 2010). In determining the collaborating partners, the colonial past and cultural ties play a key role for the African countries (Boshoff, 2009). Schubert and Sooryamoorthy (2009) expound that about 29% of all the co-authorships between South Africa and the UK might be attributed to colonial ties. Similarly, Boshoff (2009) observes that 66% and 53% of the total research output respectively for Chad and Burundi could be attributed to their colonial ties with France and Belgium respectively. In addition, France is ranked as the key collaborative partner for Tunisia, Morocco and Algeria, accounting for at least 40%, 40% and 30% respectively of the total research output (Adams *et al.,* 2010).

Furthermore, inasmuch as the USA has no colonial ties with any African country, it is one of the main non-African collaborating partners for various African countries. For instance, for the case of South Africa, the USA is ranked the first collaborative partner, given that it accounts for about 32% of the co-authorships for South Africa (Schubert & Sooryamoorthy, 2009). Similarly, in the case of Kenya, USA is ranked first collaborating partner followed by the UK as it accounts for 32 and 23% of the Kenyan co-authored papers respectively (Adams *et al.* 2010). Adams *et al.* (2010) note that the US partnership with Africa could often be attributed to the African scientists who have studied in the USA and when they returned to their home countries, they maintained links with the research groups abroad. Moreover, these countries (USA, UK and France) are the largest funders of research in most of these African countries, especially, in the biosciences emphasising on medicine and agricultural sciences. Generally, international collaborations have led to the dominance of non-African scientists in African science (Toivanen and Ponomariov, 2011). Studies show that, in general, African countries display high collaboration rates (especially international collaboration) in comparison to other countries in the world. The authors note that about twenty-nine countries have over 90% co-authorships with other countries (Pouris & Ho, 2014).

In relation to collaboration in Africa, language, culture and geographical proximity have been identified in the literature as the key factors that mainly drive inter-continental collaboration (Boshoff, 2009; Adams *et al.,* 2010). However, despite these factors, collaboration among African countries is relatively weak (Boshoff, 2010; Adams *et al.,* 2010; Toivanen & Ponomariov, 2011; Pouris and Ho, 2014); often outperformed by collaborations with other non-African countries (Onyancha & Maluleka, 2011) and in the many instances African countries collaborate, it is a non-African country that might have made the initiative (Toivanen & Ponomariov, 2011). In their study, Pouris and Ho (2014) showed an increase in international collaborative papers by 66% between 2007 and 2011 as compared to the single-authored papers. In relation to the increase in international co-authorships, Onyancha and Maluleka (2011: 333) analysing the impact and nature of research collaboration in Sub-Sahara Africa concluded that “African countries contribute very little to each other’s knowledge production in terms of research articles”. Despite the minimal numbers of articles between African countries, the authors remark that inter-continental collaboration has higher effect on the citation impact.

Scholars claim that collaboration levels and intensities depend on the size of the scientific community. In their analysis, Narin *et al.* (1991) established that scientists in smaller scientific communities collaborate more internationally. Narin *et al.* argue that scientists in small scientific communities have higher numbers of scientists outside their countries to collaborate with and smaller numbers inside, compared to larger scientific communities like the USA, which have more scientists inside their countries to engage in collaborative activities. They argue that scientists in smaller countries initiate these collaborations since they do not easily find collaborators within their countries.

From the above studies, we observe that history, culture, language and colonial ties influence the collaboration patterns and partners in Africa. In this case, African countries collaborate more with countries like US, UK, France and Belgium. Given that African countries collaborate more with non-African countries, questions have been raised on the issue un/equal partnership between these countries. Scholars like Costello and Zumla (2000) discuss the positive and negative elements of research collaboration within the African context. In the next section, Costello & Zumla (2000) and other scholars (such as Habel *et al.,* 2014; Sooryamoorthy, 2013) address the issues on unequal partnerships in research collaboration.

8.5.1 The positive and negative elements linked with research collaboration within the African context

Costello and Zumla (2000) discuss two research collaboration models characterising collaboration between African scientists and non-African scientists. The two models include the semi-colonial and the partnership model. Costello and Zumla (2000) identified various characteristics of the semi-colonial model. First, the outsiders, in this case, the non-African partners dominate the research agenda setting. Second, the research output mostly produced by the non-African researchers as the lead collaborators and agencies is disseminated through research articles in internationally recognised journals and presented at international conferences. Costello and Zumla (2000) state that given the fact that the international community or funders dominate the agenda setting in this model, the international community tend to push its interests and not the interests of the African nations. In the 'partnership model', as the name suggests, all the actors involved in the collaborative research dominate and manage the research. In the partnership model, the national representatives manage the research and the dissemination of the research is balanced between the national and international spheres. The partnership model has the high ability to yielding positive effects in the scientific community, for instance building the local academic capacity and infrastructure. Looking at the characteristics of these two models, scholars discussed the 'best practices' of collaborations between African and non-African countries.

Costello and Zumla (2000) suggested four principles that describe a truly co-operative research partnership between developing countries and developed countries. The principles include, mutual trust and shared decision making, national ownership, the emphasis of getting research findings into policy and practice and development of national research capacity. In relation to Trust, Bozeman, Gaughan, Youtie, Slade & Rimes (2016) argue that collaboration is always deemed to have positive effects, ignoring the fact that it also has negative dimensions. Therefore, scientists decide to collaborate with those whom they trust. In their study, Bozeman *et al*. (2016) identified characteristics of good collaborations as trust, complementary skills, compatible work habits and the collaborator's enjoyment of each other's company. Scientists strongly prefer to collaborate with researchers they have had previous collaboration successful experiences instead of coming up with possible collaboration networks (Bozeman & Corley, 2004). As noted earlier, prior experiences in collaborations are closely linked to trust, therefore, individuals, institutions and countries that have previous experiences, tend to concur in collaborations (Sooryamoorthy, 2013). These principles of true co-operative research collaborations are key in identifying inequalities in partnerships.

Assessing the actual involvement of the contributors from the North and the South, several scholars Habel, Eggermont, Günter, Mulwa, Rieckmann, Koh, iassy, Ferguson, Gebremichael, Githiru & Weisser (2014) discuss the unequal aspects in science with a focus on research inequality in north-south bio-diversity research. Habel *et al*. (2014: 3145) identified some of the characteristics that depict research inequality in the north-south partnerships to include:

i. Most of the lead (first), senior (last) and corresponding authors are hosted in developed countries;
ii. research activities by sub-Saharan African collaborators are still predominantly restricted to raw data collection and preliminary data analysis;
iii. the conceptualisation of study designs, sophisticated laboratory tests, most statistical data analysis, data interpretation and the dissemination of results in peer-reviewed journals are still primarily carried by "northern" institutions;
iv. benefits for countries in the "south" are often restricted to monetary profits "business of raw biodiversity data" (i.e. high fee charges for research by non-residents and for export permits, local institutions charge additional fees when acting as the affiliating body etc.);
v. state of affairs tacitly supported by institutional arrangements in the "north" (i.e. tenure decisions are mainly based on journal decisions and fundraising and nominal weights attached to training and capacity building in research evaluations)

Despite the inequalities, Habel *et al.,* 2014 suggest solutions to ensure equal partnerships between African and its international partners.

> Firstly, "institutions and funding bodies in the ["north"] need to ascribe greater weights to local engagement and capacity building in granting, promotion and tenure; […] Secondly, engagement of local stakeholder throughout the research development process, from inception and co-design of the project to the actual implementation, publication and translation into societal and economic benefits; […] lastly, institutions that fund scholarships for sub-Saharan African students to attend northern universities should also consider investment in (biodiversity) employment for post-graduates in the local countries" (Habel *et al.,* 2014: 3147).

The authors continue to emphasise that international partners should consider the national institutional policies when initiating collaborations. These policies may include the promotion and appointment policies, the capacity building policies and employment policies. These efforts from the international community will ensure that the African nations through international collaborations are able to reward and recognise its researchers and create capacity for future research.

8.6 Research collaboration: Bibliometric indicators

This section discusses the bibliometric indicators considered in measuring research collaboration in this study.

8.6.1 Trends in collaboration patterns and Intensity for Kenya for the period 1980 - 2015

Conventionally, bibliometric analysis uses co-authorships of scientific papers as a measure of research collaboration. Our analysis also looked at the patterns of co-authorship in the scientific papers to establish collaboration in Kenya. In our bibliometric analysis we classified co-authorships into four categories, namely:

- No collaboration (involves either single-authored papers or single institution authorship);
- National collaboration (multiple authors from more than one institution in Kenya);
- International collaboration with scientists from African countries only; and
- International collaboration with scientists from countries outside Africa.

The first figure below presents data on the single-authored papers and the co-authored papers (with at least two authors) for Kenya. The data show that the proportion of single-authored papers for Kenya decreased dramatically from 40% in 1980 to about 3% in 2016. During the period between 2000 and 2016, the proportion of single-authored papers were mostly less than 5%. Co-authored papers for Kenya increased from about 60%in 1980 to about 97% in 2016. For the last decade, between 2005 and 2015, the co-authored papers were at least 95%.

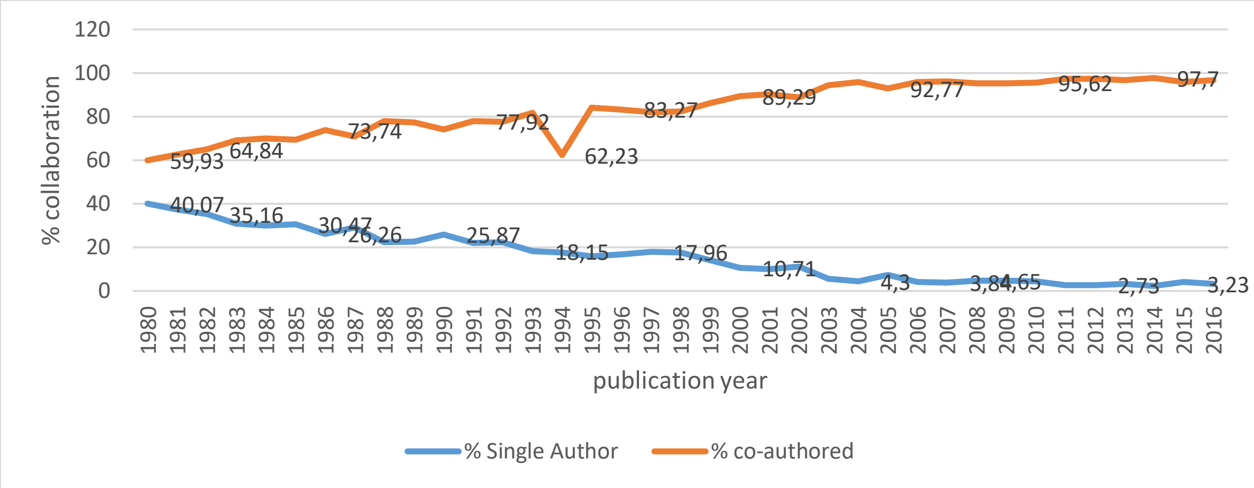

Figure 8-2: Kenya author collaboration

The results illustrated in the figure below are not surprising given global trends in collaboration. Several factors have been identified in the literature that could explain the huge increase in collaboration. For instance, in the context of 'big science' characterised by huge funding and teamwork, researchers collaborate more. Also, the increased costs of conducting scientific research (e.g. constructing large laboratories), has resulted to pooling of resources and equipment for research together, hence collaboration of researchers is seen as a mode to efficiently produce science (De solla Price, 1963). Despite the increase in research collaboration, there are still field differences. A disaggregation by main scientific field shows that the largest proportion of co-authored papers for Kenya are in the fields of Health Sciences (90%), Agricultural Sciences (89%), Natural sciences (83%) and Engineering and Technologies (76%). Conversely, a significant proportion of single-authored papers are produced in the Social sciences (29%) and particularly in the humanities (about 61%). These findings are in line with most scholarship that shows that the "readiness and need" to collaborate varies with scientific field. The example cited is that of the medical sciences where researchers often tend to work in teams and collaborate more with other teams. Whereas in the humanities, research tend to work individually, and collaborations are minimal. Studies also showed that scientists in applied fields such as engineering tend to collaborate more as compared to those in the basic sciences such as chemistry and biology. The variance in 'mutual dependence' among fields also explains the differences in the collaboration among fields. For fields such as High Energy Physics that exhibit high 'mutual dependence' (highly depend on each other for the resources and skills) researchers tend to collaborate more since they rely on each other for the skills and sharing the scarce resources (i.e. funding and equipment). Similarly, fields that display 'low degree of task-uncertainty' such as High Energy

Physics have clear work techniques and reliable results are produced its researchers tend to collaborate more (Fry and Talja, 2007).

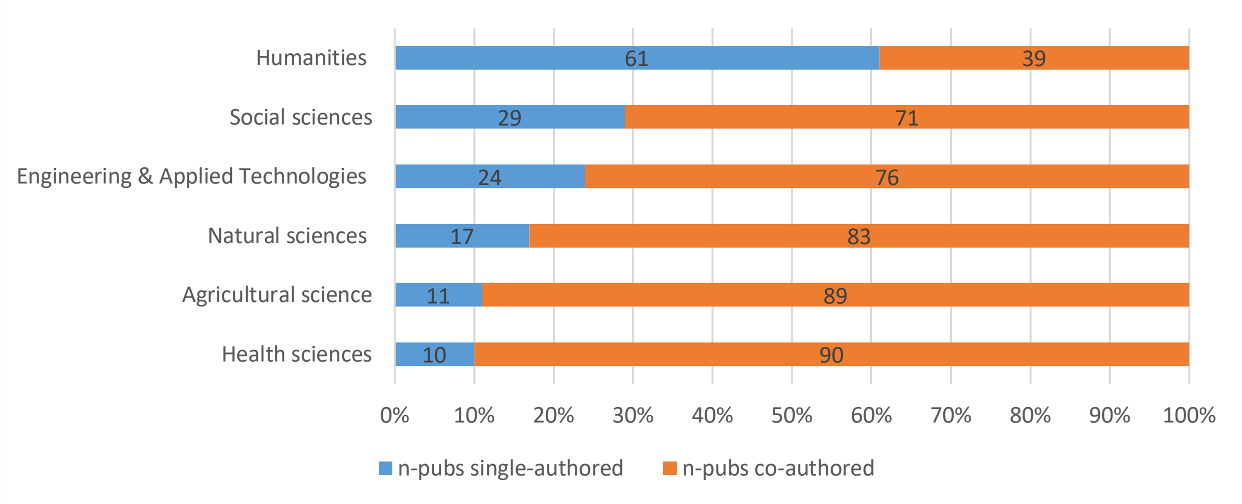

Figure 8-3: Proportion of Single-authored and co-authored publication per main science domain

Further disaggregation of the scientific fields into subfields provides a more granular picture of the field differences. This disaggregation shows that the largest proportion of co-authored scientific papers are from the Basic health sciences (95.15%), chemical sciences (89.95%), Agricultural Sciences (88.61%), clinical and public health (87.91%), Biological Sciences (86.84%), Multidisciplinary sciences (83.82%), earth sciences (77.35), psychology (76.62%) and engineering sciences and applied technologies (75.51). A significant proportion of the single-authored papers are from fields such as Religion (80.95%), Language and Linguistics (71.23%), Law (68.4%), other humanities and Arts (50.37%) and Education (41.79%). Generally, when the fields are disaggregated further at the lower level, on average, the proportion of the co-authored papers (69.96%) remains higher as compared to the single-authored papers (32.04%).

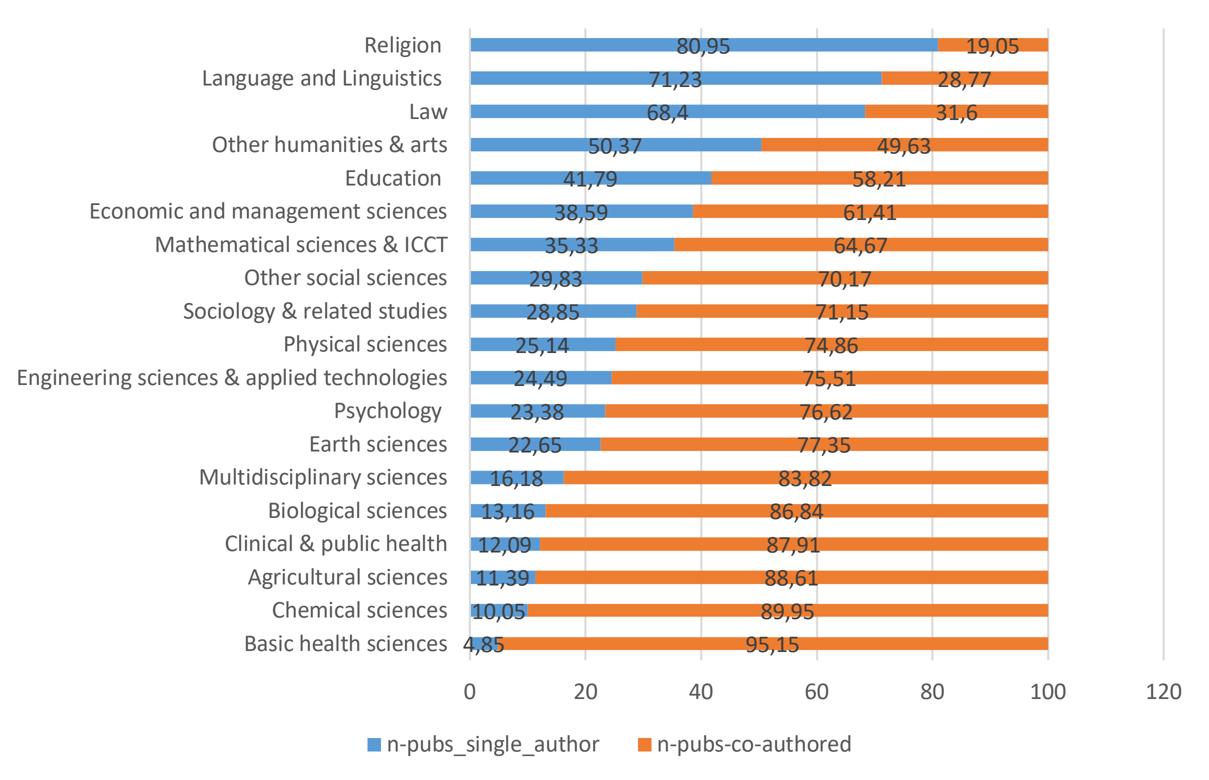

Figure 8-4: Proportion of single-authored and co-authored papers per main scientific field

The figure below compares four categories of collaboration:

- No collaboration, which refers to the single-authored papers;
- National collaboration, which refers to the collaboration with other researchers in the institutions;
- Collaboration with other African countries only: these papers consists at least one author affiliated to Kenya and one or several other authors affiliated to other African countries; and
- Collaboration between Kenya and the rest of the world: these papers comprises of authors affiliated to Kenya and to at least one country outside Africa.

Our results show a clear trend towards more international collaboration with researchers in countries outside Africa especially from 1995 onwards. The largest increase occurred over the period 2000 to 2016. In 1980, only about 27% of Kenya's scientific papers involved co-authorship with at least an author from countries outside Africa. By 2016, the proportion of the papers that involved co-authorship with at least an author from countries outside Africa had increased to 80%. In as much as international collaboration has increased tremendously over the years, national collaboration declined from 34% in 1980 to 11% in 2016. The results show a clear trend towards more national collaboration in the 1980s, as the co-authorship with researchers at other institutions in Kenya increased from 34% in 1980 to 41% in 1989.

However, this trend declined in the 1990s and 2000s. On average, about 26% of scientific papers with multiple authors from more than one institution in Kenya. A clear decline in single-authored publications has also been observed declined from 40% in 1980 to 3% in 2016. About 16% constitutes of single-authored or institution (no collaboration) scientific papers. Our results show a very small, but steady trend of the collaboration of Kenyan authors with scientists from other African countries this proportion increased from a lower base of 1% in 1980 to at least 7% in 2016. On average, about 4% of the scientific papers for Kenya are co-authored with researchers from other African countries only. In general, a majority of Kenya's papers fall into two groups: papers with authors from institutions in the same country (National collaboration) comprising of 28% of all papers and for papers where there is some collaboration with researchers from countries outside Africa (54% of the papers.

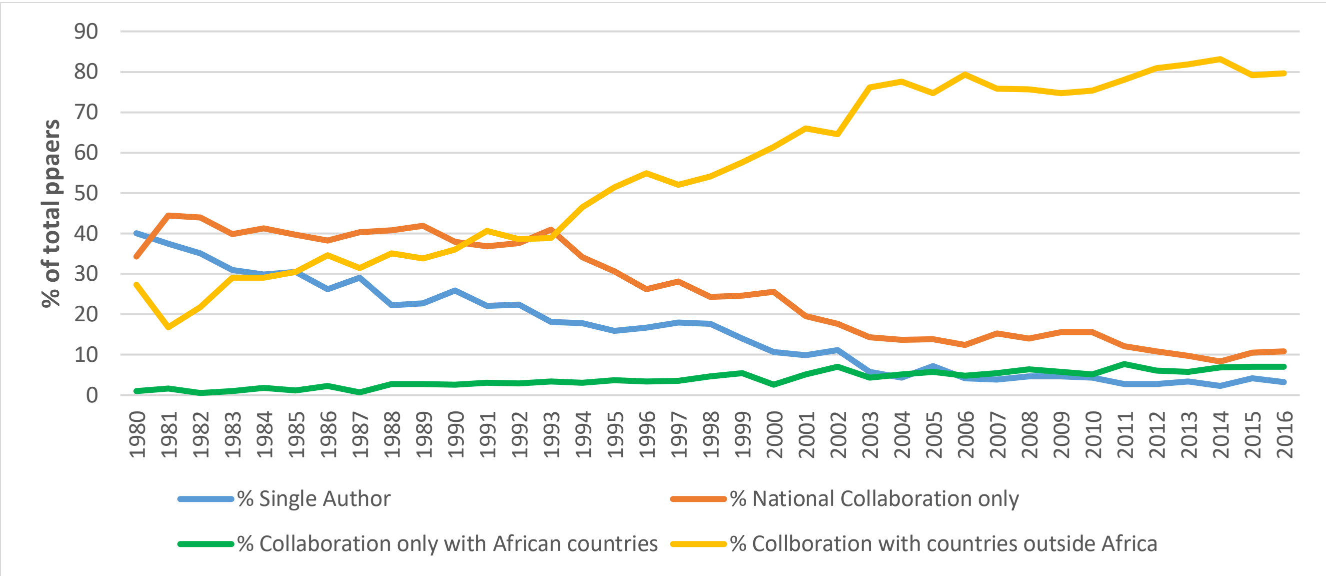

Figure 8-5: Trends in research collaboration within Kenya and with the rest of the world

This sub-section looks at how these four categories of research collaboration vary across the different main scientific domains. The clear trend towards international collaboration overall in the Kenyan scientific papers is also exhibited when the main scientific domains are disaggregated. Particularly, in the past decade, there has been the highest increase in international collaboration with researchers in countries outside Africa in the fields of Natural sciences, Health Sciences, Engineering Sciences and applied technologies, Agricultural Sciences and Social sciences. On the other hand, the humanities maintain a significant proportion of single-authored papers with slight increases in international collaboration in the past decade.

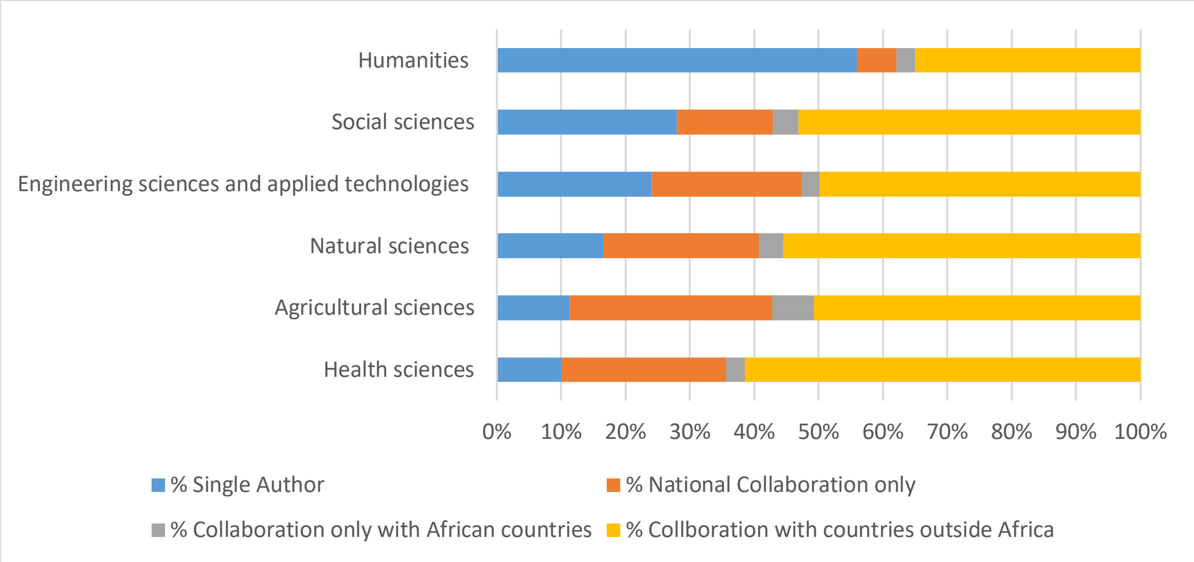

Figure 8-6: Trends of collaboration for Kenyan across the main scientific domains

The results in the figure above show that humanities registers the highest proportion (60.79%) of single-authored papers (no collaboration). However, in the recent past, the proportion (38.05%) of the papers with at least an author from outside Africa have also increased. The humanities registered the lowest proportion (3.17%) of papers with national collaboration only (with researchers from institutions in Kenya only). The social sciences recorded substantial numbers of (54%) of scientific papers with at least one other author from outside Africa. In addition, single-authored papers still constitute a significant proportion of all papers (29%). Engineering sciences and applied technologies have about half of its papers (50.63%) with at least an author from outside Africa. The other proportion of the papers in engineering sciences and applied technologies were equally spread between national collaboration only (24.5%) and collaboration with researchers in other African countries (23.7%). The natural sciences recorded a significant proportion (56.1%) of scientific papers with at least an author from countries outside Africa. This is followed by a slightly lower proportion (24.5%) of papers with researchers from Kenyan institutions only. Similarly, a majority of papers in agricultural sciences are internationally co-authored papers. The health sciences, perhaps not surprisingly, has the highest proportion (62%) of internationally co-authored.

8.6.2 Collaboration Intensity

This subsection presents maps that compare the collaboration intensity between Kenya and other African countries as well as the rest of the World. The maps are for two periods: 2005 to 2007 and 2011 to 2015 respectively.

According to the results, between 2005 and 2007 the top collaborating countries (between 354 to 735 papers) with Kenya at the international level were the United States and the United Kingdom. The second category of countries at the international level with slightly high collaboration intensity (between 82 to 354 papers) were Australia, Canada, Japan, France and Germany. The third category of countries with notable collaboration intensity with Kenya was Brazil, China and India. The results further illustrate that for the same period (2005 2010) South Africa was the top (between 82 to 170 papers) African collaborator for Kenya followed by Tanzania and Uganda as indicated in figure 7.19. The secondary category of African countries with small but notable collaboration intensity (between 19 to 40 papers) with Kenya was Nigeria, Ghana, Burkina Faso, Rwanda, Burundi, Ethiopia and Sudan, Zambia, Malawi.

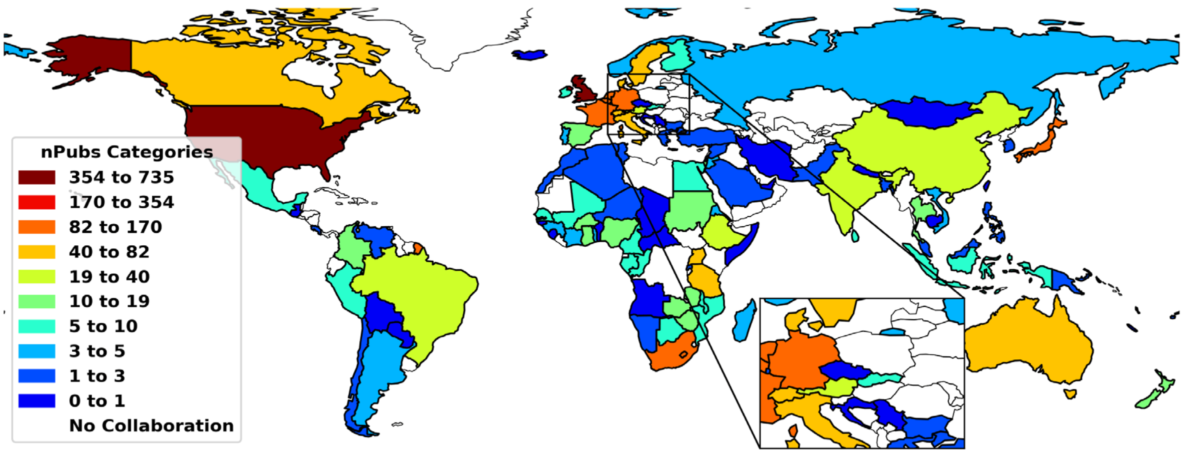

Figure 8-7: Collaboration intensity with other countries: 2005 to 2007

Between 2012 and 2014 period the top collaborating countries (between 770 to 1770 papers) at the international level with Kenya were the United States of America and the United Kingdom. The second category of countries with a high collaboration intensity (between 147 to 770 papers) was Canada, Australia, France, Germany, Sweden, Australia, New Zealand, and China. The third category of countries at the international level with notable (between 64 to 147 papers) collaboration intensity with Kenya included Japan, Brazil, Spain, India and Thailand. For the same period, the top collaborators with Kenya within the African continent, (between 147 and 770 papers) were South Africa, Uganda and Tanzania. The results show that other African countries with notable (between 64 to 147 papers) collaboration intensity with Kenya were Nigeria, Ghana, Ethiopia, Zambia and Malawi as Figure 7-20 illustrates.

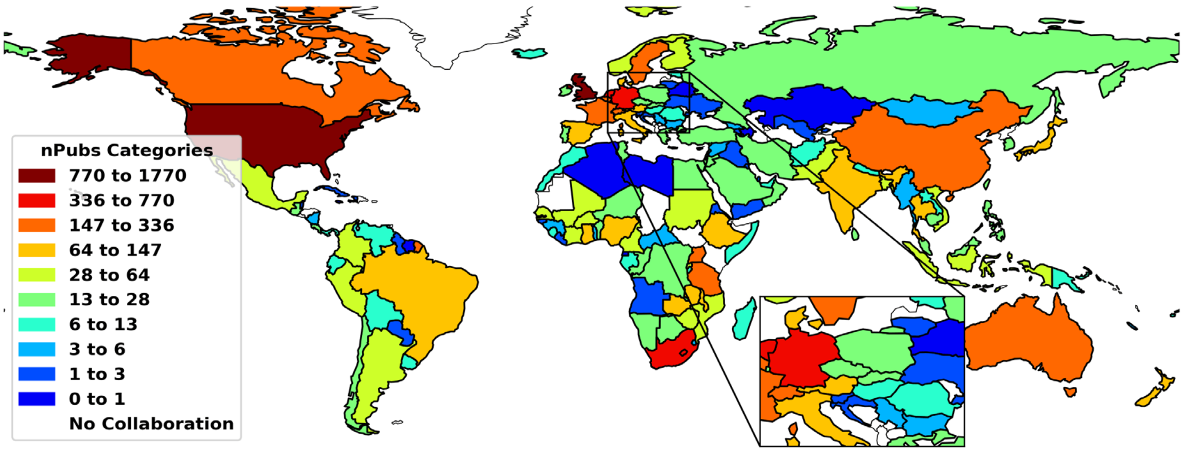

Figure 8-8: Collaboration intensity between Kenya and other countries: 2012 to 2014

8.6.3 Discussion

8.6.3.1 International research collaboration

The findings and the literature review reported (Adams, 2012; Adams *et al.*, 2010; Mouton and Blanckenberg, 2018; Mouton, Prozesky and Lutomiah, 2018; Onyancha and Maluleka, 2011) above found high average rates of international (outside Africa) collaboration (55%). My findings show that as of 2015, 79% was the proportion of the papers with international collaboration. This is corroborated by the interview data which show that respondents often collaborate with international partners. Several reasons could be attributed to the very high average rates of international collaboration. The literature I reviewed shows that there are notable field differences in research collaboration (Melin, 2000). Melin shows that scientists in the medical, agricultural and natural sciences tend to collaborate more compared to the scientists in the humanities and social sciences. These field differences in research collaboration have been linked to the differences in the equipment, funding and team effort needed for research in the health sciences and natural sciences compared to the humanities or social sciences (Ponomariov and Boardman, 2010; 2016). The results on the field profiles above illustrate that Kenya is active in the health sciences, natural and agricultural sciences, followed by the social sciences. The field collaboration profiles equally showed higher rates of international collaboration in the health sciences and natural sciences.

The authorship trends in the health, natural and agricultural sciences could be attributed to the main sources of the research funding of the projects (mostly international funding) as well as the emergence of “big science” in the health sciences. Literature shows that “big science” is linked to teamwork and international funding. In relation to “big science,” the Global Health Network oversees large research projects that involve large research teams from different countries with the aim of addressing the challenges of tropical diseases (i.e. malaria) and conduct clinical trials, in which Kenya is a key participant (Mouton, 2018). These health research projects are often multi-funded by different countries or funding organisations as well as involve multi-authorship with several researchers from different countries. In the literature reviewed, Wang and Shapira (2015) showed that multi-funded research tends to involve multi-authorships. My results support the observation by Shapira and Wang (2015) as respondents indicated that most funders require them to collaborate. This observation is confirmed by my results which show that scientists collaborate as a requirement by funders, especially for projects involving multi-disciplinary research or following the need to share limited resources (funding and equipment) for research. In some cases, international institutions conducting research in the African context will require local African partners to participate in the research. Furthermore, since collaboration and funding are intertwined (Zucker *et al.*, 2007), my results show that scientists are of the perception that collaborating, especially with researchers across the globe will enable them to secure funding.

Nonetheless, several concerns have been raised in the literature I reviewed in relation to the inequality in a research (international) collaboration that especially involves (global north-south partnerships) African countries and developed countries (Habel *et al.*, 2014; Moyi Okwaro and Geissler, 2015). In some cases, for instance, the north-south partnerships have been characterised by the following:

- African collaborators are mainly regarded as raw data collectors and preliminary data analysists and
- African collaborators have received no or less recognition in the co-authorships as the first authors or corresponding authors tend to be in the developed countries thus were not or were less acknowledged for their contributions in the research.

Scholars have made suggestions on how African countries and developed countries can achieve equal research partnerships: engaging local (African) stakeholders in the entire research development process from inception, designing of the project, implementation and publication (Habel *et al.*, 2014: 3147). The participants in the interview indicated that for international collaborations, they were involved in the different stages of research, and there was a clear division of labour of the research activities.

Intra-continental collaboration

Although, the results and the literature reviewed show high rates of international collaboration (with researchers outside Africa), my results are consistent with the findings of previous studies (Boshoff, 2009; Onyancha and Maluleka, 2011; Mouton and Blanckenberg, 2018) that there is minimal intra-continental collaboration (with researchers in Africa) for Kenyan researchers and African researchers in general. My results show that, by 2016, Kenya had only 4% of its papers co-authored with scientists from other African countries. This trend was the same for other African countries as they recorded low co-authorship rates with scientists from other African countries: Tanzania (5.5%) and Uganda (4.2%) (Mouton *et al.*, 2019). These results confirm previous findings by Onyancha and Maluleka (2011) that African countries do not contribute much to each other's knowledge production in terms of research publications.

National Collaboration

In addition, the bibliometric results show minimal national collaboration, especially in the past decade, compared to the very high rates of international collaboration. The survey results show that inasmuch as it is difficult to secure collaborators in general, respondents reported they were able to collaborate nationally with researchers from other institutions in the country easily as compared to the international level. My results show that the collaboration at the national level is faced with minimal challenges of travelling costs to conferences.

From the results and the literature, several reasons have been identified to explain the minimal collaboration at the national level. As is the case with inter-continental collaboration, my results and the literature reviewed suggest that funding hints to why national collaboration rates are minimal. Minimal funding support from the national government and institutions impedes researchers to engage in research and participate in research-related activities such as organizing for workshops or conferences. Although accessing research funding remains a challenge for Kenyan researchers in general (Chapter 6), the results show that given the minimal financial support from the government, researchers opt for international partners for funding and collaboration, and in some instances opt to support own research and engage in no collaboration (producing single-authored papers).

Apart from funding, the research capacity available to enhance collaboration within a country could also explain the minimal or high rates of national collaboration in a country. The literature shows that, small scientific communities (e.g. African countries) tend to engage in international collaboration more than national collaboration (Narin, Stevens and Whitlow, 1991). Smaller scientific communities have more researchers outside their countries to collaborate with and a smaller number inside the countries, compared to the large scientific communities. Previous studies revealed that large scientific communities such as the USA, have a large number of strong scientific institutions and more researchers that tend to collaborate with each other, hence the high collaboration rates within the country (Narin *et al*., 1991). Statistics reported show low rates of international collaboration in the large research systems, signalling a higher rate of national collaboration and single-authored papers. For instance, in 2012, the United States of America (top research performing country in the world) recorded equal proportions of national and international co-authorship, at least 30%, while the rest of the papers were single-authored (Mouton *et al.*, 2019). In addition, for the United Kingdom, the rates of national collaboration were higher than international collaboration. For the UK, France and Germany, their international collaborations rates varied between 40% and 50% (Mouton *et al.*, 2019). These figures are in contrary to the national collaboration rates experienced in most African countries, with most countries having national collaboration rates below 30% and 20%. In 2016, for instance, Kenya recorded 9% of the nationally co-authored papers compared to the 83% internationally co-authored papers. This pattern is similar to other African countries that recorded less than 15% of national collaboration: Tanzania (10.4%), Uganda (11.3%) and Botswana (11.3%). Other countries like South Africa, Egypt and Tunisia recorded more than 30% of nationally co-authored papers, implying that they are more likely to have strong scientific institutions and more researchers that allows the higher rates of national collaboration. Scholars argue that higher rates of international collaboration with low rates of national collaboration or no collaboration could signal weaker national science systems, that lacks strong scientific institutions, with a strong research culture and more researchers that will produce more nationally co-authored papers (Mouton *et al.,* 2019).

Single authored papers (No collaboration)

Previous research has pointed to a general decline in single-authored papers in recent years (Mouton and Blanckenberg, 2018; Mouton *et al.*, 2019; Onyancha and Maluleka, 2011). As signalled above, high rates of international collaboration in a country could indicate minimal single-authored papers or nationally-co-authored papers (Mouton *et al.*, 2019). My results show that, scientists (especially young scientists) face challenges in securing collaborators and funding, both internationally and locally. Young scientists fail to secure financial support for travelling to conferences to meet and network with other researchers who can be potential collaborators. Therefore, in these instances, scientists tend to fund their own research and publishing, and subsequently publish single-authored papers.

8.6.3.2 Collaboration Intensity

The results show that the United States of America and the United Kingdom are the top collaborators for Kenya. The literature reviewed showed that the colonial past and cultural ties play a key role in determining the collaborating partners for African countries (Boshoff, 2009; Sooryamoorthy, 2013). Therefore, in the case of the UK, the high collaboration intensity can be attributed to the colonial ties and similarity in language between these two countries. In as much as Kenya was never a colony of the USA, the high collaboration intensity between Kenya and the USA could be explained by two main factors. First, the results on funding acknowledgements and the main funding organizations (funding chapter) show the USA and the UK are the top funders of research in Kenya, especially in the biosciences with an emphasis on medical and agricultural sciences. Scholars have shown that research projects that receive international funding or multiple funding from different countries are more likely to involve multiple-authorship with authors from different countries (Wang and Shapira, 2011, 2015). Thus, international collaborations and international funding have resulted in the dominance of non-African scientists in Kenyan science or African science at large (Toivanen and Ponomariov, 2011). Secondly, the USA partnership with Kenya can also be attributed to Kenyan scientists who studied in the USA and upon their return, they maintained links with the research groups abroad (Adams *et al*., 2010). By 2016, the top destination for international students from Kenya was the United States of America with about 3 122 students followed by Australia (2 422) and the United Kingdom (2 173) (UNESCO Institute for Statistics, 2019). The qualitative interviews confirmed this claim, as some interviewees indicated that they continue to collaborate and co-publish with their previous mentors or supervisors and the research networks they created while working/studying abroad.

In both the literature reviewed and the results presented above, I found that South Africa was the top collaborating partner for Kenya within Africa, followed by Tanzania and Uganda. The results are consistent with previous studies which showed that some African countries like South Africa, Kenya, Nigeria, Algeria and Egypt directly linked the African scientists in the geographically defined regions (Eastern, Southern, Northern and Western) (Adams et al., 2010). The results also show that Kenya directly links to other scientists in the East African region: Tanzania, Uganda, Rwanda and Burundi. This collaboration pattern was previously observed by Adams *et al.* (2010) who showed that countries in the same geographic region are more likely to collaborate with each other than the countries in other regions. These results also confirm a pattern that previous studies found, which is that research collaboration links between these African countries are largely regional and a country's research output is supported by its neighbours (Onyancha and Maluleka, 2011). The results also support previous observations that collaboration patterns in Africa demonstrate links and clusters that can be explained by geographical proximity, history, culture and language (Boshoff, 2010).

8.7 Factors that influence research collaboration

Collaboration is influenced by several factors. These factors include personal and scientific factors among others. Personal attributes may include the demographic characteristics that impact the research collaboration process. The characteristics among others are age, gender, funding, international mobility and nationality among others (Bozeman *et al.,* 2013). The assumption is that researchers who have the same demographic characteristics are more likely to collaborate with each other. Bozeman and colleagues have conducted a number of studies investigating personal attributes specifically gender as related to collaboration patterns (Bozeman, 2001; Bozeman *et al.* 2013: 8). In the next section, I discuss the relationship between gender and research collaboration.

8.7.1 Hypothesis 1: Gender and research collaboration

Gender is seen as one of the “most personal and salient issues in one’s life”, particularly in academic science where there is under-representation of women and minorities (Pollak and Niemann 1998; see also Johnson and Bozeman, 2012, quoted in Bozeman *et al*., 2013: 8). Gender inequality and biases continue to exist in science (Larivière, Ni, Gingras, Cronin & Sugimoto, 2013; West, Jacquet, King, Correll & Bergstrom, 2013). These gender inequalities continue to be seen in “hiring, earnings, funding, satisfaction and patenting” (Larivière *et al.*, 2013: 211). Gender inequalities can also be seen in research collaboration and productivity. Gender is said to be a key “personal collaborator attribute” in science. Bozeman et al., 2013 note that, inasmuch as career attributes are among the factors that influence women collaboration, “the outcome of the female collaboration is highly personal” (Bozeman *et al.,* 2013: 8). Gender as a personal attribute has an influence on research collaboration.

A number of earlier studies in the literature have shown that women scientists tend to collaborate differently and less effectively in comparison to the men scientists (Cole and Zuckerman, 1984). Findings show that female scientists are likely to collaborate noticeably less than their male colleagues after the postdoctoral period (Sonnert & Holton, 1996). It is indicated that women are more likely to establish more formal collaborations (Sonnert & Holton, 1996), however, Bozeman and Corley (2004) showed that these collaborations and research networks tend to be less “cosmopolitan”. Examining data from 451 scientists and engineers at academic centres in the United States, Bozeman and Corley (2004) studied collaboration patterns of the researchers using regression models. Using one of the models they analysed the effects of gender, scientific field, funding and tenure on the proportion of the female collaborators for an individual researcher. Bozeman and Corley (2004) established that, female scientists who are non-tenured, tenured, hold the rank of research faculty or research group leaders collaborate with a higher proportion (36%) of other females compared to the proportion (24%) of the male scientists in the same ranks. The analysis also showed that, an overwhelming majority (83.3%) of “non-tenure track females collaborate [more] with other females” (Bozeman & Corley, 2004: 607). Thus, linked to their results that women scientists have a higher percentage (36%) of their collaborators as women, compared to men (24%). The analysis by Bozeman and colleagues on gender and collaboration is limited as the studies focus mainly on measuring gender objectively through collaboration patterns. Hence, their conclusions are centred on the patterns of collaboration for men and women researchers. The study thus lacks subjective analysis to determine whether gender similarities or differences are determinants of the collaboration process or the composition of the collaborative group.

Van Rijnsoever and Hessels (2011) using survey data examined the characteristics of scientists that are linked with disciplinary and interdisciplinary research collaborations. They found that there seem to be changed in relation to gender and collaboration patterns. Their results showed that women are more likely to be involved in interdisciplinary collaboration than men. Importantly, this study only analyses data from one university in the Netherlands with about 300 respondents, thus its results have to be applied cautiously given the low response rate of 17% reported.

Recently, Bozeman and Gaughan (2011) conducted a study to observe gender in research collaboration. The study aimed to determine whether the previous observations discussed above on the differences in collaboration patterns between men and women are linked to the “actual differences” in gender or to “false” relationships associated with imperfect models. The study Given a dataset with about 1714 respondents weighted by gender and the scientific field, Bozeman and Gaughan focused their analysis on research collaborations with industry and the motivations for collaboration. The study established, inter alia, that there are considerable gender differences in relation to the choice of strategies for collaboration. For instance, men are more likely to lean on “collaborations based on instrumentality and previous experiences” compared to females, while both men and women are motivated by “mentoring” strategies”(Bozeman & Gaughan, 2011: 1393). Importantly, the study by Bozeman and Gaughan (2011) established that when models are well developed “women tend to; have rather more collaborators on average” compared to men, especially when the model controls for age, scientific field, tenure, doctoral cohort and family status and size (Bozeman &

Gaughan, 2011: 1393). Thus, gender differences hold true for a well-developed model that also accounts for other factors such as field and age, among others.

A study by Abramo, D'Angelo & Murgia (2013) using a bibliometric approach found that women scientists record a higher capacity of collaborating in the forms analysed (intramural, domestic and international), except for international collaboration where there are still larger gaps compared to their male peers (Abramo *et al*., 2013: 811-812).

In addition, Bozeman and Gaughan (2011) also examined gender and the engagement with the industry using the 'industrial involvement index'[20] to compare the males and females collaboration with industry. Bozeman and Gaughan observed that even in models that are fully developed the involvement of men with industry is more than that of women, though, the affiliations of women with multidisciplinary research centres tend to minimize on this impact. These findings are similar to those of Gaughan and Corley (2010). Studies show that women have more interdisciplinary research and collaboration than their male peers (Araújo, Moreira, Herrman & Andrade, 2017). Similarly, Araújo *et al.* (2017) observed that across all the fields analysed, male scientists, collaborate more with other male scientists, whereas the females are more "egalitarian" (females collaborate equally with both male and female scientists). This is in spite of the scientist's number of collaborators. The only exceptions were found in the field of engineering where with an increase in the number of collaborators, the "gender bias" disappeared (Araújo *et al*., 2017:1).

From the body of literature reviewed above, several studies show conflicting or ambivalent results on the gender differences in collaboration (Bozeman and Corley, 2004; Bozeman and Gaughan, 2011). However, generally it is seen that when other factors that influence scientific collaboration are controlled for, studies show that female scientists register a greater propensity to engage in collaborative and interdisciplinary research, they may have less collaborators and tend to be less involved in international collaboration as their male peers (Cole and Zuckerman, 1984; Sonnert and Holton, 1996; Bozeman and Corley, 2004; Van Rijnsoever and Hessels, 2011). The rank of academics has been found to have an influence on research collaboration. The next section discusses studies that have analysed the association between rank and research collaboration.

[20] The industrial involvement index sums up various types of interactions that ranges from "modest and low effort" (for instance, provide research publications when requested) to "intensive" (co-develop patents).

Null Hypothesis (H_0): There is no positive association between gender and the frequency of collaboration

Alternate Hypothesis (H_a): There is a positive association between gender and the frequency of collaboration

Method of analysis: Cross-tabulation, chi-square statistic

8.7.2 Hypothesis 2: Rank and research collaboration

Several studies have investigated tenure in relation to research collaboration (Bozeman & Corley, 2004; Boardman & Ponomariov, 2007). The discourse on research collaboration always considers the need for one or more of the collaborators to have tenured positions (Boardman & Ponomariov, 2007). Despite these debates, a number of studies on research collaboration revealed that tenure does not have significant effects on the collaboration choices or the number of collaborators. In their analysis, Bozeman and Corley (2004) found that tenure was not strongly and statistically significantly associated to the number of collaborators or the proportion of the female collaborators, the collaboration strategies the proximity of researchers. When analysing the relationship between tenure and the collaboration choices and strategies, the authors observed that those untenured are more tactical in their collaboration choices and strategies. Furthermore, the authors found a statistically significant and positive relationship between tenure and the mentor collaboration strategy (Bozeman and Corley, 2004: 607). That is, in terms of collaborating with graduate students, tenured female academics and tenured male academics more often tend to participate in collaborative activities with graduate students.

From the body of literature reviewed above, it can be seen that rank has mixed results on collaboration numbers, strategies or choices. Particularly, no significant results were found between tenure and the number of collaborators or the collaboration strategies for the female collaborators. Age has been identified in the literature as a key influence of research collaboration. The next section reviews studies that have analysed the relationship between age and collaboration.

Null Hypothesis (H_0): There is no positive association between academic and collaboration

Alternate Hypothesis (H_a): There is a positive association between academic rank and collaboration

Method of analysis: Cross-tabulation, Chi-square statistic

8.7.3 Hypothesis 3: Age and research collaboration

Age is undoubtedly one of the personal characteristic likely to impact research collaboration. Though, there are limited studies that have analysed the influence of chronological age and career age on collaborations, the assumption is that the influence of age on collaboration is "obvious", that is, the older scientists are more likely to "have more collaborators and a richer and more diverse collaboration network" (Bozeman *et al.*, 2013: 7). This aspect could be linked to cumulative advantage in science where older scientists following their previous recognition in science attract more funding, resources and networks that allow them to collaborate more as compared to the younger researchers.

Several other studies that have analysed age in relation to collaboration found mixed results. Studying at least 600 scientists in the US, Lee and Bozeman (2005) found that career age has mitigating effects on the relationship between research collaboration and productivity. The younger scientists, as well as those in their mid-career, displayed substantial productivity, in terms of the research publications per collaboration. Although, at a given threshold, older scientists start to experience a lesser return on investment, as the more collaborations or collaborators minimally impacts their research productivity.

Another study by Ponomariov and Boardman (2010) showed that career age is not significantly associated with the researchers' number of publications with the industrial collaborators, that is, before controlling for various possible "confounding" variables. However, this finding is deemed less counterintuitive. Firstly, the study shows, a minimal proportion academics publish with industry-based researchers both young and old about 11.4% have no affiliation with research centres and 20.7% have affiliation with research centres. Secondly, the scientists affiliated with research centres are acquainted early on with industry staff, acquaintances that might take those faculty with no affiliations with research centres longer to establish these contacts.

Aschoff and Grimpe (2011) examined the possible early "imprinting effects" for the young scientists involved with the industry. Their analysis showed, that researchers in academic departments with a slightly higher proportion of researchers who co-author with the industry are more likely themselves to get involved with the industry. Scientists who are involved in the industry tend to co-author with scientists in the industry. The author argues that age is not a determinant of the scientist's peer group. However, what is important is the association between age and the involvement with the industry of peers in the department. The study suggests that scientists who get involved with the industry at a younger age have a stronger likelihood of having stronger and continuous industry relations. Hence, stronger collaborations later with the scientists in the industry. Van Rijnsoever and Hessels (2011) studied academics in a university in the Netherlands and that research experience has a positive relationship with disciplinary and interdisciplinary collaboration.

Studies reviewed above showed mixed results, as career age has effects on productivity as well as collaboration. Particularly, younger scientists, as well as those in their mid-career, showed higher productivity in terms of the research publications produced per collaboration. Literature has identified the scientific field as a key determinant of research collaboration. The next section discusses studies that analysed the association between the scientific field and collaboration.

Null Hypothesis (H_0): There is no positive association between age and the frequency of collaboration

Alternate Hypothesis: There is a positive association between age and the frequency of collaboration

Method of analysis: Cross-tabulation, Chi-square statistic

8.7.4 Hypothesis 4: Scientific field and research collaboration

Collaboration is influenced by several disciplinary factors outlined by the nature of the work in a scientific field, as well as, the different traditions, cultures and practices of a given discipline (Melin, 2000; Lee & Bozeman, 2005; Fry, 2007). Several studies have shown that collaboration levels and co-authorships vary with the scientific fields (Katz & Martin, 1997; Duque *et al.*, 2005). Furthermore, co-authorship practices in different scientific fields are guided by different social norms. Melin (2000) notes that the readiness and need to collaborate, as well as the forms under which collaboration is done, varies between different scientific fields (Melin, 2000: 38). For instance, in medical sciences, scientists tend to work together in teams and often collaborate with other teams. Whereas, in the humanities, there are fewer teams and collaborations are less common. Melin (2000) indicates that the above differences in the scientific fields should not be interpreted as something that needs change.

In a study with 443 academic scientists at university research centres in the USA, Lee and Bozeman (2005) used a two-stage least square analysis to investigate the factors that influence collaboration and sequentially examined how each impacts measures of productivity. Lee and Bozeman found that the scientific field has a significant impact on research collaboration. The study controlled for field differences as they classified scientists in two groups, “basic” or “applied”. Lee and Bozeman (2005) showed that applied fields like engineering are positively and significantly related to research collaboration as compared to the basic fields such as biology, life sciences, chemistry and physics. The scientist in engineering collaborated more compared to scientists in these basic fields. However, it's key to note that this study is limited to the collaboration patterns of researchers in the USA context. Apart from this study, other studies have also claimed that scientists in theoretical fields collaborate less and have lower productivity levels compared to those in "experimentally-intensive" or "applied fields" like engineering (Katz & Martin, 1997; Lee & Bozeman, 2005). Apart from the field differences in collaboration, Lee and Bozeman observed field differences in productivity. For instance, fields like Chemistry reported high productivity in terms of the number of publications as compared fields like computer science.

The 'theory of the intellectual and social organization of intellectual fields' by Whitley (2000) extended on by Fry and Talja (2007) views the differences in the 'nature of intellectual fields' mainly on the basis of how they vary in the dimensions of 'mutual dependence' and 'task uncertainty' (Fry & Talja, 2007: 3). According to Whitley (2000) – 'Mutual dependence' relates to the extent to which a field depends on other fields for knowledge/skills and/or resources needed to make a competent scientific contribution, as well as the level of 'mutual dependence' amongst scientists. The extent to which scientists are dependent on each other's work greatly varies across scientific fields. For instance, "in fields with high levels of mutual dependence", scientists depend upon knowledge produced by others or works of others and in some instances resources, in order to make significant contributions to the collective scientific goals (Whitley, 2000; Fry & Talja, 2007:3–4).

Birnholtz (2007) studying academic scientists in the USA affirmed that field differences in collaboration can be attributed to the aspects of 'mutual dependence' and 'low task uncertainty'. Birnholtz (2007) cites the example of fields like High Energy Physics where scientists are highly collaborative given the skills dependence and the need to share the scarce resources (funding and equipment, etc.). Fry and Talja (2007) observes that High Energy Physics displays a low degree of 'task [strategic] uncertainty', given that it has clear work techniques and reliable results produced in several scientific fields. The table 8-1 below summarises how mutual dependence and task uncertainty is illustrated in the social norms of different scientific fields.

Table 8-1: Summary of Whitley's theory and how it is related to research processes

Cultural identity	High mutual dependence and low task uncertainty	Low mutual dependence and high task uncertainty
Domain boundaries	Clearly delineated and not vulnerable to tribal skirmishes	Unclear and subject disagreements
Research object	Stable; single paradigm	Conceived in different ways and not standardized
Research problems and topics	Admissible problems highly restricted in type and conception	Uncertainty about intellectual priorities. A large number of different sorts of problems and different ways about how they should be sorted.
Organization of research work	Research efforts can be effectively coordinated, research is often conducted in groups.	Researchers pursue separate interests; loosely bounded groups pursuing different and differentiated goals.
Research techniques	Standardized. A well-established set of research techniques.	Not standardized. Highly tacit, personal and fluid, or tied to particular topics and research areas.
Results	Not difficult to discern and agree on.	Ambiguous and subject to a variety of conflicting interpretations
Diversity of audiences for intellectual products	Audience variety is low. Scientists rely more on a group of peers for reputations and access to resources.	Audience variety is high. Scientists don't seek to coordinate their strategies with peers.
Reporting systems and language	Language of communication of the contributions needs to be specific and detailed, impersonal and formally structured.	Language for convincing peers is more personal and variable. No tailored style to the specific message or audience.
Style of writing	Research communicated in a short space through esoteric and standardized symbol systems. Visual representations are key, i.e., graphs and formulae.	Mainly narrative-based (though use graphs to communicate descriptive statistics. Elaborate presentations used to justify particular interpretations. Often use of books.

Adapted from: Fry and Talja (2007:5)

Whitley 2000 quoted in Fry and Talja (2007) describes "'task uncertainty' as the degree to which task outcomes and research processes are predictable, visible, and clearly related to general goals" (Fry & Talja, 2007: 4). Commenting on how the impact of 'task uncertainty' on collaboration levels varies between disciplines, Melin (2000: 38) observes:

> It is probably more difficult to collaborate in the humanities than in other sciences since there is less consensus of what the actual research task is, what the relevant questions are and how to investigate them. Much of this is clear and agreed upon in medical and natural science, at least to a significantly higher degree. Individual style and literacy also matter much more in the humanities than in other sciences.

Birnholtz (2007) discusses the concept of "resource concentration", that is, an area with a high concentration of financial resources or equipment located in few locations or under the control of a small group of scientists. Arguably, at high levels of ‘resource concentration’ scientists are more likely to depend on each other more to access the equipment and finances, hence increased levels of collaboration. There are differences exhibited in the different scientific fields.

The studies reviewed above show that, in fields like medical and natural sciences, scientists are more likely to work in teams and collaborate. This scenario is different in the humanities and social sciences where scientists tend to work individually and collaborate less. Also, fields such as high energy physics that exhibit greater levels of mutual dependence for knowledge, resources and skills, or have low degrees of task uncertainty where the task outcomes are clear, scientists tend to collaborate more.

Null Hypothesis (H_0): There is no relationship between the scientific field and collaboration

Alternate Hypothesis (H_a): There is a positive association between the scientific field and collaboration

Method of analysis: One-Way ANOVA

8.7.5 Hypothesis 5: Funding and research collaboration

Several studies have explored the impact of funding on collaboration. A set of studies found that researchers who received more funding tend to collaborate more. A study by Bozeman and Corley(2004) examining 451 scientists and engineers found that for those who indicated to have received greater funds have more collaborators. The study also showed that more “cosmopolitan” collaborators are likely to have larger grants.

Another study by Adams *et a*l. (2005) used data drawn from 2.4 million research papers from 110 top research universities in the US to investigate “trends in the size of scientific teams and in institutional collaborations” (Adams *et al.*, 2005:259). The study found that “private universities and departments whose scientists have earned prestigious awards participate in larger teams, as do departments that have larger amounts of federal funding” (Adams *et al.,* 2005: 259).

Gulbrandsen and Smeby (2005) studied tenured university professors in Norway, to analyze the effect of industry funding on research performance. The study found that professors funded by the industry were more likely to collaborate and publish more with the scientists both in academia and industry. (Gulbrandsen & Smeby, 2005: 932).

Another study by Lundberg showed conflicting results. Lundberg, Tomson, Lundkvist, Skar & Brommels (2006) aimed to investigate the university-industry link by assessing how effective co-authorships were in identifying and describing the university-industry collaborations and the effect of industrial funding on collaborations. Lundberg *et al*. (2006) showed that at least 33% of the companies that funded the university had no co-authorships with the university, whereas, just a few companies (16%) had co-authored papers. These results confirm that not every funding results in co-authorships. However, Lundberg *et al.* (2006) concluded that these results are incomplete as they revealed a conflict between the funding and co-authorship indicators.

A study by Defazio, Lockett and Wright (2009) explored the influence of incentives for collaboration on scientific productivity for research networks funded by the European Commission. The study observed a positive effect of funding on scientific productivity, but a weak effect of collaboration within the EU-funded research networks. Defazio *et al.* (2009) distinguished between the pre-, during and post-funding period and observed several variations. For instance, during the funding period, the collaboration did not result in increased research production. Whereas, for the post-funding period, although they realized a decline in the number of collaborations within the network, they observed a positive and significant effect of collaboration on productivity. In conclusion, Defazio *et al.* (2009) noted that collaborations established to maximize on funding opportunities may not improve on research productivity in the short run, but may positively influence the formation of collaboration networks in the long run.

The review of the literature on funding and its effect on collaboration shows a number of results. Some studies show that researchers who received funding had more collaborators. On the other hand, researchers who collaborate more tend to receive more funding. The studies also show that, apart from funding, scientists who received prestigious rewards collaborated more. In contrast, the studies reviewed also showed that funded research doesn't necessarily lead to a higher number of co-authored papers.

Null Hypothesis (H_0): There is a positive relationship between receiving funding and the frequency of collaboration

Alternate Hypothesis (H_a): There is no positive relationship between receiving funding and the frequency of collaboration

Method of analysis: Chi-square statistic

8.7.6 Hypothesis 6: Scientific productivity and research collaboration

A review of the literature shows that research collaborations result in increased productivity. A number of studies found a positive association between collaboration and productivity. In contrast, another set of studies showed no clear relationship between the two variables. Lee and Bozeman (2005) using a sample of US scientists investigated the impact of research collaboration on research productivity. The study found a positive and significant relationship between collaboration and the normal count or full count (total number) of research publications. On the other hand, the study found no significant relationship between collaboration and the fractional count of research publications. In addition, Beaudry and Clerk-lamalice (2010) and Beaudry & Allaoi (2012) showed that a strong position in the previous collaborative networks has a positive impact on scientific output.

The study by Duque, Ynalvez *et a*l. (2005) reported ambivalent results in relation to the effect of collaboration on publication output. Duque *et al.* (2005) sought to establish if there is an association between collaboration and productivity using a sample of scientists in Ghana, Kenya and the state of Kerala in India. The study revealed that, "the number of collaborations has no association with total productivity for the sample as a whole, a limited association [positive and significant] with the productivity of academic scientists and, a negative [and significant] association with the productivity of scientists in government research centres" (Duque *et al.,* 2005:30). According to Duque *et al.,* not only does collaboration fail to increase the productivity for government scientists, but their evidence shows it may hinder the researchers to publish their research findings (Duque *et al.,* 2005:23). From the study, Kenyan scientists had the least productivity levels, but with the most external collaborations, compared to Kerala which had higher levels of productivity but less collaborative research (Duque et al., 2005:22). Among other reasons, Duque *et al.* (2005: 22) linked the low productivity to "the costs associated with collaboration" that involves extensive communication, interaction and information exchange that is not fully supported. Also, some scientists may participate in collaborative activities with government institutes, international organizations and NGO's, who might not be keen on research publications as the output needed from the collaborations. To support this argument, Dimitrina and Koku (2009, cited in Muriithi, 2015), noted that academic scientists publish peer-reviewed articles needed to advance their research careers, whereas, non-academic scientists tend to produce other outputs like manuals, innovations, policy briefs and reports.

Null Hypothesis (H_0): There is a positive association between scientific productivity and the frequency of collaboration

Alternate Hypothesis (H_a): There is no positive association between scientific productivity and the frequency of collaboration Method of analysis: Cross-tabulation, Chi-square statistic

8.7.7 Summary of the literature review

From the above literature review, several factors have been identified to correlate with patterns in research collaboration. These factors include scientific field or area of specialization (Lee & Bozeman, 2005; Melin, 2000); amounts of funding available (Bozeman & Corley, 2004; Lee & Bozeman, 2005); networks and the size of professional connections (Bozeman & Corley, 2004; Ynalvez & Shrum, 2011); having a PhD and the place/country of the PhD training (Ynalvez & Shrum, 2004); number of years into the PhD (Lee & Bozeman, 2005) and age. This study infers to most of these discussions as it seeks to understand the trends of research collaboration of Kenyan authors. This study reports the results of the bibliometric data, the secondary analysis of the survey data[21] and re-analysis of the in-depth interviews[22] with young scientists. The results reported include the collaboration types and an analysis of how the age, gender, scientific field and academic rank of the scientists in Kenya influence how often they collaborate.

8.8 The empirical findings on factors that correlate with reported research collaboration

In the African Young Scientists Survey of 2016, respondents were asked to report on how often they collaborate with researchers in their own institution (intra-institutional collaboration), in other institutions in their country (national collaboration), in institutions in other countries in Africa (African collaboration) and outside Africa (international collaboration). They could rate the frequency of their collaboration with these different types of researchers on a 5-point Likert-type scale (1: 'never or rarely; 2: 'rarely'; 3: 'sometimes'; 4: 'often'; 5: 'very often'). In some sub-sections of the data presentation, the respondents are divided into two categories, those who collaborate 'often' or 'very often' with the different types of collaboration, and those who collaborate less often or not at all.

[21] Based on the African Young Scientists Web-based Survey conducted at the Centre for Research on Evaluation Science and Technology (CREST) in 2016.
[22] Follow-up in-depth interviews conducted by CREST, following the web-based survey

8.8.1 Reported collaboration types

From our analysis, our results (figure 10.1) shows, 70% of academics and scientists in our sample (n=153) reported that they most frequently collaborate with researchers in their own institution (intra-institutional collaboration). This is followed by 52% who reported they engage in national collaboration (n=114) and 50% in international collaboration (n=109). About 34% of respondents (n=75) reported that they frequently collaborate with researchers from other African countries (African collaboration). About 38.4% and 19.6% academics and scientists reported that they less often or never participate in African and international collaboration respectively. This may imply more single-authored papers are produced by academics and scientists.

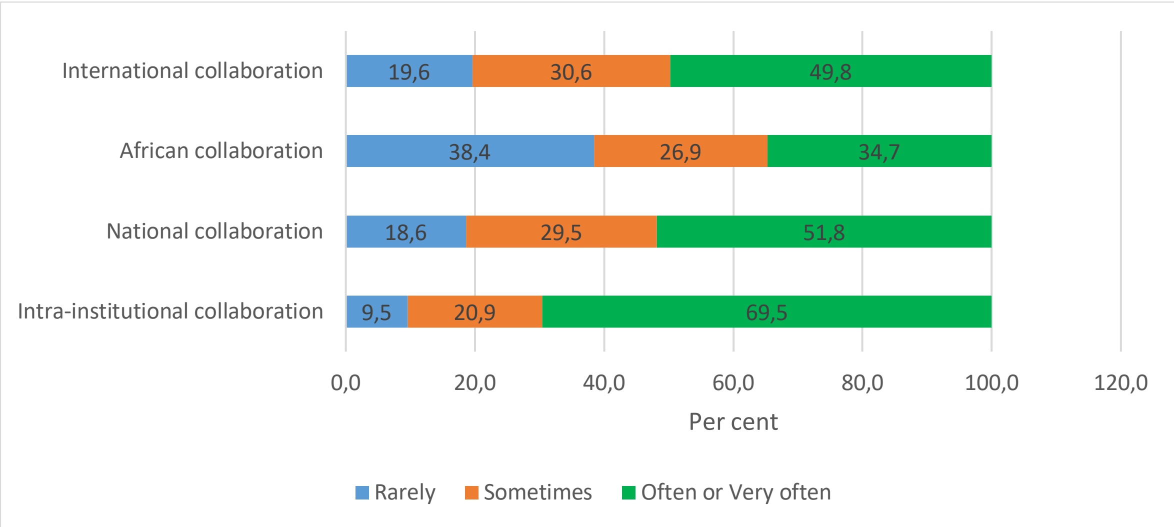

Figure 8-9: Frequencies of the reported collaboration types

In this section, I test whether there is a relationship between the different types of collaboration (as 'self-reported') and six variables: age, gender, and rank, scientific field, funding and international mobility.

8.8.2 Reported collaboration by gender

From the literature review, there are conflicting findings on gender differences in collaboration (Bozeman & Corley, 2004; Bozeman & Gaughan, 2011). In this analysis of the survey data, I hypothesised that there is a relationship between male and female scientists in terms of how frequently they collaborate. The results show small differences in how males and females frequently collaborate. More or less the same proportions of males (68.7%) and females (71.9%) reported that they frequently participate in the intra-institutional collaboration. For the academics or scientists who reported they collaborate internationally, 53.7%% are males compared to 38.2% of females.

Table 8-2; Frequency of reported collaboration (often or very often) by gender

	Male		Female		Total	
	Count	Row N %	Count	Row N %	Count	Row N %
National collaboration	84	51.2%	30	53.6%	114	51.8%
Intra-institutional collaboration	112	68.7%	41	71.9%	153	69.5%
African collaboration	59	36.6%	16	29.1%	75	34.7%
International collaboration	88	53.7%	21	38.2%	109	49,8%

This analysis tested the association between gender and the frequency of (reported) collaboration. The chi-square (χ^2) statistic shows there is a significant association between gender and international collaboration $\chi^2(1) = 3.95$, $p<0.05$. This finding is in accordance to studies that show that women are more likely to collaborate more at the other levels of collaboration, except for international collaboration where they still have larger gaps compared to their male counterparts (Abramo *et al.*, 2013); and that women are likely to have more collaborators (Bozeman & Gaughan, 2011).

8.8.3 Reported collaboration by age

In this analysis, I tested whether there is a relationship between the frequency of collaboration and age. Small differences emerge in how the younger scientists and older scientists participate in the four collaboration types. The analysis of the age by collaboration confirms some of the findings of the previous studies. The results show there are significantly higher proportions of younger scientists who reported they frequently participate in all the four collaboration types, except for the international collaboration. The respondents in the 40-50 age category reported the highest frequencies of international collaboration.

Table 8-3: Frequency of collaboration by age (often or very often)

	39 or younger		40-50		Older than 50	
	Count	Row N %	Count	Row N %	Count	Row N %
Intra-institutional collaboration	49	74.2%	60	68.2%	41	67.2%
National collaboration	35	53.0%	46	51.7%	30	50.0%
African collaboration	28	42.4%	25	28.4%	19	32.8%
International collaboration	32	48.5%	50	56.2%	25	42.4%

The chi-square (χ^2) statistic show there is no significant association between age and research collaboration, for all the collaboration types χ^2 (2) = 0.92, p>0.05 (national collaboration). This implies that there is no relationship between the chronological age of the scientists and how frequent they collaborate with other researchers either nationally or internationally.

8.8.4 Reported collaboration by Rank

In this analysis, I considered the relationship between rank and the frequency of collaboration. This analysis confirms the findings in the previous studies reviewed, as there is a significantly higher proportion of academics or scientists in the higher ranks (especially the professoriate, followed by the senior lecturers) who reported high frequencies of all the four collaboration types. The results also show that the higher proportions of researchers/scientist reported more frequencies in all collaboration types.

Table 8-4: Frequency of reported collaboration by academic rank (often/very often responses)

	Professor, Associate professor		Senior Lecturer		Lecturer		Researcher/Scientist	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
National collaboration	27	51.9%	14	60.9%	13	35.1%	38	54.3%
Intra-institutional collaboration	29	56.9%	14	60.9%	22	57.9%	63	91.3%
African collaboration	14	27.5%	9	42.9%	7	19.4%	26	37.1%
International collaboration	27	52.9%	14	60.9%	11	29.7%	44	62.9%

As is the case for age, the propensity of professors to frequently collaborate could be attributed to the processes of accumulative advantage where professors are able to access more resources, are leaders of big research groups, belong to strong research networks, thus collaborating more (Alisson & Stewart, 1974; Merton, 1968).

We tested the association between rank and the frequency of collaboration. The chi-square (χ^2) statistic shows there was a statistically significant association between rank and frequency of collaboration at own institution or outside Africa. That is, χ^2 (9) = 29.71, P =0.000< 0.005 for intra-institutional collaboration and χ^2(9) =28.19, P=0.001<0.005 for international collaboration (with researchers outside Africa). This implies there is a relationship between rank and the frequency of collaboration with researchers at own institution (intra-institutional collaboration) and outside Africa (international collaboration).

8.8.5 Reported collaboration by scientific field

In this analysis, I considered the relationship between reported collaboration and scientific field. Our analysis confirms the findings in previous studies, as the academics and scientists in the natural sciences, agricultural sciences and health sciences recorded the highest frequencies for all the four collaboration types (see table 9-5). On the contrary, respondents in the humanities and social sciences reported significantly lower frequencies for all the four collaboration types. However, academics and scientists in all the scientific fields including engineering and applied technologies reported higher proportions for intra-institutional collaboration.

The chi-square (χ^2) statistic shows there was a statistically significant association between the scientific field and intra-institutional collaboration χ^2 (5) = 18.05, $P<0.005$ ($P=0.003$). In contrast, the chi-square χ^2 statistic shows there was no statistically significant relationship between the scientific field and the frequency to participate in national, African and international collaboration ($p>0.005$).

Table 8-5: Frequency of reported collaboration (often/very often) by scientific field

	Natural sciences		Agricultural sciences		Engineering sciences		Health sciences		Humanities		Social Sciences		Sub- Total	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
Intra-institutional collaboration	37	67,3%	34	81,0%	13	72,2%	38	79,2%	2	20,0%	28	60,9%	152	69,4%
National collaboration	30	54,5%	23	54,8%	8	44,4%	30	62,5%	3	30,0%	19	41,3%	113	51,6%
African collaboration	20	37,0%	13	31,7%	6	33,3%	15	31,3%	2	22,2%	18	40,0%	74	34,4%
International collaboration	24	44,4%	21	50,0%	8	44,4%	29	60,4%	4	40,0%	22	47,8%	108	49,5%

This analysis used One-way ANOVA to test the difference in mean collaboration frequencies between the six scientific fields. The results show that there are statistically significant differences between intra-institutional collaboration and the scientific fields because of the ANOVA test $p=0.002<0.05$. However, there is no statistically significant differences between the scientific fields and the other types of research collaboration (national, African and international) because the ANOVA tests $p>0.05$.

8.8.6 Reported collaboration by funding

From the literature review above, the link between funding and research collaboration shows that researchers who access more funding have more collaborators. At the same time, those who collaborate more tend to receive more funding.

In this analysis, I considered the relationship between receiving funding and frequency of collaboration. Our results confirm the findings in the previous studies, respondents who reported they received funding, recorded significantly high frequencies for all the four collaboration types. However, the respondents who indicated they received no funding reported they most frequently participated in intra-institutional collaboration.

Table 8-6: Frequency of collaboration (often/very often) by funding

	No		Yes	
	Count	Row N %	Count	Row N %
Intra-institutional collaboration	38	61.3%	114	72.6%
National collaboration	27	44.3%	86	54.4%
African collaboration	17	28,3%	58	37.4%
International collaboration	15	24.6%	93	59.2%

Notable differences are seen with the respondents who indicated they collaborate less. Our results show that, for the academics and scientist who reported they received no funding, participated less in all the four collaboration types. These results confirm the findings in the previous studies. Interestingly, there is a large proportion of academics and scientists who indicated they received funding but reported to have participated less in African and national collaboration.

Table 8-7: Frequency of collaboration (less than often or not at all) by funding.

	No		Yes	
	Count	Row N %	Count	Row N %
Intra-institutional collaboration	24	38.7%	43	27.4%
National collaboration	34	55.7%	72	45.6%
African collaboration	43	71.7%	97	62.6%
International collaboration	46	75.4%	64	40.8%

In this analysis, I looked at the relationship between the intensity of collaboration by the amount of funding amount. The chi-square (χ^2) statistic shows there was a statistically significant association between accessing funding and the frequency to collaborate especially at the intra-institutional and international level because of $p<0.05$. The results showed no statistically significant association between access to funds and at the national and African level. Respondents with less funding also indicated the high intensity of intra-institutional collaboration.

Table 8-8: Frequency of collaboration (very often) by the amount of funding

	Less than US$ 250 000		More than US$ 250 000	
	Count	Row N %	Count	Row N %
Intra-institutional collaboration	70	70.7%	38	74.5%
National collaboration	55	55.0%	27	52.9%
African collaboration	32	32.7%	24	48.0%
International collaboration	54	54.5%	36	70.6%

8.8.7 Reported collaboration by Mobility

As expected, this analysis confirms that researchers who indicated they are mobile (studied or worked abroad) reported that they most frequently participated in intra-institutional and international collaboration. Although, for the scientists who reported they were mobile, reported significantly higher proportions of participating less or not at all in national and African collaboration. Mobility is also not necessarily linked to more intra-institutional collaboration as most researchers who were not mobile collaborated often or very often with researchers in their own institution.

Table 8-9: Frequency of reported collaboration by international mobility

	Yes				No			
	Less than often		Often/very often		Less than often		Often/very often	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
Intra-institutional collaboration	27	26.2%	76	73.8%	40	34.2%	77	65.8%
National collaboration	55	52.9%	49	47.1%	51	44.0%	65	56.0%
African collaboration	65	62.5%	39	37.5%	76	67.9%	36	32.1%
International collaboration	44	42.3%	60	57.7%	66	57.4%	49	42.6%

The results also show that, for the academics and scientists who indicated they are not mobile, they reported higher frequencies for the intra-institutional and national collaboration. Also, for the respondents who indicated they were not mobile, higher proportion reported they less often participate in African and international collaboration. The chi-square (χ^2) statistic shows there was a statistically significant association between mobility and international collaboration χ^2 (1) = 4.9, p =0.03<0.05. The results show that there was no statistically significant relationship between mobility and other types of collaboration.

8.8.8 Reported collaboration by publication output

From the literature review, the relationship between research collaboration and publication productivity shows that scientists who collaborate more are likely to increase their output (Lee and Bozeman, 2005). In our analysis, we considered the relationship between the reported frequency of collaboration and publication output.

Table 8-10: Frequency of reported collaboration (often/very often) by reported publication output (N=224) Mean

		Articles	Books	Book chapter	Conference papers	Presentations at conferences	Policy documents	Popular articles
Intra-institutional collaboration	Mean	18,33	15,38	10,44	10,48	16,86	11,54	8,46
	N	145	109	111	133	137	118	112
National collaboration	Mean	19,64	15,11	10,79	9,81	18,40	9,89	10,51
	N	110	83	85	100	102	94	85
African collaboration	Mean	20,30	16,12	8,65	7,25	18,73	9,79	9,77
	N	71	52	57	64	67	57	56

International collaboration	Mean	19,80	14,09	8,41	6,19	17,74	6,76	8,33
	N	105	82	85	98	100	87	84

Table 8-11: Frequency of reported collaboration (often/very often) by reported publication output (N=224) Median

		Articles	Books	Book chapters	Conference papers	Presentations at conferences	Policy documents	Popular articles
Intra-institutional collaboration	Median	5,00	0,00	1,00	3,00	5,00	2,00	2,00
	N	145	109	111	133	137	118	112
National collaboration	Median	5,00	0,00	1,00	3,00	5,00	2,00	2,00
	N	110	83	85	100	102	94	85
African collaboration	Median	5,00	0,00	1,00	3,00	5,00	2,00	2,00
	N	71	52	57	64	67	57	56
International collaboration	Median	5,00	0,00	1,00	3,00	5,00	2,00	2,00
	N	105	82	85	98	100	87	84

The results above, disaggregated by frequency of collaboration and reported output shows, the median of the output of those who frequently collaborate across the categories do not vary greatly. Significantly higher averages of the reported articles and books are observed across all the four collaboration types. The averages of the reported conferences papers and policy documents are highest at the intra-institutional collaboration.

8.9 Enablers and constraints of research collaboration

During the interviews, participants were asked to expound on various aspects related to research collaboration. These included addressing the following key questions:

- Why do scientists engage in collaboration?
- Why did other scientists report that they do not engage in collaboration?
- If they collaborate, with whom do the scientists collaborate?
- Which strategies were used in collaborating with others?
- What are the scientists' experiences of research collaboration, including, the enablers and constraints of research collaboration?

8.9.1 Reasons why scientists collaborate

This section discusses the reasons why scientists choose to collaborate with other scientists.

8.9.1.1To secure funding

Some interviewees felt that, collaborating with researchers, especially internationally may increase their chances of securing funding.

> I would prefer to be able to work in a group with people from other places because as you can be able to see nowadays for you to get some serious funding you have to work with people from all over the globe. Not really your own country but other people. So, that is something that I have just started doing, I keep looking for people I can collaborate with concerning our research (34-year-old male respondent from Kenya, R_187)

Through collaboration, some respondents were able to secure funding for their research and for the students' projects

> So, I think those are the key areas. And through that collaboration [West Virginia University and even this University of Vienna], also some residents [graduate students in medical sciences] managed to get funding for their pathology projects to we, I think those are the main benefits of collaboration. (35-year-old male respondent from Kenya, R_189).

Some interviewees reported that they are compelled to engage in collaboration so as to meet the specified research funding criteria, especially for multidisciplinary research grants.

> Then the last one we did in Kenya. Within our country institutions... I work for Kenya Medical Research Institute, but we do have other institutions which are also interested in research in Hepatitis B. So, we also work closely with them. For example, when we were applying for a multidisciplinary grant, you must look for other collaborators. You cannot apply alone. (35-year-old male respondent from Kenya, R_073).

8.9.1.2 To share resources and equipment and divide labour or share research activities

Interviewees indicated they collaborate so as to share resources and equipment

> I maintained the contacts in the local universities which have also helped me because if I want to do a chemical analysis of a nutritional profile Jomo Kenyatta the lab has better labs than ours here. So then I ask my contact person there, [to] … help me … run the analysis (40-year-old male respondent from Kenya, R_079).

> We continue to do the teleconferencing … we got some donations in the form of bone marrow. This is an instrument which we could understand that quite well. (35-year-old male respondent from Kenya, R_189).

In addition to sharing resources and equipment, scientists indicated they collaborate to divide labour or share research activities

> At the moment, for example, the project I was telling you about, what we did, we collected the sample and we isolated the DNA. Then from there, we sent the sample to our colleague in Japan who did the date of the sequencing and the… Because they have access to equipment and also the reagents and everything. So they were able to do that component and us, we're able to do the component that we can be able to do on our side. (33-year-old male respondent from Kenya, R_186).

8.9.1.3 To promote knowledge dissemination

In some instances, respondents indicated they were approached by international institutions or funders for collaboration, based on a publication that had been produced in the area of the funders' research interest. The respondents reported that these kinds of collaborations often resulted in the co-authorship of several papers both with the partners locally or internationally.

> Yes, I was funded by Canadian agencies, basically because of their interest. How I got to know about it is they were in Kenya and they had an interest in a given infectious disease and it happened that I'm the one who had that publication of what they wanted. So, they contacted me on those grounds, saying you have one, two, three, are we able to work together … Actually, it has not ended but it may end this year … we have published around four papers with them. We did publish four in the area of interest and one is in the pipeline. Maybe it will come out very soon (35-year-old male respondents from Kenya, R_073).

> Another one is when I was doing my Master's I got some collaboration with South Africa. I know you call it at Witwatersrand University. So, we did some collaboration with them. That is research on hepatitis B which is run by someone called Professor … So, we did work with her and there were some papers that were generated between us. (35-year-old male respondent from Kenya_073)

> There is one we published with one of my colleagues here at the university and other colleagues from different countries because it was a project involving many countries. So, we published with a group of… With many authors from different countries. (33-year-old male respondent from Kenya_186)

8.9.1.4 To train, acquire knowledge and skills

During the interviewees, respondents indicated that they engage in collaboration to acquire knowledge or skills.

> They have had training in collaboration with West Virginia University and the even this University of Vienna. And from that we've had recent training people have been training on palliative care, cancer diagnosis, yes. (35-year-old male respondent from Kenya, R_189).

8.9.2 Reasons for no collaboration

Interviewees identified several reasons that hinder the to collaborate with other researchers. Interviewees indicated that, it is not easy to secure collaborators or build research networks in their fields, especially the international collaborators.

> And also, like for example if you come from Kenya and you are looking for a collaborator, an EU collaborator, sometimes it is so difficult to get, I don't know, it is a miracle for you to get one. (34-year-old male respondent, R_187)

> So, there is one we've been trying to apply, but currently, we haven't been able to get a collaborator. Sometimes, it's also not easy. You write to someone, someone tells you that he's not available or he doesn't have an interest in that area or at the moment, he's a bit busy. It's also not very easy. You can't say that it's very easy. (33-year-old male respondent, R_186).

The inability of scientists to secure collaborators or build research networks in their fields is seen as a hindrance to their research processes in their fields.

> I think that it is also a limiting factor in terms of full realization of research in my field because there are some institutions that I would really like to collaborate with but it takes time to make contacts, and actually make useful contacts for that matter, that you can get into a collaborative arrangement. So, still, my collaboration network is still thin, so not so much has changed. (40-year-old male respondent from Kenya, R_077)

Bureaucratic processes are a hindrance to inter-institutional collaborations, especially when it involves equipment and laboratories.

> We are able to [share resources]. But that is a personal kind of thing because when we tried as a university the bureaucracy there is too much. As a university, between universities is very bureaucratic but individuals then I see that works very well for me … Because then when you go to the university they say, ah, this is university X, what is our stake in this? And they will tell of course in the lab there are these consumables and stuff. So, the labs say well to run to this we need this much, and this is the account and we will invoice you this way. And the university processing that money is never easy, and you feel like if I have to go to a collaborative university then they ask you where is the money upfront to buy the chemicals. Yes, then you don't have it, it doesn't work. (40-year-old male respondent from Kenya, R_079)

Some interviewees indicated that they lack financial support to travel to meetings and/or conferences, especially internationally, to network with other researchers.

> Internationally, now movement becomes an issue if you have to travel to go, maybe to meet someone there is an issue of which vote head do we get the money for the travelling. Which

vote head, that is the question you ask. Fine, it is good, it is a good initiative, but from which vote head do we get the money, that becomes the problem. (40-year-old male respondent from Kenya, R_078)

There's a lack of opportunities for us to find our [sound slip], like here in Kenya, there are problems with, the main problem of us interacting with other scientists outside of Kenya. So, for you to interact with any others it will probably only be in the conference, which our institutions do not support you that you have to [sound slip]. (34-year-old male respondent from Kenya, R_187)

Most of the time it's the funding because the university doesn't afford the international conference, so most of the time, it actually supports the local one. So, for the international one, I have to look for the funds out there. So, if I'm not lucky, I won't be able to attend

Interviewees felt that not getting opportunities to attend conferences due to lack of financial support, impedes them to develop strong research networks and gain new knowledge.

There are limited opportunities, like when there is even a conference somewhere, the universities have little funding to fund lecturers to move out and to gain some new knowledge. So, the first question you asked, what is the university going to gain, what is going to come in? So sometimes missing an opportunity to sit in a conference elsewhere, sometimes very difficult to get that. (40-year-old male respondent from Kenya, R_078)

Some interviewees reported that there are challenges for them to collaborate with their students as they are unable to secure scholarships opportunities for them. Scientists are of the perception that research funding and scholarships will attract students hence allowing mentor/supervisor-student collaborations.

So, the infrastructure is our problem; infrastructure for collaboration, infrastructure for funding and other kinds of support that researchers may need. Because also for us to get students within Africa that would really be developed in such fields, we must be able to reach out to them and then we must also be able to have scholarship opportunities for them. But those ones are really weak and limited. I think those are some of the issues that are affecting our research environments. (40-year-old male respondent from Kenya, R_077)

8.9.3 Whom the scientists collaborate with

During the interviews, interviewees identified collaborating partners they tend to or are more likely to collaborate with. Respondent indicated that they collaborate more with international partners, local partners, colleagues at own institution, mentors and students.

8.9.3.1 International partners

In terms of collaborations, I collaborate with experts in my field in Africa and Asia, much of which is in Japan, and also here now in South Africa because I'm now making a new network. So, I think largely my collaboration network has remained the same, only that I've been able to acquire more collaborators from South Africa. It is something that I'm still building on. (40-year-old male respondent from Kenya, R_077)

When these opportunities come, I'll give you a very good example, in the area moving more to randomised control trials in all these hypes about ethics and so on. We have a very good organisation here called KEMRI, the Kenya Medical Research Institute, collaborating again with some institutions in the US and so on. (40-year-old male respondent from Kenya, R_079).

Yes, I've been lucky from my PhD time when I did my PhD in a DANISA funded project, DANISA is the Danish-based [overtalking]. So, the good thing is that I still maintain those contacts, we work very closely, and I come in as a collaborator. (40-year-old male respondent from Kenya, R_079).

… we published with … other colleagues from different countries because it was a project involving many countries. So, we published with a group of… With many authors from different countries (33-year-old male respondent from Kenya, R_186).

8.9.3.2 With colleagues at own departments or institutions

In the past two years, [I have published] I think three or more … There is one we published with one of my colleagues here at the university (33-year-old male respondent from Kenya, R_186).

8.9.3.3 With researchers from other local institutions or partners

I was a PhD student at the University of Nairobi, and I had such collaboration from Jomo Kenyatta University, which is another university in Kenya … So, when the collaboration of that time ended then I maintained the contacts in the local universities which have also helped me because if I want to do a chemical analysis of a nutritional profile Jomo Kenyatta the lab has better labs than ours here. So, then I ask my contact person there, I say John can you help me do this and he will run the analysis, or I can send the student there with the samples to do the analysis and we get the results. (40-year-old male respondent from Kenya, R_079).

Sometimes we can write a paper with a colleague from another place. That one is easy to do because you just get an area to write on, then we write, then we publish. That one we have been able to do … otherwise locally we do that a lot. We share, we talk, we do collaborate with colleagues locally. That happens a lot. (40-year-old male respondent from Kenya, R_078).

8.9.3.4 With previous mentors and research networks

These are professors, one of my mentors I had known for a very long time and they responded to a call through the media in Denmark several years… And they wanted to do this in resource-limited setting so some of their worksites were in Cambodia, some of it was in Burkina Faso …

> So, then the Kenyan one of course. So, when they came to Kenya for almost three-four years they had a contact person to do the work coming to collaborate with. But I think he was too busy for the people … We then had a response with our contacts, the PhD students. (40-year-old male respondent from Kenya, R_079)

> In terms of contacts with people, because during my master's training, I was trained outside, during my PhD training, I was trained outside. So, I managed to link up with some people, and we continue to carry on. But we do not have a specific funded project that we'd say. We just… Whatever we are able to do without funding, we are only… We keep collaborating until we get (32-year-old male respondent from Kenya, R_192)

From the above excerpt, we see that the researchers indicated they have networks, but they haven't really worked on funded projects.

8.9.3.5 Students-Supervisor collaboration

Some scientists have opted to collaborate with their postgraduate students on research projects, a strategy that has allowed them to publish together.

> I think for me in the strategy I've tried to develop now is to use really the postgraduate students to do the real research with me doing the mentoring … Though currently I have one PhD student and I have two masters students who are working on a project I got a little money from the [unclear]. So, those guys are helping me by actually doing the research and I do more of the mentoring. (40-year-old-male respondent from Kenya, R_079).

> In the past two years, [I published], I think three more. For the past two years, I think it's three or four, around three or four … Some with colleagues, some with the students whom we've done a project together. (33-year-old-male respondent from Kenya, R_186).

8.9.3.6 Preferred collaborators

Interviewees, especially those in the engineering and applied technology, indicated that they will like to collaborate with the industry, so as to strengthen the industry-university linkages

> [T]here are managerial training just to understand the system and so on. But now in terms of maybe taking some time to be out to really meet the industry and really appreciate some of the challenges that are happening to the industry, such opportunities aren't there. The academia and industry linkages are still not strong. I think that it's stronger than in Kenya, but it is still an issue for me. (40-year-old-male respondent from Kenya, R_077).

8.9.4 Strategies to enhance research collaboration

During the interviews, respondents expounded on the strategies they have adopted to begin or enhance research collaborations.

Being part of a research project: Collecting the data and reporting to other researchers

> I was taking part in a research project back here in Kenya then, after my internship. And this research project was on man… On live [?] formal [?] basically, on the back end of HIV. And the project was funded by NIH. So, we did a number of teleconferencing with West Virginia University. Yes, so one… My role basically was to get cases all over Kenya, summarise them and then present them in a teleconference to the American researchers in West Virginia. (35-year-old male respondent from Kenya, R_189).

An interviewee reported that including his postgraduate students on the research projects has enabled him to collaborate with them more, as they conduct the research and he does the mentoring.

> We can require like I mean... We then had a response with our contacts [to collaborate, together with] the PhD students. So that is also my learning point for adopting PhD students and master's students in my researches. (35-year-old male respondent from Kenya, R_189).

Some interviewees indicated that contacting researchers working on a specific research project in their field, as well as, contacts from fellow colleagues is a probable strategy of securing collaboration opportunities.

> Looking for collaborators. For example, if there is a call, I just go email colleagues who are within my field and then maybe if they are interested in working with them, also referrals from those and from colleagues who might be able to know someone out there. (33-year-old male respondent from Kenya, R_186).

8.9.5 Suggestions and ideas on what can be done to improve research collaboration

Respondents interviewed pointed to several suggestions or ideas on what can be done to improve research collaboration. Availability of information on collaboration and the need for more collaboration opportunities.

> Just probably the way of improving the way we operate in Kenya, Africa probably in general, is that we need more collaborations and even more opportunities for people to be aware of what is happening when and where and probably that is key … So, probably I would suggest that if people receive applications from people from Africa, and Kenya, like, I mean, Africa, I mean, from Kenya and they wish to have a research partner, you ask any of the developed countries to consider us. I think that would be good, a good match to improve research in Africa or Kenya. (34-year-old male respondent, R_187)

A respondent in the field of engineering sciences suggested that institutions should establish university-industry linkages that will allow collaboration and ensure the creation and application of knowledge.

> Well, yes, I think, all through my research, I think it would have been good if I had a better understanding of how to work with industry, maybe how to take ideas to research to actual development to things that people actually use, as opposed to it just being an academic exercise. (33-year-old male respondent from Kenya, R_072)

8.10 Discussion

This section discusses the results presented in the sections above. The discussion focuses on the following aspects of research collaboration: whom scientists collaborate with, reasons why scientists collaborate, reasons why scientists don't collaborate and collaboration strategies.

8.10.1 Why scientists collaborate

The results presented in this chapter are consistent with previous studies which show that funding is one of the main determining factors of research collaboration (De Solla Price, 1963; Glänzel & Schubert, 2005; Katz & Martin, 1997; Thakur *et al.,* 2011). Previous studies show that 'big science' is characterized by teamwork and huge funding (Price, 1963). Similarly, previous studies (Adams, 2012; Katz & Martin, 1997; Wuchty *et al.*, 2007;) reveal that in the context of the increased cost of funding of research, that is, researchers are compelled to collaborate to share the limited resources (funding and equipment). My results further illustrate that, scientists collaborated to fulfil the required criteria of research funding, thus, before the application of funding, researchers were expected to have collaborators or be part of a research network. To corroborate this observation, the results show that choosing to conduct own research interests and not adhering to the requirements of funding resulted in unsuccessful funding applications. Additionally, my results and a previous study (Mouton *et al.,* 2018) show that, although it was not a funding criterion, scientist are of the view that research collaboration may increase the possibility of securing funding.

Furthermore, our analyses and a previous study (Ponds, 2009) revealed that the rise of multidisciplinary and interdisciplinary research compels researchers to collaborate. Cross-fertilization between disciplines and the need for different perspectives and skills increases collaborative work as researchers may be drawn from different fields, departments, institutions or countries (Ponds, 2009). Furthermore, related to the above, the results and literature show specialization in certain scientific fields require teamwork to perform the different specialized tasks of a research project, therefore the division of labour that comes with field specialization stimulates collaboration. In support of this observation, my results show that for the research projects they were involved in, the different task data collection, data analysis, report writing and report presentation were divided amongst the different researchers. Therefore, given the specialized knowledge or skills needed for different research projects, my results show that researchers were approached by international funders or institutions for collaboration, based on their publication in their field. Apart from sharing their already existing skills and experience, my results show that scientist also collaborates to gain skills and knowledge in their specific fields. This finding is consistent with previous studies (Melin, 2000; Bozeman & Corley, 2004) which identified several reasons why researchers engage in collaborative research, including gaining skills and knowledge, as well as, meeting the experts in their fields.

Researchers collaborate to access equipment mostly not available outside the collaboration context, that are needed for their research (Beaver & Rosen, 1978; 1979; ; Katz & Martin, 1997; Luukkonen *et al.*, , 1992, 1993; Tijssen, 2006). The results discussed on funding (chapter 6) show that scientist who collaborated more were likely to secure more funding for research equipment and infrastructure.

The results in this chapter support previous studies which showed that engaging in collaboration with other scientists or students increases publication productivity (Beaudry & Allaoui, 2012; Beaudry & Clerk-Lamalice, 2010; Lee & Bozeman, 2005; Mouton e*t al.*, 2018). My study observed significantly higher averages of the reported articles and books across all the four collaboration types.

8.10.2 Reasons for no collaboration

Inasmuch as researchers have several reasons to engage in collaborative research, the results in this chapter show that some researchers are unable to engage in research collaboration. Several reasons and barriers for researchers not engaging in research collaboration were identified. The results show that scientists lack funding to attend conferences which impact on the scientists' ability to meet researchers in their field and network. As discussed above, funding institutions require scientists to have collaborators or be part of a research network when applying for funding, therefore, the inability to collaborate can be a barrier in securing funding, as well as the research process.

Apart from financial support for collaboration researchers, especially young scientists are faced with the challenge of securing collaborators. A previous study has shown that funding agencies may prefer to fund researchers with a variety of skills and knowledge, which young researchers may lack (Mouton *et al.,* 2018). Studies have shown that older researchers, comparatively, have cumulative advantages, thus have more experience, have more access to research networks and funding, than the young scientists (Merton, 1968; 1988), young researchers are likely to lack these advantages. The lack of these skills, research networks may also be a challenge for the researchers to secure collaborators.

In addition, institutional promotional policies may discourage research collaboration. My results are consistent with the findings by Mouton *et al.* (2018) which found that promotional policies in some African institutions or universities require scientists to publish single-authored papers, which is a barrier for them to engage in collaborative research.

8.10.3 Whom the scientists collaborate with

Scientists tend to collaborate with international partners. Several reasons have been identified as to why researchers often collaborate with international partners. First, research funding has been a key determinant of researchers collaborating with international partners, as also shown by (Mouton *et al.,,* 2018) in their study on the collaboration of young scientists. Researchers will collaborate with international collaborators as a funding requirement by the international funders. Though not a funding requirement, my results are consistent with a previous study (Mouton et al., 2018) which showed that, scientists believe that collaborating with international partners increases their ability to secure funding. In addition, my results are in support of a similar study (Mouton *et al.,* 2018) which show that African young researchers were of the perception that international collaborators have more skills and knowledge.

8.10.4 Research collaboration strategies

The results and previous studies reviewed (Beaver, 2001; Bozeman & Corley, 2004; Beaver & Rosen, 1978, 1979; Melin, 2000; Mouton *et al.,* 2018) in this chapter identified several strategies scientists used to facilitate research collaboration. My results support the findings of other studies which showed that conferences and workshops provide a platform to meet scientists, experts in the field or funders, and thus build a research network.

As signalled earlier, the results in this chapter corroborate the findings of previous studies which show that 'supervision-student collaboration' or also referred to "mentoring motivated strategy" (Bozeman & Corley, 2004: 605) is also one of the effective strategies to develop networks and facilitate research collaboration. The results show that students who were involved in research projects with their supervisors/mentors were more likely to publish. Furthermore, some respondents confirmed that they had published several papers with their students or with their mentors/supervisors. A previous study looking and the gender differences in research collaboration, especially in relation to strategies (Bozeman & Gaughan, 2011) showed that both men and women are "motivated by the mentoring collaboration strategies. This implies that, all researchers, regardless of gender, have the interest of collaborating with their students and publish together.

8.11 Summary and conclusions

In this chapter, I investigated the types, motives, strategies, partners of research collaboration, as well as, factors that determine research collaboration. In relation to collaboration types, this study shows that there has been a high increase in international collaboration, which is consistent with indications of past studies. To corroborate this finding, respondents indicated they tend to collaborate with researchers outside Africa. On the other end, national collaboration has been on the decline which could be a signal of weak national research systems. Respondents confirmed that they collaborate less with researchers in own country. Consistent with previous studies, intra-continental (African) collaboration has equally declined. With the increase of internationally co-authored papers, single-authored papers have declined to almost negligible numbers. In relation to collaboration intensity, the international level, the United States of America, the United Kingdom, Germany and France recorded the highest collaboration intensity with Kenya. The findings show that, on the African continent, Kenya collaborates more with South Africa followed by her regional neighbours Tanzania and Uganda. The high collaboration intensity with these countries has been attributed to the culture, language, history (colonial legacy), and the geographical proximity and in some instances, funding between these countries. The fields that recorded the highest levels of collaboration are the health, natural, and agricultural sciences.

This chapter also investigated the relationship between different factors and research collaboration. These results show that there are no huge age differences that emerge in relation to respondent's collaboration with different researchers. Although, there are notable patterns. The older respondents are more likely than their younger counterparts to indicate they collaborate less or not at all with other researchers, irrespective of the collaboration type When we account for gender, no huge differences are observed in relation to the frequency of collaboration across the four types of collaboration. Some differences are worth noting. This study reveals males are more likely to collaborate internationally (with researchers outside Africa) compared to the female counterparts, which is consistent with previous studies. Females are more likely than males to indicate that they collaborate less with other researchers across different categories, especially for African collaboration.

This study shows that, across all sectors, respondents reported they frequently collaborate with researchers in their own institution, followed by researchers in their own country and outside Africa. Researchers in higher/tertiary institutions, public research institutions, private research institutions, and non-governmental organizations reported significantly higher proportions of collaborations with researchers in their own institution and outside Africa. Surprisingly, higher frequencies of researchers in non-governmental and international organizations reported they collaborate less often or not at all with researchers outside Africa. Researchers in business enterprises reported that they don't collaborate with researchers outside Africa.

Considering the scientific field and collaboration, respondents across all fields tend to collaborate more with researchers in own institution followed by researchers in other institutions in their own country, but less with researchers from other African countries. Unsurprisingly, this study reveals that respondents in the health sciences and agricultural sciences reported they collaborate more with researchers outside Africa, which support the findings of previous studies.

This study revealed that engaging in collaboration with scientists or postgraduate students is important for their productivity. Results show that collaborative work enables researchers to meet experts in their fields (especially internationally) as well as gain skills and knowledge.

As identified in the previous studies, this study highlighted important factors that constraint the frequency and effectiveness of research collaboration. The factors identified in this study include lack of funding, lack of financial support to attend meetings and conferences, institutional policies and strategies, the inability to secure collaborators and lack of skills and experience. Although the previous studies were mostly conducted in the developed world and with African researchers, the results of Kenyan researchers identified similar factors that constraint research collaboration. Following these challenges, respondents made suggestions that the government and institutions should support research collaboration. This support may include availing funding opportunities and financial support for research and attending conferences, so as to develop research networks. Apart from the international collaborators and national collaborators, this study reveals that supervisors/mentors often collaborate with their students to increase publication output, as well as a mentor in research and publishing. Apart from the mentioned collaborators, these results indicate that respondents prefer to collaborate with the industry, in order to understand how the industry operates and ensure industry-academia linkages. However, the results show that institutions have weak or no university-industry linkage strategies, which contribute to minimal industry-academic linkages.

Chapter 9 Citation Impact

9.1 Introduction

This chapter provides a discussion of the following research questions:

1. What are the trends in the citation impact of Kenya's scientific output?
2. What is the citation impact of scientific output across different scientific fields?
3. What is the research quality of Kenya' scientific output?

To address the following research questions, this chapter starts with a brief review of literature on citation impact indicators. The chapter describes the basic indicators of citation as well as the main indicator presented and discussed in this chapter: the 'field-normalised score' (MNCS). The literature review also provides, in brief, some of the studies that have analysed citation impact within the African context. I subsequently present and discuss bibliometric data on citation impact. This involves bibliometric data on MNCS, the positional analysis that combines the citation impact of a field or subfield (MNCS) and the relative field strength (RFS) index, and research quality.

9.2 Citation impact

Citation impact indicators are said to play a key role in research evaluation (Waltman, 2016). Waltman (2016) notes that in the past decades, the importance of citation impact indicators in the context of research evaluation has been on the increase, which is seen in the increase in the bibliometric or scientometric literature on citation impact indicators. Notably, "citation impact indicators are indicators of scientific impact based on an analysis of citations received by research publication"(Waltman, 2016:366). The visibility and recognition of science are partially captured by the number of references ('citations') a research publication receives from the publications of other scientists in the same scientific field or related scientific fields (Waltman, 2016; Waltman & van Eck, 2013).

9.2.1 Basic citation indicators

Given the importance of citation impact indicators in research evaluation, several basic indicators have been suggested in the literature. The number of publications of any given research unit (individual, institution or country) and the number of citations received by the publications are likely to vary with different databases. The number of citations to a research publication also depends on the citation window within which the citations are analysed. Therefore, during bibliometric analysis one has to choose a period within which the citations will be counted, for instance, it can be within the past 5 years or 3 years since a paper was published. Given the above considerations on citations, the literature (Wouters *et al.*, 2015; Waltman, 2016) identifies several basic indicators as illustrated below.

- Total number of citations: The total number of citations of the publications of a research unit
- The average number of citations per publication: The average number of publications of a research unit.
- The number of highly cited publications: The number of publications of a research unit that are considered to be highly cited, where a given threshold has to be chosen in determining whether a given publication is counted as highly cited or not.
- The proportion of highly cited publications: The proportion of the publications of a research unit that are considered to be highly cited.
- *h-index:* A research unit is said to have index *h* if h of publications each has at least *h* citations and the other publications each have more than h citations.

The literature shows that citations that a research publication receives vary by scientific field and publication type (Wouters *et al.*, 2015). Given these field differences in citations of scientific publications, "citation counts of publications from different fields should not be directly compared with each other" (Wouters *et al.*, 2015:39). Some fields are "fast" or "slow" in relation to receiving citations (Moed *et al.*, 2004). Therefore, given the field differences, normalisation of such indicators is common practice, so as to correct for the field differences and allow comparisons across different scientific fields (Waltman, 2016; Waltman & van Eck, 2013; Wouters *et al.*, 2015). Apart from normalisation for field differences, authors proposed the normalisation for the differences between older and more recent publications, as well as, for the document type differences between publications such as journal articles and review articles. Review articles followed by journal articles are likely to receive more citations, compared to book chapters or books, therefore, these document type differences should be corrected, allow fair comparisons.

The 'field-normalised citation score' (MNCS) has been identified in the literature as one such indicator that corrects for field differences. Given that this chapter mainly presents and discusses data on the MNCS, I will briefly describe the MNCS and how it is calculated. The positional analysis combines two indicators, that is, the citation impact (MNCS) and the relative field strength indicator of fields or sub-fields. The aim of the positional analysis is to identify scientific fields that are both strong (in relative world share, indexed by RFS) and have high visibility (MNCS).

9.2.2 Field-Normalised Citation Score (MNCS)

The calculation of the Field-Normalised Citation Score begins with a calculation of the expected number of citations for any publication in a specific field. Publications are related to several fields, thus, all the citations received for each publication are attributed in equal proportions to all the scientific fields related to it (Mouton *et al.*,, 2019).

$$e_i = \frac{\sum_{j=1}^{N_i} \frac{c_j}{f_j}}{\sum_{j=1}^{N_i} \frac{1}{f_j}},$$

where e_i is the expected number of citations for any publication in the field for any publication in the field i, Ni is the number of publications in the field *i*, c_j is the number of citations received by publication *j* and f_j is the number of fields associated with publication *j*. The calculation of the mean normalised citation score of the publication is as follows:

$$ncs_j = \sum_{i=1}^{f_j} \frac{c_j}{e_i f_j},$$

$$ncs_j = \frac{c_j}{f_j} \sum_{i=1}^{f_j} \frac{1}{e_i}.$$

The mean normalised citation score for a set of publications is calculated as follows:

$$mncs = \frac{1}{n} \sum_{j=1}^{n} ncs_j.$$

The citation window considered when calculating the mean normalized citation score varies as a studying evaluating performance may consider a two-year citation window or a three-year citation window. In other words, this implies that the only citations counted are those that accumulate after the second or third year of publication.

9.2.3 Positional Analysis

Positional analysis is a combination of three indicators: the total number of publications in each sub-field, the relative field strength and the citation impact (MNCS) of the sub-fields. The positional analysis results in a two-dimensional positioning of all sub-fields, forming four quadrants. The top-right-hand quadrant indicates high visibility and high activity. This implies that the fields in this quadrant have a higher citation impact (visibility) and have a strong relative field strength (are more active) as compared to other fields. The ideal quadrant for most sub-fields to be located in is the top-right-quadrant.

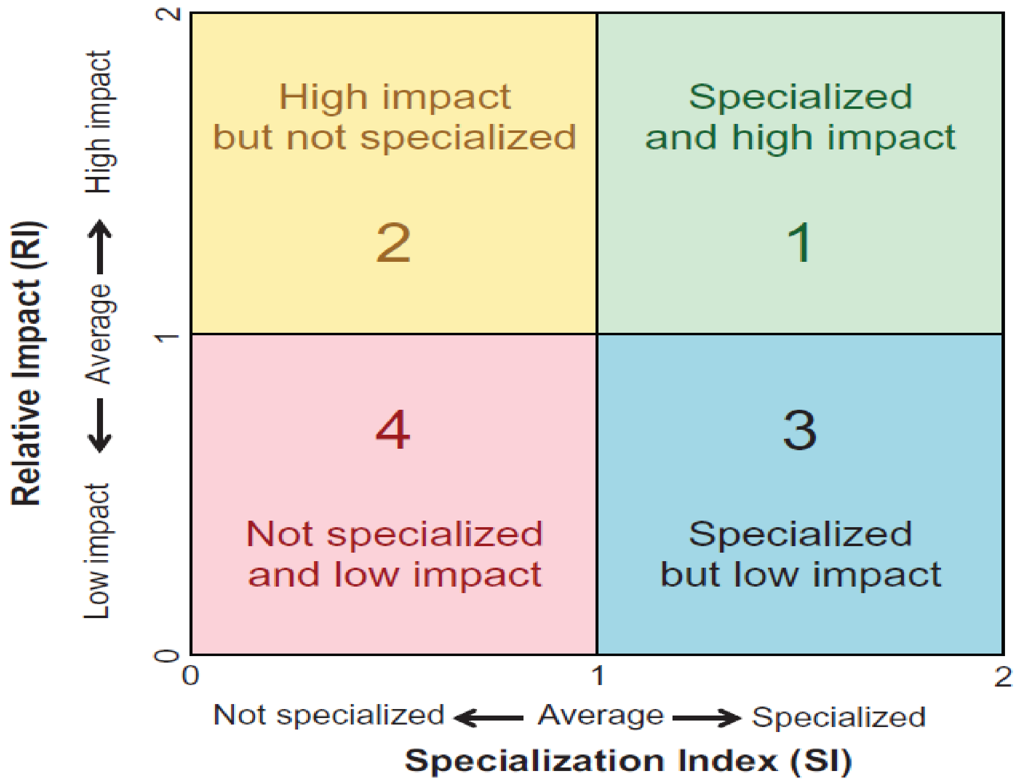

Figure 9-1: Positional analysis

9.3 Citation Impact of Kenyan authored papers

From our analysis (Figure 9-2), it is clear that the citation impact of Kenyan-authored papers has increased steadily over the past thirty-six years: from 0.89 in 1980 to 1.35 in 2016. In the years 2000 to 2016, the papers maintained a citation impact of above 1 ('the gold standard'): for instance, they had 1.01 in 2000 and 1.3 in 2016. The overall citation impact of the papers authored by the Kenyan researchers is at 1.02, which is slightly above the 'gold standard' of 1 – which implies that it generates similar citation rates than other countries.

The results presented in the figure refer to all scientific fields in which the Kenyan authors and co-authors published. The next sub-section will present some results of the fields in which Kenya has a higher than average citation impact, that is, where the MNCS is greater than 1. To present a detailed overview of the high-impact fields we selected only those fields that have at least 1200 publications produced during the 2005 and 2015 period. Following this set threshold, 7 fields (level 2 in the WoS field category) registered an MNCS of greater than 1.

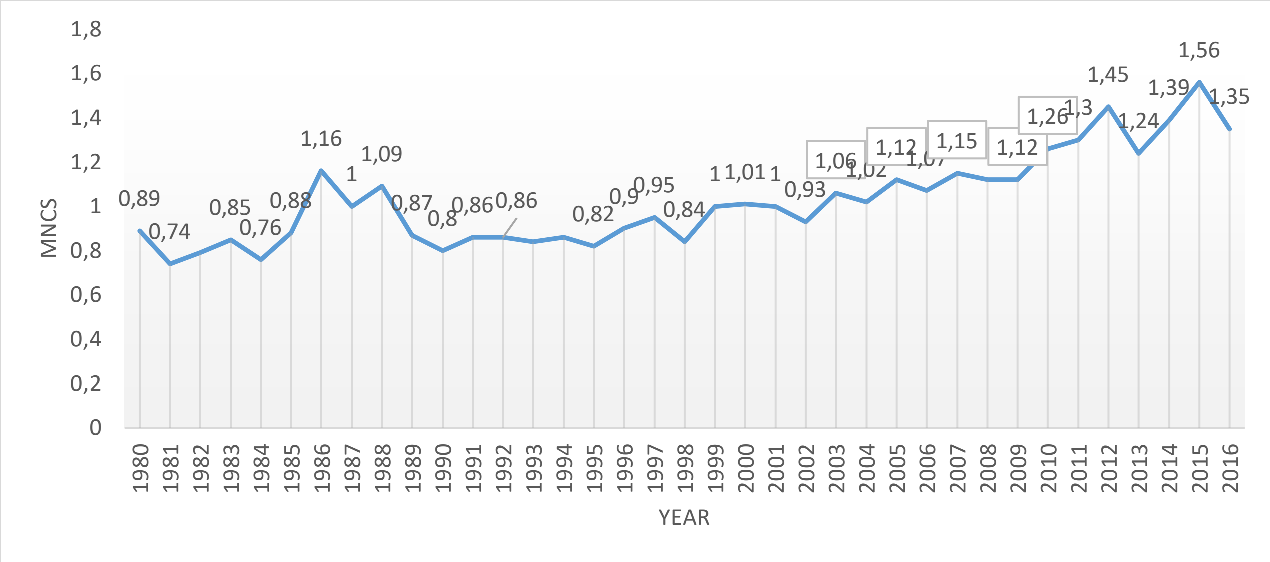

Figure 9-2: Trends in the citation impact of Kenyan science: 1980 to 2016

These fields presented in a descending order include the Clinical and Public Health, Basic Health Sciences, Agricultural Science, Other Social Sciences, Biological Sciences, Earth Sciences and Engineering and Applied Technologies.

Table 9-1: Kenya's high-impact fields

	Npubs (2005-2007)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Clinical & Public Health	5757	1,26	1,28	1,39	1,36	1,18	1,57	1,63	1,95	1,34	1,67	1,92	1,5
Basic Health Sciences	3176	1,16	1,14	1,32	1,22	1,22	1,19	1,26	1,23	1,06	1,21	1,12	1,22
Agricultural Science	2808	0,88	0,81	0,95	1,05	1,02	0,95	1,18	0,93	1,41	1,34	1,44	1,27
Other Social Sciences	2482	1,01	1,01	1,02	1,02	1,17	1,13	1,09	1,19	1,24	1,24	1,36	1,3
Biological Sciences	2353	1,29	1,27	1,42	1,01	1,12	0,99	1,01	1,28	1,18	1,17	1,4	1,27
Earth Sciences	1617	0,99	0,91	1,06	0,96	1,01	1,01	1,14	1,01	1,18	1,16	1,49	1,41
Engineering Sciences & Applied Technologies	1412	1,78	0,52	0,61	1,31	1,45	1,46	1,02	1,33	1	1,11	1,29	1,55

9.4 Positional Analysis

The first figure below shows the plotting for the broad domains for 2005 to 2007 and 2012 to 2014. The results show that two broad domains – the health sciences and Natural and agricultural sciences – were relatively strong but with a slightly low citation impact (just below 0.9), that is less visible, for the period of 2005 and 2007. Whereas for the period of 2012 and 2014 the health sciences stood out as having above-average relative field strength and high citation impact. Our analysis for the two periods shows that the humanities stood out as having above-average citation impact but with low relative field strength. Notably, Kenya has a high citation impact (slightly above 1) in Engineering and applied technologies (with a steep increase between 2005 to 2007 and 2012 to 2014) but had the lowest field strength for the all the periods analysed. In the 2005 to 2007 period, the Engineering and applied technologies registered a very low relative field strength, as well as a low citation impact that is below the world average. The broad domain of social sciences stood out as the strongest field, having above-average relative field strength, but has a low citation impact that is below the world average. Although for the period of 2012 to 2014, the social sciences recorded a noteworthy citation impact, that is, were equally visible.

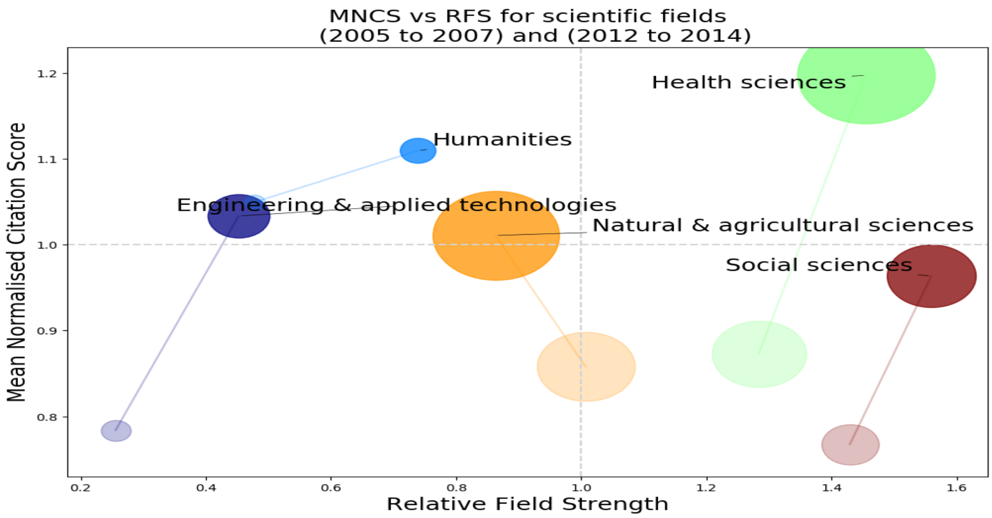

Figure 9-3: Positional Analysis for the broad domain fields

9.5 Assessment of fields

This section illustrates and discusses the citation impact for the different scientific fields: the health sciences, agricultural sciences, engineering, social sciences and humanities.

9.5.1 Health sciences

Citation impact: between 2000 and 2016, the results show that the field normalised citation score (MNCS) in the health sciences were above the world average (that is above 1). The results further show Kenya's field normalised citation score (MNCS) in the health sciences increased from 1.1 in 2000 and increased to 1.8 in 2015 before a slight decline to 1.4 in 2016 as illustrated in the figure below.

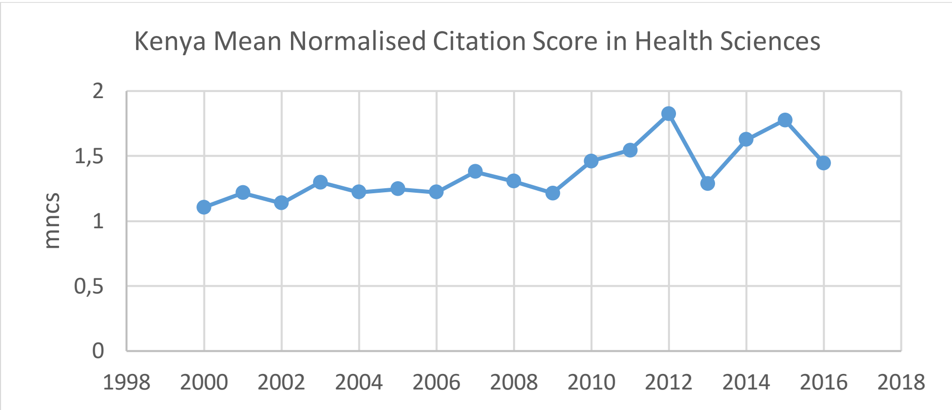

Figure 9-4: Health Sciences: Field Normalised Citation Score (2000 -2016)

The proportion of papers in the top quartiles of the WoS journals (quartiles as categorised by the journal impact factor) is used as a proxy indicator for the research quality of papers. The figure below illustrates the distribution of the papers in the health sciences by quartile. The results in figure 7.25 illustrate no substantial increase in the proportions of the papers published in high impact journals, that is, the Q1 and Q2 ranked journals.

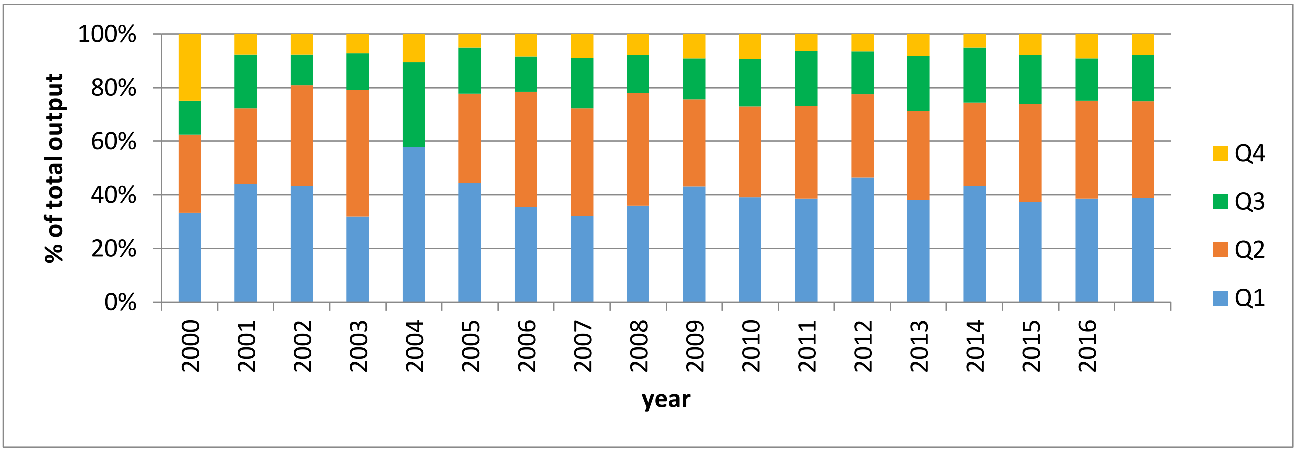

Figure 9-5: Health Sciences: Kenyan distribution of output JIF quartiles (2000 -2016)

The results of the positional analysis show that the top-right-hand quadrant consists of several sub-fields large fields such as infectious diseases and general and internal medicine as well as other smaller fields such as parasitology, tropical medicine, health care sciences and paediatrics. A few fields such as peripheral vascular disease, orthopaedics and oncology are included in the top-left-hand quadrant, which indicates that these fields have a higher citation impact than the world average for the sub-fields. In general, the results illustrate a positive overall picture, as there are few smaller fields (e.g. allergy, emergency medicine and geriatrics and gerontology) clustered in the lower-left-hand quadrant indicating lower activity and lower citation impact.

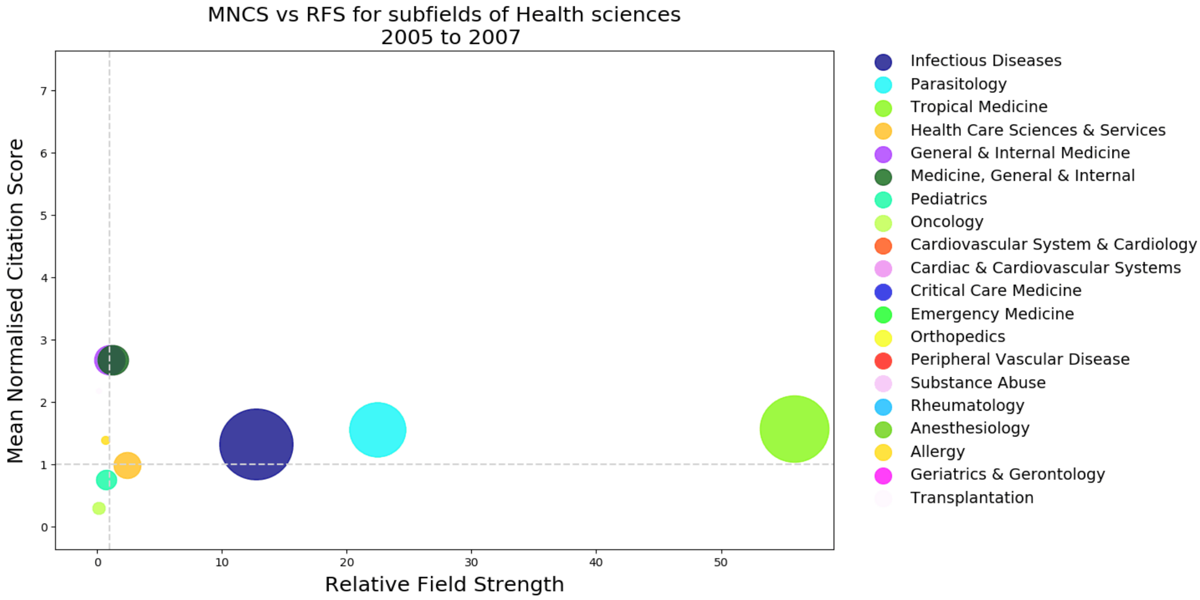

Figure 9-6: Health Sciences: MNCS vs RFS for sub-fields

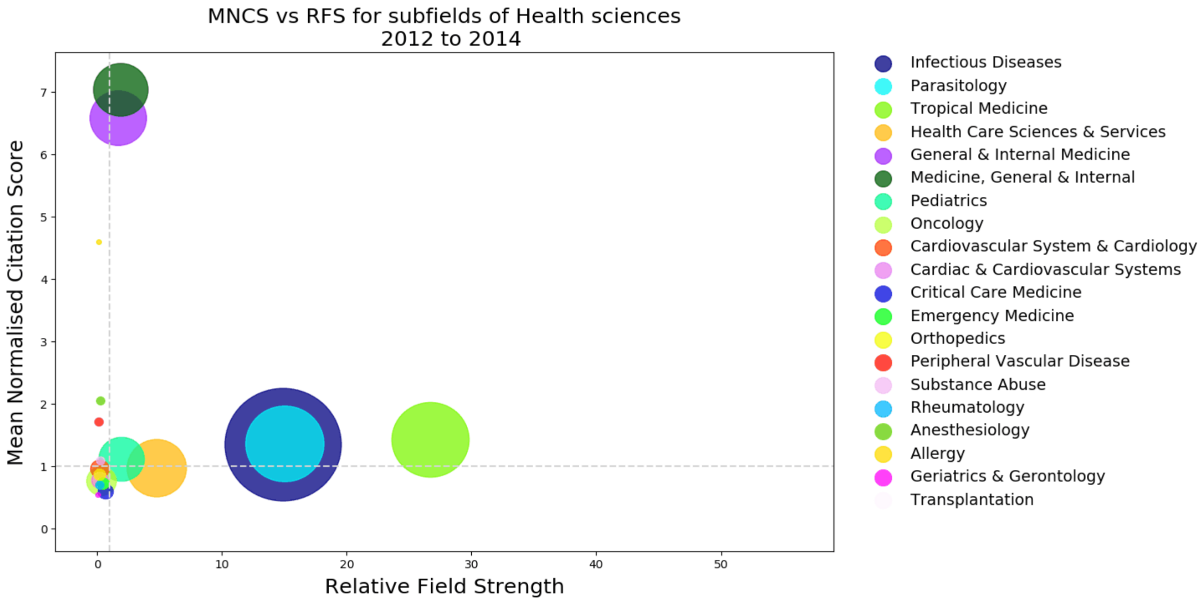

Figure 9-7: Health Sciences: MNCS vs RFS for sub-fields

9.5.2 Agricultural sciences

Citation impact: Kenya's mean normalised citation score (MNCS) in the agricultural sciences increased from 0.9 in 2000 and increased to 1.4 in 2013 before a slight decline to 1.3 in 2016 as illustrated in the figure 7-32 below.

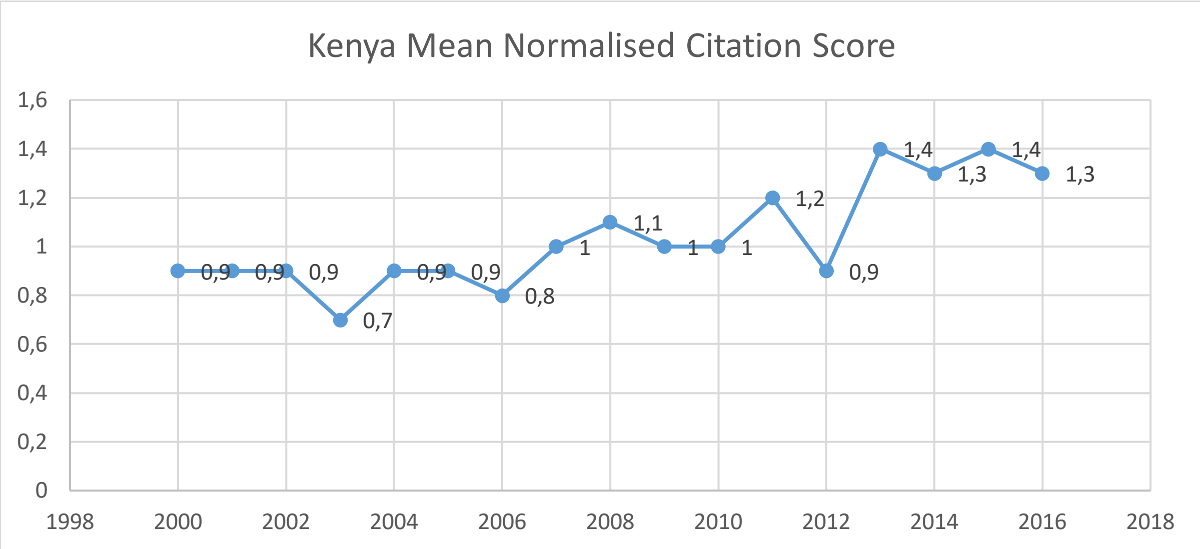

Figure 9-8: Agricultural Sciences: Mean Normalised Citation Score (2000 -2016)

This analysis uses the proportion of papers in the top quartiles of the WoS journals (quartiles as categorised by the journal impact factor) as a proxy for the research quality of papers published in the agricultural sciences. The figure below illustrates the distribution of the papers in the agricultural sciences by quartile.

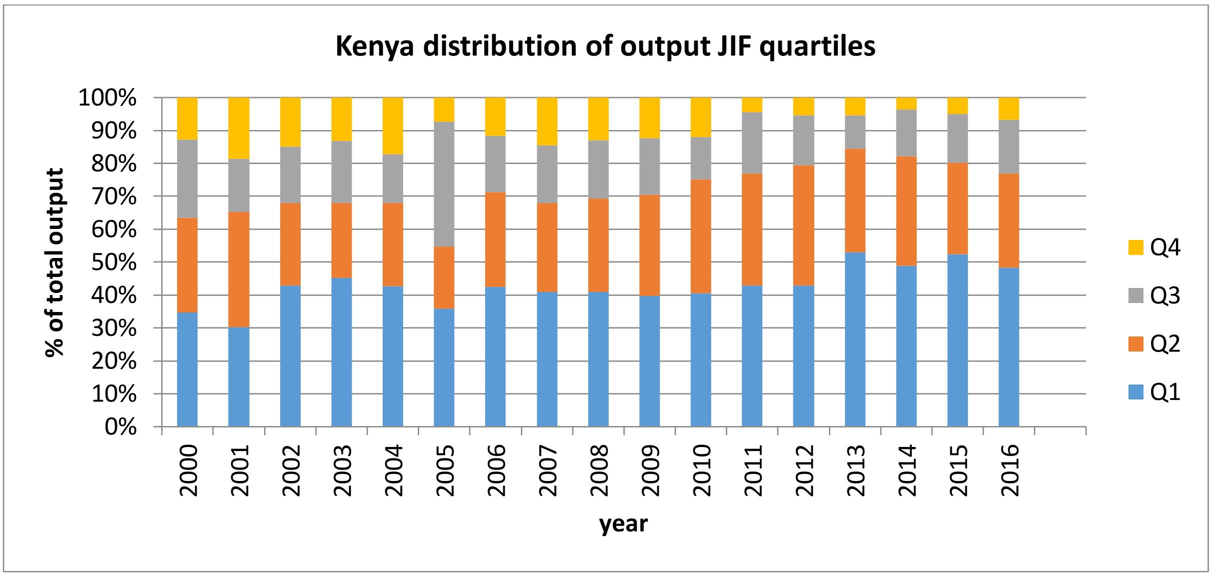

Figure 9-9: Agricultural Sciences: distribution of output JIF quartiles (2000 -2016).

The results in Figure 7-33 above illustrate a substantial increase in the share of articles published in the journals with a high impact factor, that is the Q1 and Q2 categorised journals. In 2000, the number of articles published in the high impact journals (i.e. Q1 and Q2) was over 60% of all papers. In 2016, the papers published in the high impact journals had increased to over 75% of the papers.

The results of the positional analysis show that between 2005 and 2007 veterinary sciences were the only sub-fields that appeared in the top right-hand quadrant. This implies that Kenya was active or specialised in publishing veterinary sciences papers and at the same time had a higher citation impact than the world average. Several sub-fields that appeared in the lower-right-hand quadrant: food science and technology, fisheries, agriculture, agronomy, horticulture, plant sciences, soil science, forestry, agricultural engineering, agriculture (multidisciplinary) and agricultural economics and policy. For these subfields, the results suggest that Kenya was active or specialised in producing papers in these fields however; they had a lower citation impact than the world average.

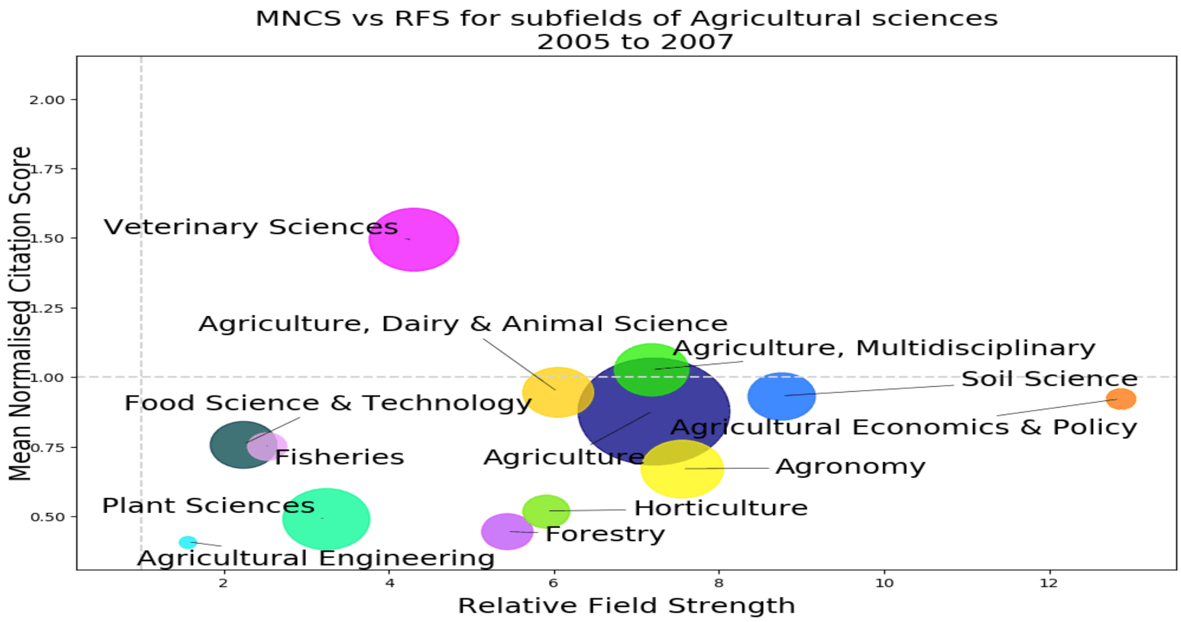

Figure 9 10 Agricultural Sciences: MNCS vs RFS for subfields of agricultural sciences (2005 -2007).

For the period between 2012 and 2014, more subfields in the agricultural sciences appeared in the top-right-hand quadrant. In other words, there was an increase in the subfields Kenya specialised in as well as the increase in their visibility. These subfields included horticulture, agricultural economics and policy, agronomy, agriculture, veterinary sciences, agriculture (multidisciplinary) and forestry. These results suggest that Kenya was specialised in these fields as well as had higher citation impact than the world average. Overall, the results illustrate a positive picture, because the two periods analysed (2005 -2007 and 2012 -2014) no subfields appear in the lower left-hand quadrant, indicating lower activity and lower citation impact.

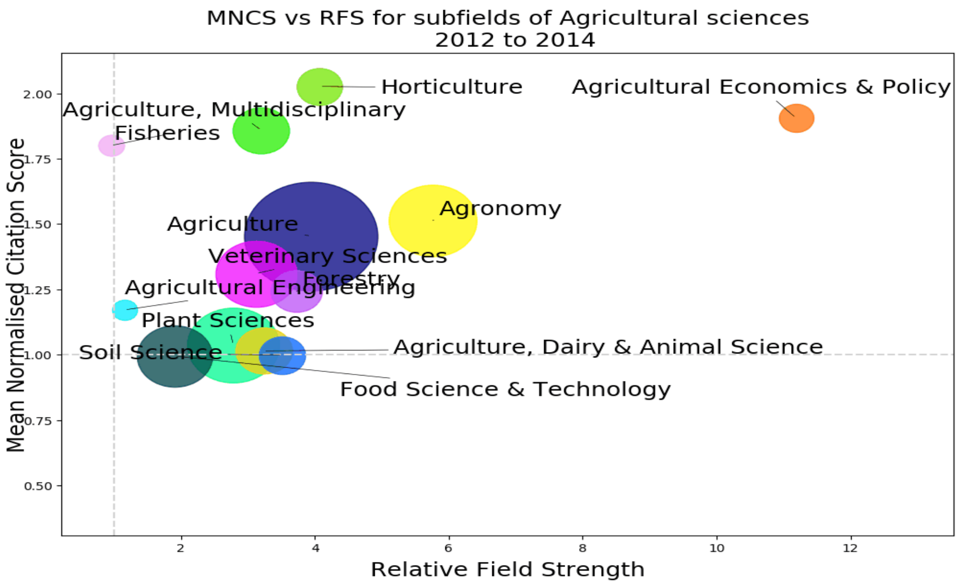

Figure 9-10: Agricultural Sciences: MNCS vs RFS for subfields of agricultural sciences (2012 -2014).

9.5.3 Natural sciences

Citation impact: Kenya's mean normalised citation score (MNCS) in the natural sciences increased from 1.05 in 2000 and increased to 1.4 in 2016 as illustrated in the figure below. These results show that Kenya is less specialised in the natural sciences; however, the papers in the natural sciences have maintained high visibility, especially in the last decade.

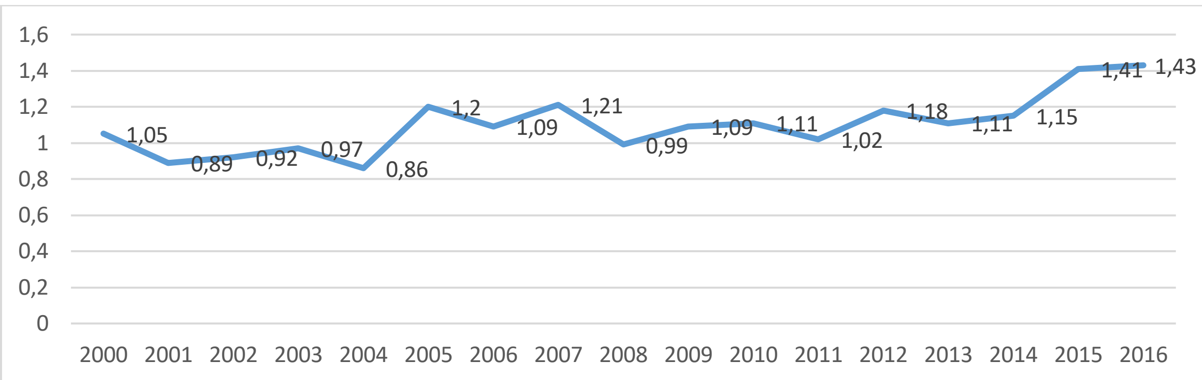

Figure 9-11: Natural Sciences: Kenya Mean Normalised Citation Score (2000 -2016).

This analysis uses the proportion of papers in the top quartiles of the WoS journals (quartiles as categorised by the journal impact factor) as a proxy for the research quality of papers published in the natural sciences. The figure below illustrates the distribution of the papers in the natural sciences by quartile.

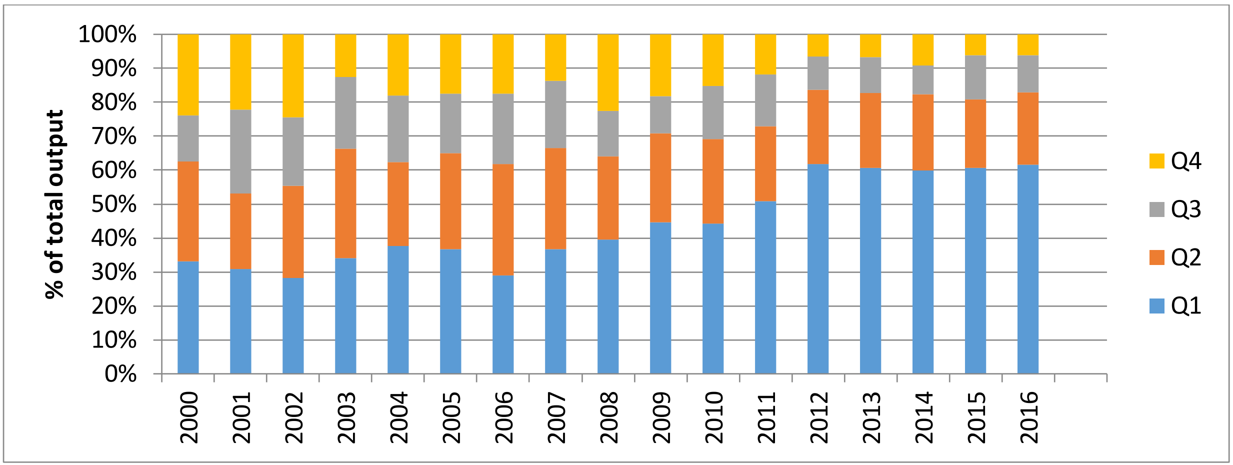

Figure 9-12: Natural Sciences: Kenyan distribution of the output of JIF quartiles (2000 -2016).

The results in the figure above show a considerable increase in the share of articles published in the journals with a high impact factor, that is the Q1 and Q2 categorised journals. In 2000, the number of papers authored in the high impact journals (i.e. Q1 and Q2) was above 60% of all the papers. In 2016, the papers published in the high impact journals had increased to over 80% of all the papers in the natural sciences.

The results of the positional analysis show that between 2005 and 2007, two main subfields: entomology and biodiversity conservation are located in the top-right-hand quadrant that implies that they are relatively active subfields (in comparison to the world averages of these fields) and have high visibility (above the world average (MNCS>1). In addition, several sub-fields appeared in the top-let-hand quadrant: applied physics, physical geography, mycology, physics, mathematics, statistics, and probability. These results suggest that these sub-fields are less active (compared to world averages of 1), but they have high visibility above the world average (MNCS>1). In addition, Cell biology and computer science are the only fields that appear in the lower left-hand quadrant. These suggest that these subfields are less strong or active (RFS<1) and their citation impact or visibility is below the world average (MNCS<). Sub-fields such as water resources, ornithology and physical geography were active (compared to the world averages of 1) but their citation impact was below the world average (MNCS<1).

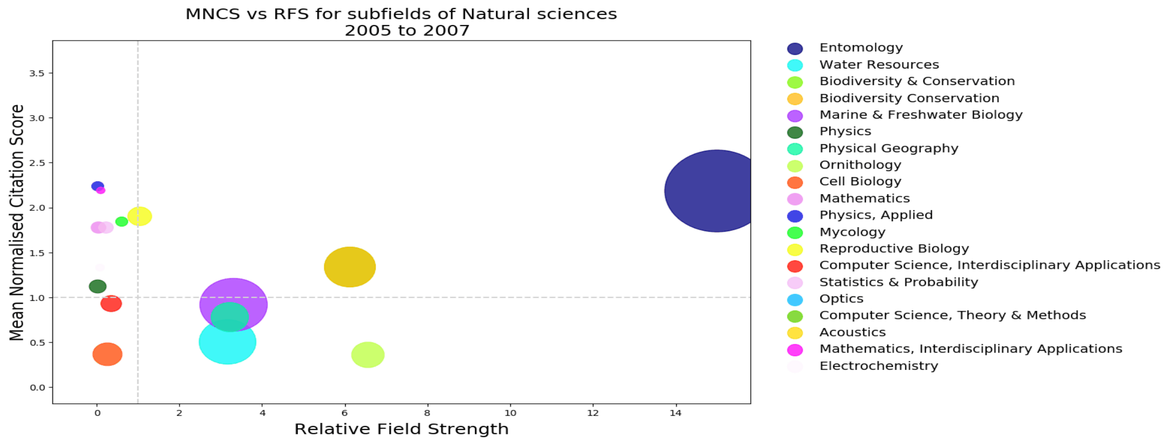

Figure 9-13: Natural Sciences: MNCS vs RFS for Sub-fields (2005 -2007).

The results show that for the 2012 to 2014 period, three subfields, that is, entomology, biodiversity conservation and physical geography were relatively active (RFS>1) and had high visibility (MNCS>1). Several subfields appear in the top-left-hand quadrant. These subfields (including reproductive biology, computer science, theory and methods, acoustics, cell biology, computer science and interdisciplinary applications and optics) are less active (RFS<1) but have high visibility above world averages (MNCS>1). Compared to the previous period (2005-2005), in 2012 to 2014, Kenya recorded low numbers of the relative field strength and low citation impact for physics, mathematics, applied physics, and statistics and probability. These sub-fields appeared in the lower left-hand quadrant, which implies they were less strong (RFS<1) and have low visibility below the world average (MNCS<1). Few sub-fields such as marine and freshwater biology, water resources and reproductive biology are relatively active or strong, however, have very low visibility below world averages (MNCS<1).

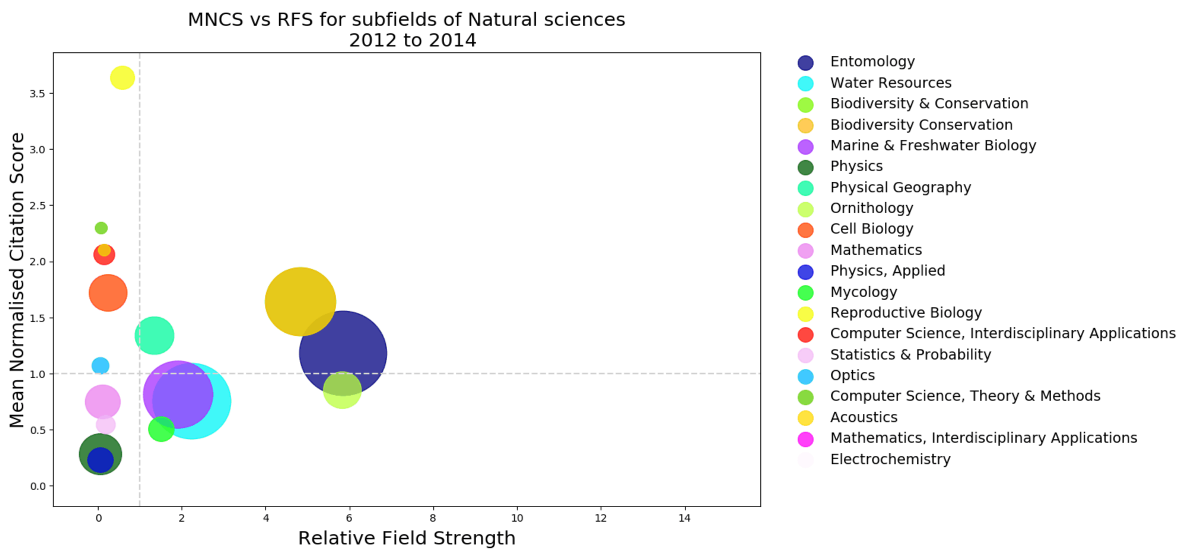

Figure 9-14: Natural Sciences: MNCS vs RFS for Subfields (2012 -2014).

9.5.4 Social Sciences

Citation impact: The results also show that between 2000 and 2016, the visibility for the social sciences is above the world averages. This implies that the citation impact for the social sciences was above the world averages (MNCS>1). A breakdown per year shows that the citation impact of the social sciences slightly increased from 1.1 in 2000 to 1.2 in 2016.

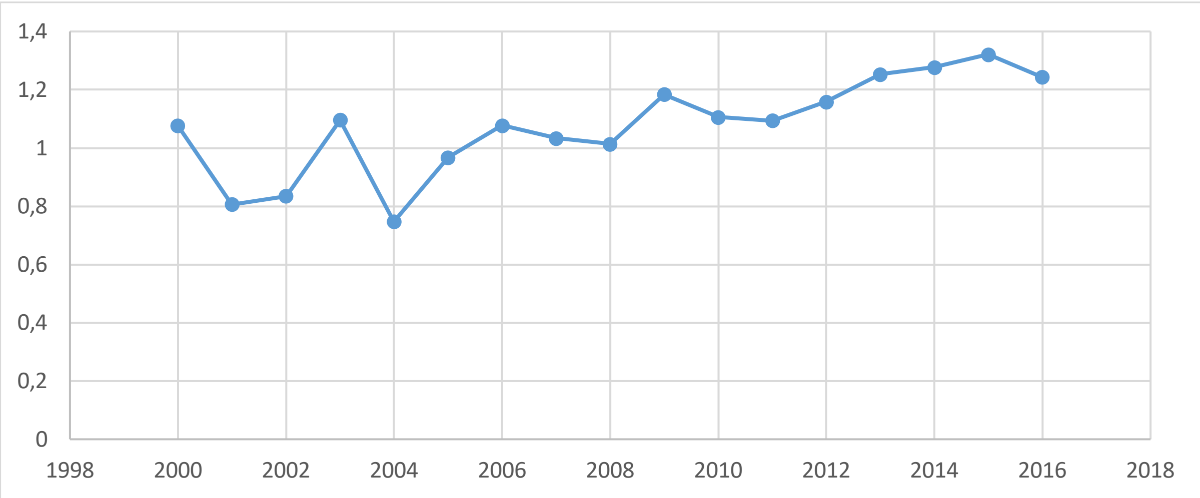

Figure 9-15: Social Sciences: Mean Normalised Citation Score (2000 -2016).

In this analysis, I use the proportion of papers in the top quartiles of the WoS journals (quartiles as categorised by the journal impact factor) as a proxy for the research quality of papers published in the social sciences. The figure below illustrates the distribution of the papers in the social sciences by quartile.

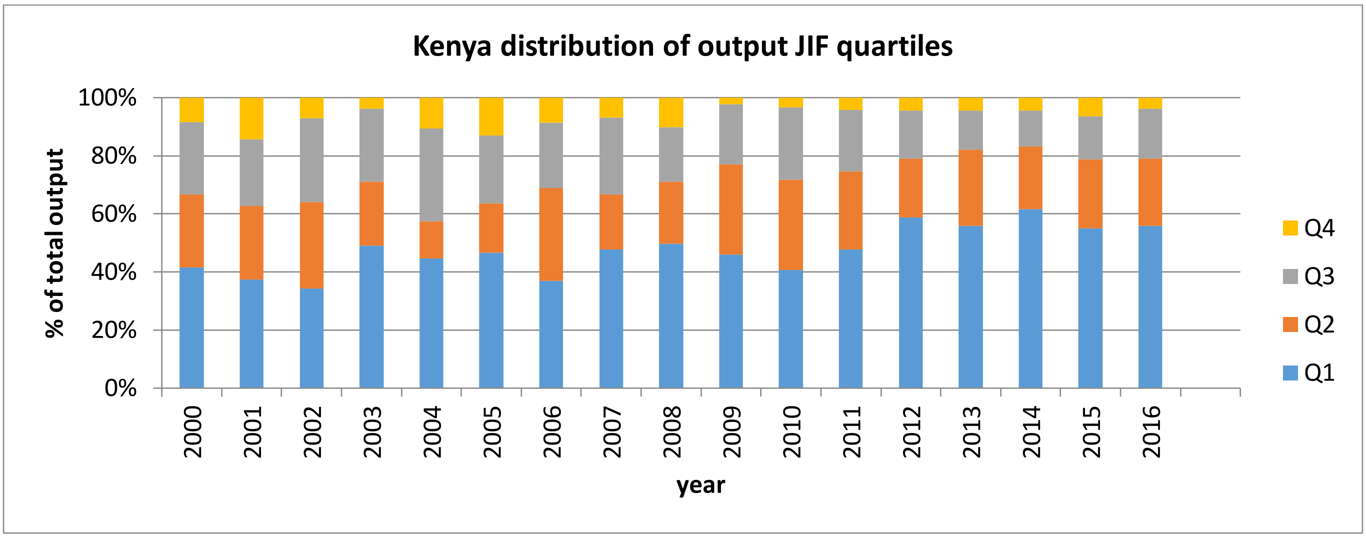

Figure 9-16: Social Sciences: Distribution of output JIF quartiles (2000 -2016).

The results in the figure above show a slight increase in the share of articles published in the journals with a high impact factor, that is the Q1 and Q2, in brief, journals. In 2000, the number of papers authored in the high impact journals (i.e. Q1 and Q2) was above 60% of all the papers. In 2016, the papers published in the high impact journals had increased to about 80% of all the papers in the social sciences.

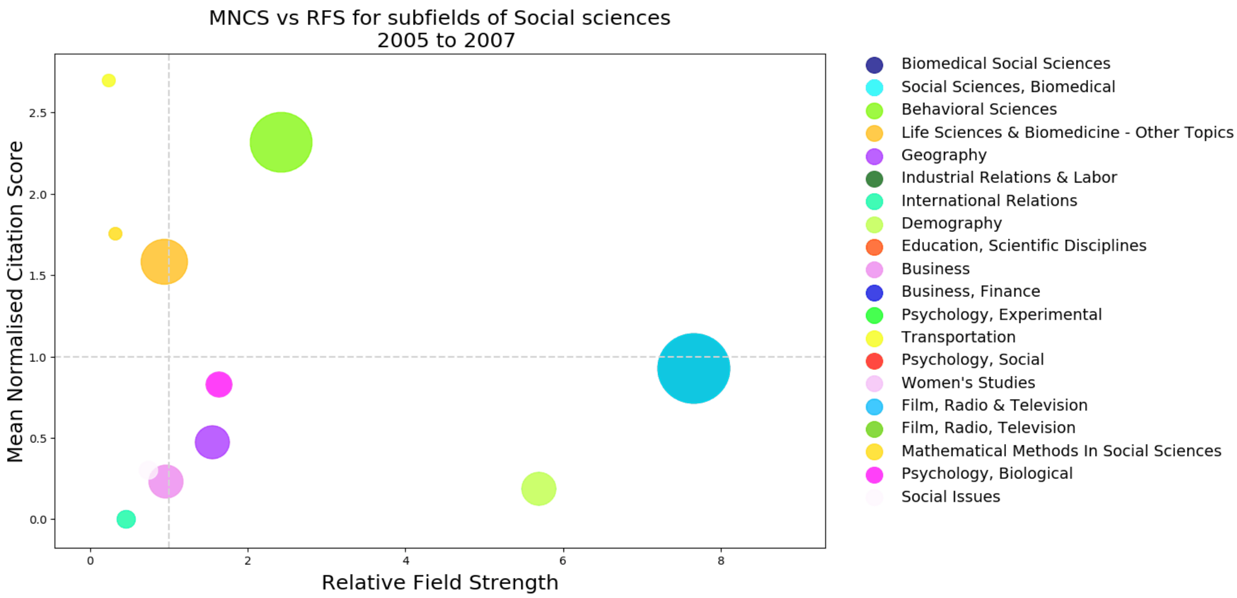

Figure 9-17: Social Sciences: Positional analysis (2005 -2007).

The results of the positional analysis show that between 2005 and 2007, two main subfields: behavioural sciences are located in the top-right-hand quadrant that implies that they are relatively active subfields (in comparison to the world averages of these fields) and have high visibility (above the world average (MNCS>1). In addition, several sub-fields appeared in the top-let-hand quadrant: life sciences and biomedicine – other topics, transportation and mathematical methods in social sciences. These results suggest that these sub-fields are less active (compared to world averages of 1), but they have high visibility above the world average (MNCS>1). In addition, international relations, women studies and business subfields are less active as well as have a lower citation impact. Subfields such as geography, psychology, biological social issues, demography, biomedical social sciences are located in the lower-right hand quadrat were active (RFS>1) however recorded a lower citation impact.

Between 2012 and 2014, the results show that more subfields (film, radio and television, behavioural sciences, industrial relations and labour, demography, geography) were located in the top right-hand quadrant compared to the previous field analysed. This implies that these fields were relatively active (high RFS) and recorded high (citation) visibility. Similarly, more subfields (education and scientific fields, psychology and social issues, recorded higher (citation) visibility but lower citation or visibility. In addition, subfields such as psychology, experimental, life sciences and biomedicine – other topics, psychology - biological social issues, and women studies recorded a lower RFS and lower (citation) visibility.

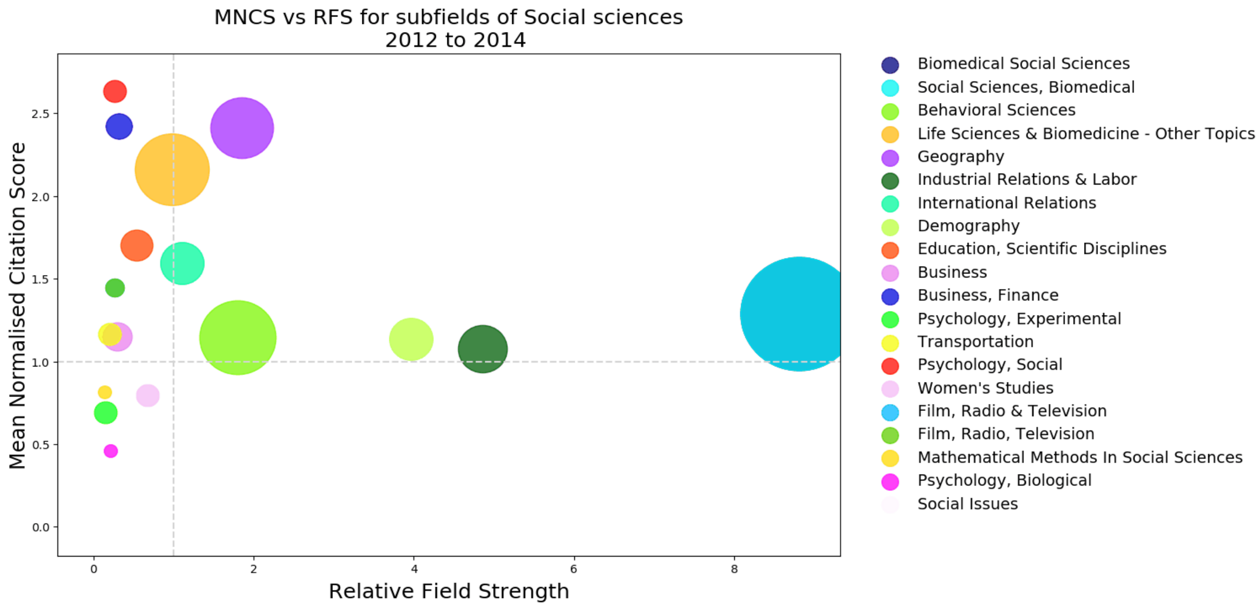

Figure 9-18: Social Sciences: Positional analysis (2012 -2014).

9.5.5 Engineering and Technology

Citation impact: The results also show that between 2000 and 2016, the visibility for engineering and applied technology is above the world average (where the world average is 1). This implies that the citation impact for engineering and applied technology was above the world averages (MNCS>1), thus the work is cited more. A breakdown per year shows that the citation impact of engineering and applied technology tripled from 0.8 in 2000 to 1.7 in 2005 and slightly declined to 1.5 in 2016. These results suggest that Kenya is less strong in engineering and applied technology, the few articles published are cited more compared to the world average.

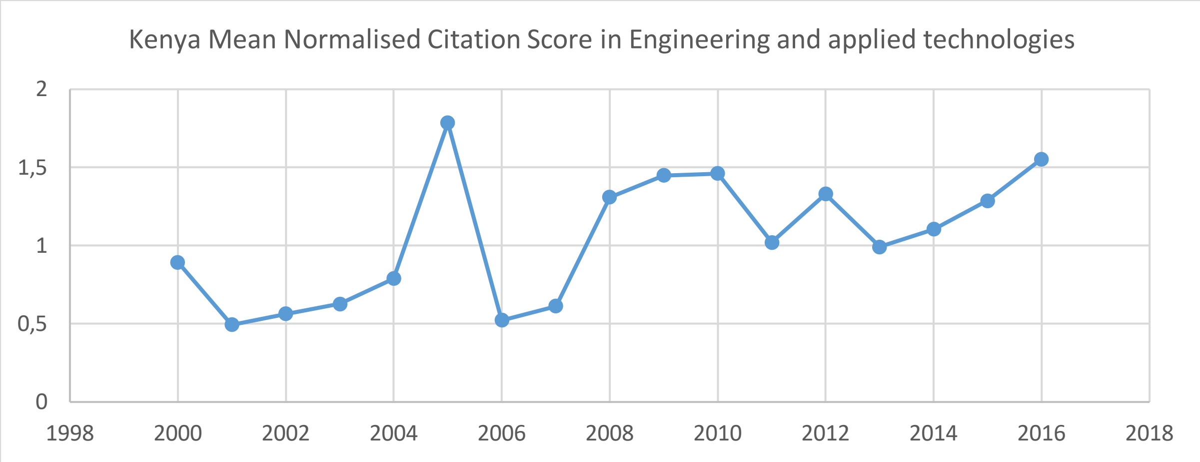

Figure 9-19: Engineering and applied technology: Mean Normalised Citation Score (2000 -2016).

Research quality: The figure below illustrates the distribution of the papers in engineering and applied technology by quartile.

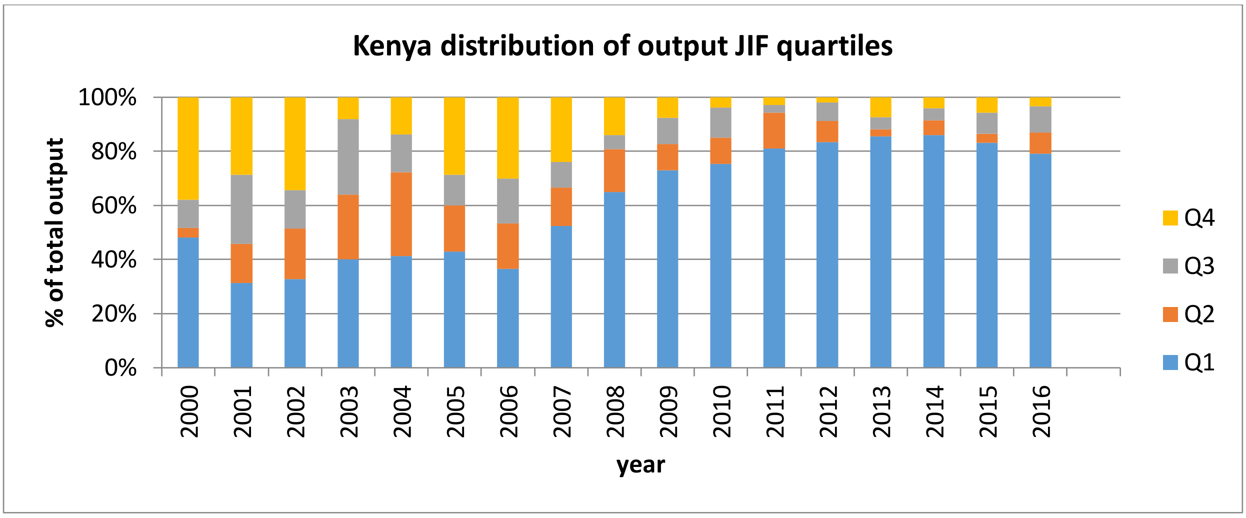

Figure 9-20: Engineering and applied technology: Distribution of output JIF quartiles (2000 -2016).

The results in the figure above show a substantial increase in the share of articles published in the journals with a high impact factor, that is the journals characterised in the Q1 and Q2. In 2000, the number of papers authored in the high impact journals (i.e. Q1 and Q2) was about 55% of all the papers in the engineering and applied technology increasing to about 96% in 2011 and slightly decreasing to about 85% in 2016.

Positional analysis: Between 2005 and 2007, science and technology (other topics) was the only subfield located in the top right-hand quadrant which implies that it is a relatively active subfield (in comparison to the world averages of this field) and have high visibility (above the world average (MNCS>1). Two main sub-fields appeared in the top-let-hand quadrant:

material science (ceramics) and operations research and management. These results suggest that these sub-fields are less active (compared to world averages of 1), but they have high visibility above the world average (MNCS>1). The majority of engineering sub-fields are located in the lower-left hand quadrant: mechanical engineering, material science, industrial engineering, geological engineering, and manufacturing engineering. For most of these sub-fields, they were less active (RFS>1) and recorded a lower citation impact.

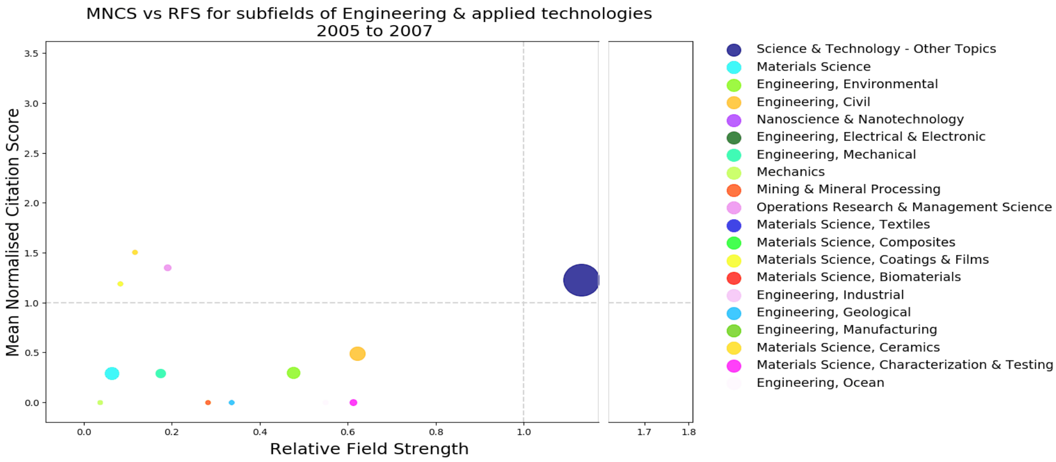

Figure 9-21: Engineering and applied technology: Positional analysis (2005 -2007).

Between 2012 and 2014, the results show that similar to the 2005 and 2007 period, one sub-field, science and technology (other topics) was located in the top right-hand quadrant. This implies that this sub-field was relatively active (high RFS) and recorded high (citation) visibility. Similarly, more subfields compared to the previous period analysed (Nano-science and technology, mechanics, mechanical engineering, civil engineering, environmental engineering and manufacturing engineering) appeared in the top left-hand quadrant indicating that the subfields have a higher citation impact (visibility) but less active relative to the world averages. In addition, subfields such as material science, electrical engineering, material science (textiles) mining and mineral processing recorded a lower RFS and lower (citation) visibility.

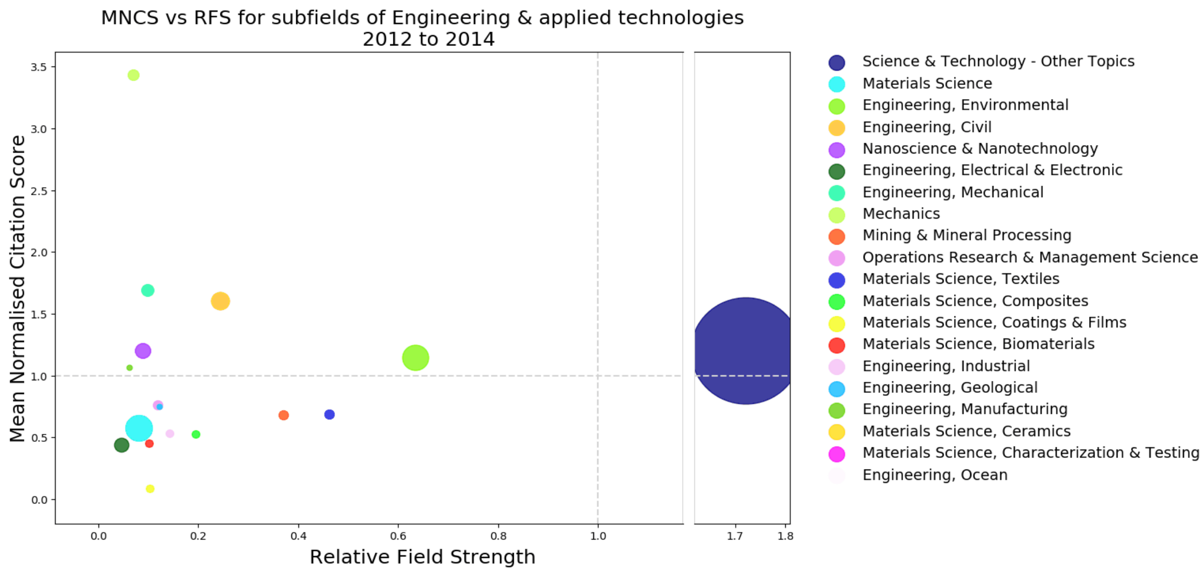

Figure 9-22: Engineering and applied technology: Positional analysis (2012 -2014

9.6 Discussion

As far as the citation impact is concerned, the results show that fields such as the natural sciences, health sciences, agricultural and social sciences recorded high citation impacts above the world average. The high citation impact could be explained by the higher rates of internationally co-authored papers recorded in general and in these fields. Previous studies show that citation impact is typically higher when researchers collaborate, but the citation impact is even greater when the papers are internationally co-authored (Adams, 2013; Onyancha & Maluleka, 2011). This implies that papers that are internationally co-authored tend to be cited more compared to the nationally co-authored papers or single-authored papers (Adams, 2012; 2013). Similarly, previous analysis shows that elite national universities are the research universities and institutes tend to engage in international collaboration. These universities have exceptional research groups which share ideas, outcomes and resources, hence positively impacting the visibility of the papers they co-author with their international collaborating partners (Adams, 2012; 2013). This analysis shows a similar pattern as Kenya's top international collaborating partners are elite universities in the USA and the UK which include the University of Oxford, the University of London, the London School of Hygiene and Tropical Medicine, the University of California System, the Centres for Disease Control (USA), the University of Washington and Wageningen University. These universities are high ranking and renowned thus may strengthen the citation impact of the papers co-authored with Kenyan institutions. Similarly, a previous study revealed that the number of countries funding research and the country of origin of the funding are positively associated with citation impact. In relation to the country of origin of funding, Wang and Shapira (2015) observed that when research funding originated from the European Union (EU), the USA and Germany it had positive effects on the citation impact. The results show that Kenya receives large proportions of its funding from the EU, the USA and Germany. Thus, based on the previous findings and my results we could argue that research papers funded by these countries are likely to receive more citations.

The breakdown by field shows that Kenya's papers have high citation impact, especially in the health sciences, engineering and applied technology and humanities. However, Kenya's research activity in the humanities and social sciences is weak, the papers produced recorded a higher citation impact. In relation to research quality, we can conclude that in general, the number of articles published in the high impact journals (i.e. published in Q1 and Q2) had increased over the period analysed. This applies to all fields, however, the results for the natural sciences, agricultural sciences and health sciences showed that they were mostly published in high impact journal. 9.10 Summary and conclusion

The analysis in this chapter shows a steady increase in the citation impact of the Kenyan authored papers for the past thirty-six years analysed (1980 – 2016). Specifically, the results show that seven level 2 fields recorded a citation impact above the world average of 1. These fields inter alia include clinical and public health, basic health sciences, agricultural sciences and biological sciences. For the period analysed (2000 – 2016), the results show a steady increase in the citation impact of the agricultural sciences, natural sciences, social sciences, engineering and applied technology and the health sciences.

A further positional analysis of the agricultural sciences shows that, between the period of 2005 and 2007, the veterinary sciences recorded the highest citation impact as well as was the active field in Kenya. For the later period of 2012 and 2014 more agricultural subfields such agricultural economics, agronomy and forestry recorded a higher citation impact, implying higher visibility of the papers produced in these fields. The positional analysis of the natural sciences shows for the periods analysed (2005 and 2007; 2012 and 2014), the subfields of entomology, biodiversity conversation and physical geography were relatively active and recorded the citation impacts above the world average, implying high visibility of the fields. The positional analysis of the health sciences identified fields such as infectious diseases, general and internal medicine, parasitology, tropical medicine and paediatrics to be the most active fields and with high visibility, implying that they recorded the citation impacts, above the world average. For the social sciences, the analysis in this chapter identified several sub-fields that were relatively active and have high visibility: behavioural sciences, life sciences, biomedicine, industrial relations and labour demography and geography.

Chapter 10 Conclusion

The main objective of the study was to evaluate the science system in Kenya. More and more governments demand evaluation of the outcomes of public investments and the need to increase public investment in research and development. This study used bibliometric data, standard R&D data, supplement by survey data and qualitative data to evaluate the following key aspects of Kenya's science system: research investment, research capacity, research performance (i.e. research output, research collaboration and citation impact). Additionally, the study conducted a historical review of the science system.

The evaluation results show that in relation to research investment and research capacity, Kenya still lags behind its own set targets of investing up to 1% of its GDP in science and increasing the numbers of human resources. As far as publication output is concerned, Kenya has increased its output significantly in recent years. Kenya's scientific output recorded high citation impact, especially in the fields of natural sciences, agricultural sciences, health sciences and the social sciences.

10.1 Main findings

The first research objective: *To reconstruct the history of the development of scientific research in Kenya: especially in agricultural and medical research*

I conducted a historical account that reconstructed the development of scientific research in Kenya, focusing on the early history of agricultural research, medical research, universities, museum and international research organisations. From the historical account, it is clear that the colonial government played a key role in establishing agricultural research institutions and funding of agricultural research. After independence, the GoK took up the role of funding of agricultural research and the establishment of semi-autonomous agricultural research institutes. The GoK was also involved in the formation of the coordinating and advisory body needed for agricultural research. Similarly, the historical review reveals that Kenya has several international research organisations in Kenya, especially in agricultural sciences, which contribute to Kenya's scientific output.

In relation to the history of medical research, from the times of the Wellcome Trust Research Laboratories in Thessaloniki in 1938 to the establishment of the Wellcome Trust Nairobi Unit in 1949. The Wellcome Trust Nairobi unit, one of the first institutions focusing on health research, provided a framework for health research and the works of the Wellcome Trust overseas and in Kenya. The Wellcome Trust has remained one of the key institutions undertaking health research and a funder of medical Science in Kenya, together with other international funders (i.e. WHO, CDC and NIH). The key medical research areas of the Wellcome Trust units included malaria, nutritional disorders, sickle cell anaemia and other blood disorders. This research also included schistosomiasis, hypertension and renal diseases. In addition, I also reviewed the history of higher education institutions in Kenya. The review shows that higher education institutions in Kenya have a long history dating back to the early 1930s with the establishment of the Royal Technical College, which became the University of Nairobi. The University of Nairobi was the first and only fully-fledged university in 1971, and currently, Kenya has a total of 74 universities. The history of higher education in Kenya, together with the increase in the number of universities and the number of academics and researchers, could explain why the higher education institutions in Kenya dominate the production of Kenya's scientific output.

The second research objective: *To analyse trends in research and innovation investment in Kenya*

With regard to research investment as per the R&D indicators, the findings show that the Kenyan national government makes a minimal investment in research and development. The proportion of its GDP that is invested in research and development is still below the government's own target of investing 1-2% of GDP to R&D.

The R&D statistics also show that about half of Kenya's funding is from international sources. Similarly, apart from Kenya's NACOSTI, most of the major funding organisations listed by respondents were mainly international organisations or agencies. This supports the observation that international funders largely contribute to Kenya's funding.

Kenyan researchers continue to rely heavily on international funding. This is illustrated by the higher numbers of respondents who indicated that for the funding they had received a larger proportion was from international sources. The results show that for the younger scientists (39 or younger) especially those in the natural sciences and engineering, who indicated to have received funding, the higher amounts were from the national sources. The results show that for the older respondents (with the exceptions of those in engineering and applied technology) who indicated that had received funding, indicated that they received higher amounts from international sources. The results showed some field differences between male and female researchers on receiving funding. Male respondents in the natural sciences and engineering, regardless of their age, received a higher proportion of funding from the national sources as compared to their female colleagues. Respondents in the natural sciences and engineering indicated that they had received most of their funding from the national sources. On the other end, respondents in the humanities, followed by those in the agricultural sciences, health sciences and social sciences indicated had received a larger proportion of their funding from the international sources.

These findings identified several barriers scientists face in securing funding for research and equipment and infrastructure and attending conferences. Among others, the barriers include long and many bureaucratic processes that delay the availability of funds, heavy workloads hence limited time to apply for grants and lack of skills to apply for funding. Following these barriers, and the importance of funding for researchers, respondents in this study made recommendations for the Kenyan government to increase the investment.

The third research objective: *To analyse and assess the research capacity for science and technology in Kenya*

In relation to human resources available for research, the data available, especially for the R&D personnel indicator, was found to be completely unreliable. Because of this, we confined our analysis to only those indicators that have some face validity. Between 2007 and 2010 results show that Kenya recorded increases in the number of researchers in several human resource indicators (i.e. researchers per million inhabitants, researchers per thousand labour force, researchers per thousand employment and the total number of researchers (HC and FTE). Despite the increases that are recorded these numbers remain low compared to the country's target to increase the number of researchers. Kenya acknowledges the need to increase these numbers required for research and development in the country if they have to achieve their goal of becoming a middle-income country by 2030. These initiatives are seen in the targets to increase doctoral graduates per annum and the number of academics in the universities who will train more researchers and engage in research.

When the researchers (HC and FTE) indicator is disaggregated by sector, data revealed that the higher education sector recorded the highest number of researchers, followed by the government institutions. The business sector and private organisations had the least number of researchers. As far as the disaggregation by scientific field is concerned, the agricultural and health sciences recorded the highest number of researchers. These findings also reveal that the largest proportion of researchers (HC and FTE) has a college or equivalent as their highest qualification. A small number of researchers, mostly those in the higher education sector, hold a master level degree or doctoral level qualification.

In relation to the female researchers' indicator, when compared to other sub-Saharan African countries, Kenya is ranked tenth behind countries like South Africa, Namibia and Botswana. Kenya records the highest number of research and development staff per million inhabitants compared to Uganda and Tanzania. Similarly, Kenya reported the highest share of female researchers in absolute numbers in the East African region, while her regional neighbours (Tanzania, Uganda and Rwanda) reported similar shares of their country's researchers.

In relation to international mobility, our analyses show that the opportunities to be mobile have several advantages as allows scientists to access training opportunities, develop research networks, access research experts in a given scientific field, access 'state-of-the-art equipment, have access to funding opportunities and acquire work opportunities in institutions with a strong research culture.

The findings of this study showed that a considerable proportion of respondents were mobile in the preceding three years. Scientists in all age groups and scientific fields consider studying/working abroad beneficial to their careers. A further disaggregation by age shows that a larger group of younger scientists had mobility opportunities in the preceding three years, however, this is a small proportion compared to the majority who lack mobility opportunities. The study identified several benefits for the individual scientists who had the opportunity to study/work/travel abroad including acquiring research networks, training in research proposal and funding applications, access to research facilities/equipment, publishing opportunities among others.

Challenges related to mobility were mostly because of lack of information about the mobility opportunities as well as funding challenges. In some instances, scientists are not to travel for conferences or training because their local institutions or the government is not able to fund international travels. The lack of mobility opportunities was reported to have the most negative impact on the careers of scientists in the humanities, health sciences, agricultural sciences and natural sciences. This could be attributed to the research networks, training opportunities and access to 'state-of-art' equipment that is needed for research in these fields. This study identified several reasons as that will make them leave their country, including career opportunities, salary/remuneration, academic reasons, further studies, funding, institutional reasons and social welfare and state provision.

In relation to mentoring and support, the findings show that, factors associated with research work - research methodology, presentation of results, scientific writing an introduction to networks - were identified as the main support and training received and which were valuable thereof to the scientists. Fundraising and career decisions, although is needed by the scientists, was identified as one of the mentoring and support least received.

Field differences were observed in relation to the cases where a lack of mentoring and support as well as a lack of training opportunities was mentioned as a challenge. For instance, a larger proportion of respondents in engineering and applied technology (STEM) indicated to have faced this challenge than their peers in the social sciences and humanities. The scientists in the fields of engineering indicated the need for mentoring and training opportunities to develop skills in the industry, thus emphasising the importance of academia-industry linkages.

According to the results, young scientists in the early stages of their careers identified several needs that would be useful for their careers and skill development. These include guidance on fundraising, preparation on how to conduct research and publish, guidance on teaching-related activities, introduction to academia-industry linkages. However, younger scientists are faced with several challenges in receiving mentoring and support in these areas, including, few established scientists who can act as mentors, the available mentors are often too busy and overburdened given a large number of young scientists in need of mentoring. Given the challenges of a lack of mentoring and training opportunities, respondents suggested the need for information on available opportunities and the availability of forums that scientists can offer the skills and mentoring needed by the young scientists.

The fourth research objective: *To describe the trends in the scientific output*

Using bibliometric analyses supplemented by survey data and qualitative data, I analysed the scientific output for Kenya and the factors that influence research productions. Both full counting and fractional counting methods were used in the counting of the scientific output. In particular, the study analysed the barriers to publishing.

In relation to scientific output, in general, both the full counting and fractional counting show that Kenya's scientific output has been on a steady increase over the years analysed. In the instances where the measurement of research production is based on whole counts, the increased publication output for Kenya is mainly due to a fast-increasing number of articles where authors from other countries also contribute to Kenya's scientific output. This scenario is different, to a smaller extent, when fractional counts are used in the measurement of the publication output.

Particularly, when fractional counting is used in the analysis of Kenya's scientific output, the number of publications recorded are more compared to the output counted when fractional counting is used. From the literature it is clear that full counting illustrates the perspective of participation, whereas on the other end, fractional counting illustrates the perspective of contribution, which is clearly shown in these results. Therefore, despite the minimal efforts from the national resources, the bibliometric results from fractional counting show a minimal but steady increase in what Kenya contributes to scientific output. Research in Kenya is still at large where research performance is highly dependent on other countries, both financially and by collaboration. Therefore, the growth in Kenya's output will seen given the high rates of international collaboration, as well as, the high proportions of international funding.

The increase in the scientific output translates into an increase in Kenya's world share. Despite the increase in scientific output, Kenya's world rank or the position has declined over the years. The decline in the ranking could be attributed to collaboration. Kenya's scientific output is largely dependent on collaboration. When whole counts are used, Kenya's scientific output has a higher contribution from other countries and their authors as well. This implies that the contribution of these collaborating authors to their own countries also increases with time, which might me more than Kenya's output, hence the decline. Fractional counts show consistent results, they show a small number of articles contributed by the Kenyan authors (with the exclusion of contributions of authors and organizations in other countries), which indicates that in instances of collaboration, the other countries output increases as compared to Kenya's output. In relation to scientific output disaggregated by the scientific field, it is shown that the health sciences, agricultural sciences and natural sciences recorded the highest number of papers. The majority of the papers were produced by the oldest and largest universities (University of Nairobi, Kenyatta University, Jomo Kenyatta University of Agriculture and Technology, Maseno University and Egerton University), the public research universities (KEMRI, KALRO) and the international research organisations (ILRI, ICIPE, ICRAF, ICRISAT, CDC-Kenya and CIMMYT).

In relation to the research activity index or relative field strength (RFS), Kenya is relatively strong and active in the health sciences and social sciences. This implies Kenya specialises in producing papers in these fields. Kenya's activity index in the natural sciences has weakened in the past decade. Conversely, Kenya is weak and less active in the engineering sciences and humanities.

Based on the survey data, I analysed several factors such as age, gender, and scientific field, which have significant influences on research production. In general, my findings show age, gender and scientific field are key predictors of reported scientific output. Statistically significant differences between age categories, although small, and research production were found as older scientists reported higher publication output in some fields and publication forms as compared to the younger scientists. Gender differences in scientific output were also observed, as male scientists, irrespective of age and scientific field, with a few exceptions, recorded the highest number of reported scientific output in the preceding three years. In some fields such as the health sciences and social sciences, female scientists reported the highest number of publication output.

The results in this study show that in the context of increased demand to publish, scientists have devised several structures to enable them to publish. This includes publishing their work as final-year undergraduate students, publishing from their PhD work, supervisors/mentors publishing with their post-graduate students. Similarly, given the heavy workloads, scientists in the field of engineering prefer publishing conference papers, which are likely to take minimal time to publish as compared to a journal article.

The fourth objective: *To describe and assess trends and patterns in the research collaboration of Kenyan authors*

Bibliometric data complemented by survey and qualitative data was used to assess the trends of research collaboration in Kenya. The results show that there has been a high increase in international collaboration, which is consistent with indications of past studies. To corroborate this finding, respondents to the survey indicated they tend to collaborate with researchers outside Africa. On the other end, national collaboration has been on the decline, which could be a signal of weak national research systems. This study confirms that scientists collaborate less with researchers in own country. This is consistent with the empirical literature, which showed, intercontinental (African) collaboration has equally declined.

In relation to collaboration intensity, at the international level, the United States of America, the United Kingdom, Germany and France recorded the highest collaboration intensity with Kenya. The findings show that, on the African continent, Kenya collaborates more with South Africa followed by her regional neighbours Tanzania and Uganda.

The findings show that, on the African continent, Kenya collaborates more with South Africa followed by her regional neighbours Tanzania and Uganda. The high collaboration intensity with these countries has been attributed to the culture, language, history (colonial legacy), and the geographical proximity and in some instances, funding between these countries. The fields that recorded the highest levels of collaboration are the health, natural, and agricultural sciences.

I also investigated the relationship between different factors and research collaboration. The results show that there are no huge age differences that emerge in relation to respondent's collaboration with different researchers. This study reveals that males are more likely to collaborate internationally (with researchers outside Africa) compared to the female counterparts, which is consistent with previous studies. Females are more likely than males to indicate that they collaborate less with other researchers across different categories, especially for African collaboration.

Across all sectors, respondents reported they frequently collaborate with researchers in their own institution, followed by researchers in their own country and outside Africa. Researchers in higher/tertiary institutions, public research institutions, private research institutions, and non-governmental organisations reported significantly higher proportions of collaborations with researchers in their own institution and outside Africa. Surprisingly, higher frequencies of researchers in non-governmental and international organisations reported they collaborate less often or not at all with researchers outside Africa.

This study identified a number of important factors that constraint the frequency and effectiveness of research collaboration. The factors identified in this study include lack of funding, lack of financial support to attend meetings and conferences, institutional policies and strategies, the inability to secure collaborators and lack of skills and experience. Although the previous studies were mostly conducted in the developed world and with African researchers, the results of Kenyan researchers identified similar factors that constraint research collaboration. Following these challenges, respondents made suggestions that the government and institutions should support research collaboration. This support may include availing funding opportunities and financial support for research and attending conferences, so as to develop research networks. Apart from the international collaborators and national collaborators, this study reveals that supervisors/mentors often collaborate with their students to increase publication output, as well as a mentor in research and publishing. Apart from the mentioned collaborators, these results indicate that respondents prefer to collaborate with the industry, in order to understand how the industry operates and ensure industry-academia linkages.

The fifth objective: *assessing and describing the citation impact of Kenya's scientific output*

In relation to citation impact, findings to this study show that Kenya's papers have high citation impact which has steadily increased over the period analysed (2000-2016) The high citation impact is particularly observed in the health sciences, engineering and applied technology and humanities. As in the case of publication output, discussed above, we also conclude that because of the measurement is based on the whole counts, the increased citation impact of Kenya's publication output is mainly due to a fast-increasing number of co-authored articles where other countries contribute with their authors as well. Although Kenya's research activity (measured by RFS) in the humanities and social sciences is weak, the papers produced recorded a higher citation impact. In relation to research quality we can conclude that in general, the number of articles published in the high impact journals (i.e. published in Q1 and Q2) had increased over the period analysed. This applies to all fields, however, the results for the natural sciences, agricultural sciences and health sciences showed that they were mostly published in high impact journals.

10.2 Contributions of the study

Few studies (Mouton & Waast, 2005; Mouton & Boshoff, 2010) have provided a comprehensive evaluation of science in Africa and particularly looked in detail at the trends of research capacity, research investment and research performance (i.e. research output, research collaboration and citation impact) for the Kenya's science system (Mouton & Waast, 2005). Although other existing studies have evaluated research, the majority have evaluated scientific fields (Onyancha, 2009; Onyancha & Ocholla, 2007), research institutions (Rotich & Onyancha, 2017), research theme (Gupta, Ahmed, Gupta & Tiwari; Macías-Chapula & Mijangos-Nolasco, 2002; Onyancha & Ocholla, 2004; Pouris & Pouris, 2011), region (Onyancha & Maluleka, 2011) or the African science (Mouton, 2018; Tijssen, 2007).

This study makes both an empirical and methodological contribution. The current study provides a comprehensive evaluation of science in Kenya. Through a historical assessment and international benchmarking, this study evaluates the research investment, research capacity and research performance (i.e. research output, research collaboration and citation impact). In addition to the aspects analysed above, this study provides the perception of scientists on funding, research collaboration and scientific/academic career challenges.

Apart from the empirical contribution, this study also makes a methodological contribution. The previous studies that evaluated science in the African context including Kenya mostly used standard R&D data and bibliometric data to evaluate science. Bibliometric data, as well as the R&D data, have several limitations. As shown in this study the R&D data for some years are incorrect and thus requires to be supplemented with data from other sources. This study used a case study design in the evaluation of science in Kenya. The case study design allows for triangulation of methods for an in-depth understanding of the Kenya's science system.

10.3 Recommendations of the study

- The government should increase research and innovation investment to its target of about 1% to 2% of GDP as indicated by the government in the STI policy framework.
- The government through NACOSTI and other research funding bodies in the country should design and create more research supporting programs for researchers, especially female and young researchers to optimise the performance and impact of young scientists and female scientists.
- Increase support in relation to research equipment and machines in all the scientific institutions in Kenya. This will maximise applications of available research equipment and increase the research collaboration culture among the R&D institutions in the country and internationally at large.
- Human resources in R&D institutions should be increased. Despite the increase in the number of researchers between 2007 and 2010, the research and innovation capacity of the country is lower in relation to the government's targets of increasing the number human resources needed for knowledge production in the country. To increase these

numbers the government has to train more researchers, thus the need to increase the investment in train more doctoral students and hiring more post-doctoral researchers.

- The Ministry of Education, Science and Technology, which is responsible for research and education, should accredit all scientific journals, which will be used for promotion of researchers and academicians. This will ensure publications in genuine journals rather than predatory journals.
- The government should have a monitoring and evaluation framework and perform a regular monitoring and evaluation exercise of the implementation of the science and technology policy. This will be a dashboard and a feedback mechanism to provide the progress of implementation of the policy.
- It is recommended that the country to establish a knowledge database which will contain the characteristic features of human resources (number, available skills and level of education, age and so on. The database should be regularly updated and contains all scientific outputs from scientific institutions.
- The study suggests that the country should routinely collect data on all the publications published within its institutions so that it is scrutinised and available on-demand rather than having to be collected a new each time a research evaluation occurs. The government should conduct regular STI survey to monitor and evaluate the progress of science and technology in the country.
- Young scientists, in particular, are faced with challenges in terms of human capacity building and professional development (mentoring and support; lack of training opportunities to develop professional skills and; lack of mobility opportunities). Bilateral and multilateral collaboration research programs are crucial for then career development of young and senior scientists to advance and develop their research skills and mobility opportunities. It is also of paramount importance for scientific institutions in the countries to institutionalise the mentoring and support programs for young scientists.

10.4 Limitations of the study

- The list below indicates several limitations of this study, based on the methodology applied in the study or the theoretical aspects underpinning this study.
- Bibliometrics – The bibliometric study of this research analysed publications outputs (articles and reviews) from Thomson's Reuters Web of Science (WOS) and Elsevier's Scopus database. As we have already seen, the main databases are reliable, however, their coverage is more in the natural sciences, agriculture sciences, medical sciences,

and engineering and applied technologies scientific fields and limited coverage in the humanities and social sciences. The WoS and Scopus remains biased towards the humanities and social sciences since these scientific fields publish more in books and book chapters.

- The survey part of this study comprised data extracted from the self-administered questionnaire with information based on the self-reporting responses. This could result in over-reporting or underreporting of information.

The inaccuracies and gaps in the R&D data. For instance, the R&D personnel data is problematic as it showed huge increases that are unexplainable.

10.5 Future Research

Given the limitations of the international databases in relation to coverage of African scientific publications, I would suggest further analysis should be conducted on the local journals in the country.

Although the study used some qualitative data, the numbers of the respondents interviewed were few. Therefore, given this limitation, a more qualitative approach to the study could allow the study to further expound on research funding, research collaboration and research output. The importance of qualitative research such as case study research allows the researchers to understand how researchers continue to publish even when they receive minimal funding.

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Appendices

Appendix A: Chapter 4: Methodology: African Young Scientists Research Questionnaire

Survey on the research performance and career development of African scientists

Dear

Thank you for agreeing to complete the questionnaire for our study on the research performance and career development of scientists in Africa.

We are quite aware of the demands made on people – and especially academics and scientists – to complete surveys of this nature. Given the importance of the study and the fact that it should not take you more than 20 minutes to complete the survey, we sincerely hope that you will take the time to do this.

Participation in this survey is voluntary and there are no known or anticipated risks. This study has received formal ethical clearance from both Stellenbosch University and Polytechnique Montréal. You may decline to answer any of the questions. All data collected will be treated as confidential and you and your organisation's anonymity will be protected in any reports or publications produced from the survey.

If you have any questions or concerns about the research contact the project manager, Dr Charl Swart (charlswart@sun.ac.za). If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; (+27) 0-21 808 4622] at Stellenbosch University's Division for Research Development.

We would like to thank you for your willingness to participate. Cordially yours
Prof Johann Mouton Prof. Catherine Beaudry
Director CREST Polytechnique Montréal,
Stellenbosch University Canada

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POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING

Educational background

EDU.1 What is your highest qualification? (Tick appropriate box)
[ ] Doctoral or equivalent [ ] Master or equivalent
[ ] Bachelor
[ ] Other (Specify)

EDU.2 When did you obtain your highest academic qualification?
Year __

EDU.3 In which field did you obtain your highest qualification? (e.g. Engineering, Psychology, Virology, Agriculture etc.)

____

EDU.4 Was your highest qualification conferred by a university in one country?
[ ] Yes
[ ] No

EDU.5 IF Yes, in which country did you obtain your highest qualification?

Country: ……………………………………………………………

EDU.6 If NO, in what countries did you obtain your highest qualification?

Country: …………………………………………… Country:
……………………………………………
EDU.7 Are you currently enrolled in further postgraduate studies? (Tick appropriate box_
[ ] Yes
[ ] No

EDU.8 If YES to previous question: At which institution and in which country?

………………………………………………………. – University

………………………………………………………. – Country
EDU.9 If YES to EDU7: Are your receiving a bursary or scholarship for your current studies?
[ ] Yes
[ ] No

Employment

EMP.1 Please specify the sector of employment of your current main job (Tick appropriate box)
[ ] Higher/tertiary education [Explanation: university (public or private), college of technology, polytechnic and other institution providing tertiary education, or other institution directly under control of higher education institution]
[ ] Public research institution [ ] Private research institution [ ] Business enterprise
[ ] Non-governmental/non-profit organisation
[ ] Other Please specify: _____

EMP.2 What is your current employment status? If you hold more than one job, please answer for your main job. (Tick appropriate box)
[ ] Professor, Associate Professor or Reader at a Tertiary Institution [ ] Senior lecturer at a Tertiary Institution
[ ] Lecturer or equivalent at a Tertiary Institution [ ] Researcher/scientist
[ ] Postdoctoral fellow [ ] Self-employed
[ ] Unemployed or inactive
[ ] Other Please specify: _____

EMP.3 Is this position (as selected in previous question) permanent or contract-based?
[ ] Permanent [Permanent employees are employed on an ongoing basis until the employer or the employee ends the employment relationship]
[ ] Contract-based [Contract employees are employed for a specific period of time or task, for example 6 to 12 months period, and employment ends on the date specified in the contract]

Working Conditions

WOR.1 On average, how many hours do you spend on your main job per week?

………….. (maximum accepted: 100 hours)

WOR.2 In a typical year, what percentage of your working time do you spend on each of the following tasks?
[ ] % Undergraduate and Postgraduate teaching [ ] % Training/supervising postgraduate students [ ] % Research
[ ] % Administration and management
[ ] % Service (counselling of patients, voluntary services within or outside your organisation, article review, editorial duties)
[ ] % Consultancy
[ ] % Raising funds/grants for research
[ ] % Other, please specify ___

Research Output

RO.1 Please indicate how many of the following research output types you have produced over the last three years (write number in box):
[ ] Articles published/accepted (including co-authored) in refereed or peer reviewed academic journals
[ ] Books (i.e. monographs and edited volumes) [ ] Book chapters (including co-authored)
[ ] Conference papers published in proceedings
[ ] Presentations at conferences to predominantly academic audiences [ ] Written input to official public policy documents
[ ] Research reports (contract/consultation research)
[ ] Articles in popular journals/magazines, essays, newspaper articles or other public outreach media
[ ] Patents (applied for and/or granted)
[ ] Computer programmes (including co-writing)
[ ] Creative/artistic works of art performed or exhibited (e.g. music, sculpture, paintings, theatre, film)

Others, please specify: _____

RO.2 When did you publish your first research article in a refereed or peer-reviewed journal?

Year: _

RO.3 As far as your research is concerned, which of the following statements best describe the overall value or outcome of your research? Also rate the extent to which you believe that these have been successfully attained where applicable. (Please circle appropriate response)

	Highly successful	Successful to some extent	Not successful at all	N/A
Advancement of knowledge	3	2	1	0

Solving of theoretical problems	3	2	1	0
Solving of immediate technical/applied problems	3	2	1	0
Solving of environmental or social problems	3	2	1	0
Development of skills and competencies	3	2	1	0
Change behaviour/attitudes/values	3	2	1	0
Influence policy/decision-makers	3	2	1	0
Influence practice	3	2	1	0
Stimulation of discussion/debate	3	2	1	0

RO.4 Please indicate which of the following stakeholders you consider when conceptualising your research (Please tick all appropriate boxes):
[ ] Colleagues/scholars/peers in own discipline [ ] Colleagues/scholars/peers in other discipline [ ] The contracting agency
[ ] Industry/business/firm(s)
[ ] Ministry/government agency
[ ] Specific interest groups (e.g. farmers, researchers, nurses, doctors, consumers) [ ] General public/society/community

Funding
FUN.1 Have you received any research funding over the past three years? (Excluding bursaries or scholarships for studying purposes) (Please tick all appropriate boxes):
[ ] No
[ ] Yes - but I am not the primary recipient/grant holder of the funding [ ] Yes- I am the primary recipient/grant holder of the funding
[ ] Yes – In some cases I am the primary recipient and in some cases I am not the primary recipient of the funding

FUN.2 [Only if Yes to FUN1] Approximately what percentage of this funding was for infrastructure and equipment? (Don't know, N/A, 0%,10% intervals)
[ ] %

FUN.3 [Only if Yes to FUN1] What proportion of this funding was obtained from national and international sources? (10% intervals)
[ ] % National
[ ] % International

FUN.4 [Only if Yes to FUN1] Which amount best correspond to the total amount of research funding you have received during the past three years? (Circle appropriate response)

Less than US$10 000	1
US$10 000-25 000	2
US$25 000-50 000	3
US$50 000-75 000	4
US$75 000-100 000	5
US$100 000-250 000	6
US$ 250 000 – 500 000	7
US$ 500 – 1 000 000	8
More than US$ 1 000 000	9

FUN.5 [Only if Yes to FUN1] Please specify the three organisations/agencies from which you have received the most funding over the past three years

____

____

____

Challenges

CHA.1 Indicate, where applicable, which of the factors listed below have impacted negatively on your career as an academic or scientist (Circle appropriate response)

	Not at all	To some extent	To a large extent
Lack of mentoring and support	3	2	1
Job insecurity	3	2	1
Balancing work and family demands	3	2	1
Lack of mobility opportunities	3	2	1
Lack of training opportunities to develop professional skills	3	2	1
Lack of access to a library and/or information sources	3	2	1
Lack of research funding	3	2	1
Lack of funding for research equipment	3	2	1
Limitation of academic freedom	3	2	1
Political instability or war	3	2	1

Other, please specify	3	2	1

International Mobility

MOB.1 In which country do you currently work/reside?

____

MOB.2 During the past three years, have you studied or worked in a country other than what you would consider your home country (i.e. abroad)?

[ ] Yes

[ ] No

MOB.3 [Only if Yes to MOB 2] Compared to the study/working conditions in your home country, how would you rate the study/working conditions abroad? (Circle appropriate responses)

Researchers from:	Much worse abroad	Somewhat worse abroad	About the same	Somewhat better abroad	Much better abroad
Employment/job security	1	2	3	4	5
Work-family balance	1	2	3	4	5
Training opportunities	1	2	3	4	5
Opportunities for research collaboration	1	2	3	4	5
Research resources (personnel, scientific literature, material, etc.)	1	2	3	4	5
Research funding opportunities	1	2	3	4	5
Others, please specify [< open form>]	1	2	3	4	5

MOB.4 [Only if Yes to MOB 2] How would you rate the importance of having studied/worked abroad for your career development?

[ ] Not important

[ ] Somewhat important [ ] Important

[ ] Very important [ ] Essential

MOB.5 Have you ever considered leaving the country where you currently work?

[ ] No, never

[ ] Yes, sometimes [ ] Yes, often

MOB.6 [Only if Yes to MOB 5] List the main considerations for leaving the country:

Collaboration
COL.1 How often do you collaborate, either in joint research or through joint publications, with the following categories of researchers (Circle appropriate responses):

	Never or very rarely	Rarely	Sometimes	Often	Very often/ always
Researchers at your own institution	1	2	3	4	5
Researchers at other institutions in your own country	1	2	3	4	5
Researchers at institutions in other African countries	1	2	3	4	5
Researchers at institutions outside of Africa (e.g. Europe, North America, Asia, etc.)	1	2	3	4	5

Mentoring
MO.1 During your career so far, have you ever received mentoring, support or training in the following (Circle appropriate responses)

	Never or very rarely	Yes but it was not valuable	Yes and it was valuable
Career decisions	1	2	3
Introduction to research networks	1	2	3
Attaining a position/job	1	2	3
Research methodology	1	2	3
Fundraising	1	2	3
Scientific writing	1	2	3
Presenting research results	1	2	3

Demographic background
DEM.1 Are you?
[ ] Male
[ ] Female

DEM.2 What is your year of birth?

Year: _

DEM.3 What is your nationality?

____

DEM.4 How many children or other dependents do you have?
Please enter a number in the relevant boxes.
[ ] Number of children/dependents aged 0 to 5 [ ] Number of children/dependents aged 6 to 18
[ ] Number of adult dependents aged 19 or older (including elderly) [ ] I do not have any dependents.

DEM.5 How is the care-work and general housework for all dependents distributed in your family/relationship/household?
[ ]% me [ ]% partner [ ]% others (e.g. extended family, paid service)

Follow-up
If you wish to receive a report on the results of the study, please provide us with your name and email address:

Name:_ E-mail: ______

Completion of the questionnaire is confidential. However, we would like to follow up on some of the interesting responses by means of Skype interviews. We are particularly interested in canvasing the opinions of young and emerging scientists/scholars/researchers as well as that of established scientists/scholars/researchers who can shed light on the factors influencing the career development of African scientists. If you would be willing to talk in more depth about your own career experiences, please provide your contact details in the spaces below. Please note that provision of these details is voluntary and not compulsory, if you prefer not to provide any details, please leave the spaces blank

Name_ E-mail: ___________

THANK YOU AGAIN FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE!

Appendix B: Technical Appendix
R&D Explanations

R&D activities are undertaken in four major sectors, namely: state agencies, higher education institutions, business enterprises or private-non-profit organizations. In general, the source of funds has a greater influence on the sector in which research is performed. For instance, research in higher education institutions is largely funded by governments, whereas research in the business enterprises is mainly self-financed. GERD, percentage of R&D expenditure performed in the government, higher education, business enterprise and private non-profit sectors is the amount spent on R&D (GERD) by the institutions corresponding to these sectors (whatever the source of funds), expressed as a percentage of the total R&D expenditure on the national territory during a given year (UNESCO, 2015).
In the context of R&D statistics, the business enterprise sector includes all firms, organizations and institutions charged with the primary role of producing goods and services (except higher education) for public consumption; and the private non-profit institutions mainly serving them. This also includes public enterprises. The higher education sector in the context of R&D statistics includes all universities, colleges of technology and other institutions of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control of, administered by, or associated with higher education institutions (UNESCO, 2015).

R&D activities generally receive funding from governments, businesses, higher education institutions and private non-profit organizations. Additionally, more funding is disbursed from public and private foreign institutions to support research (UNESCO, 2015).

GERD by sector of funding

The private non-profit sector in the context of R&D statistics includes private individuals, households and non-market, private non-profit institutions serving the public.
The government sector in the context of R&D statistics includes all departments, offices and other bodies, which furnish, but normally do not sell to the community, those common services, other than higher education, as well as those that administer the state and the economic and social policy of the community. Also, include non-profit institutions controlled and mainly financed by government, but not administered by the higher education sector. This excludes public enterprises (UNESCO, 2015).

GERD by type of research activity

The types of research activities highlight to what extent a country focuses on innovation, creation and improvement of the existing technologies. Generally, universities and public research centres actively undertake basic research, whereas business enterprises heavily invest in experimental research, aimed at developing new or enhanced products for the market.

Appendix C: Mobility Profile

studied or worked abroad - mobile

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	104	46,4	46,4	46,4
	No	120	53,6	53,6	100,0
	Total	224	100,0	100,0	

studied or worked by field-

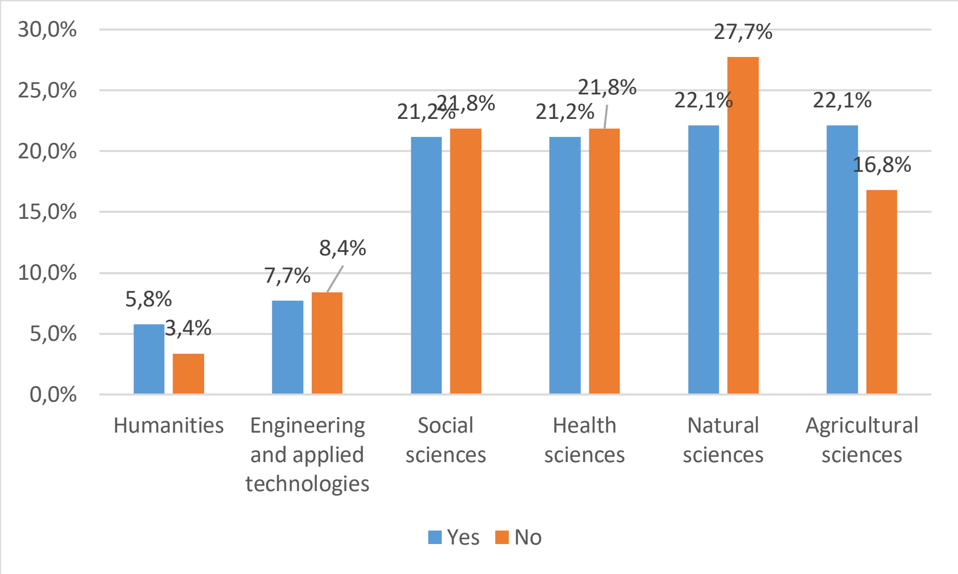
			field						
			Natural sciences	Agricultural sciences	Engineering and applied technologies	Health sciences	Humanities	Social sciences	Total
MOB2_ studied or worked. abroad	Yes	Count	23	23	8	22	6	22	104
		% within	22.1%	22.1%	7.7%	21.2%	5.8%	21.2%	100.0%
	No	Count	33	20	10	26	4	26	119
		% within	27.7%	16.8%	8.4%	21.8%	3.4%	21.8%	100.0%
Total		Count	56	43	18	48	10	48	223
		% within	25.1%	19.3%	8.1%	21.5%	4.5%	21.5%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.285[a]	5	.808
Likelihood Ratio	2.288	5	.808
Linear-by-Linear Association	.101	1	.751
N of Valid Cases	223		

a. 1 cells (8.3%) have expected count less than 5. The minimum expected count is 4.66.

Proportions of international mobility by scientific mobility



Rating MOB4 How would you rate the importance of having studied/worked abroad for your career development?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Somewhat important	3	1,3	2,9	2,9
	Important	11	4,9	10,8	13,7
	Very important	58	25,9	56,9	70,6
	Essential	30	13,4	29,4	100,0
	Total	102	45,5	100,0	
Missing	System	122	54,5		
Total		224	100,0		

International mobility according to receipt of funding

MOB2_1 studied or worked abroad

			FUN1 received any research funding in the past three years				
			No	Yes – but I am not the primary recipient	Yes – I am the primary recipient	Yes – in some cases I am the primary recipient	Total
MOB2_ studied or worked abroad	Yes	Count	26	23	26	28	103
		% within MOB2	25.2%	22.3%	25.2%	27.2%	100.0 %
	No	Count	37	32	25	26	120
		% within MOB2	30.8%	26.7%	20.8%	21.7%	100.0 %
Total		Count	63	55	51	54	223
		% within MOB2_	28.3%	24.7%	22.9%	24.2%	100.0 %

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.204[a]	3	.531
Likelihood Ratio	2.206	3	.531
Linear-by-Linear Association	1.886	1	.170
N of Valid Cases	223		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 23.56.

Proportions of Lack of mobility

CHA1 Has the following impacted negatively on your career as an academic or scientist - lack of mobility opportunities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	55	24.6	26.8	26.8
	To some extent	82	36.6	40.0	66.8
	To a large extent	68	30.4	33.2	100.0
	Total	205	91.5	100.0	
Missing	System	19	8.5		
Total		224	100.0		

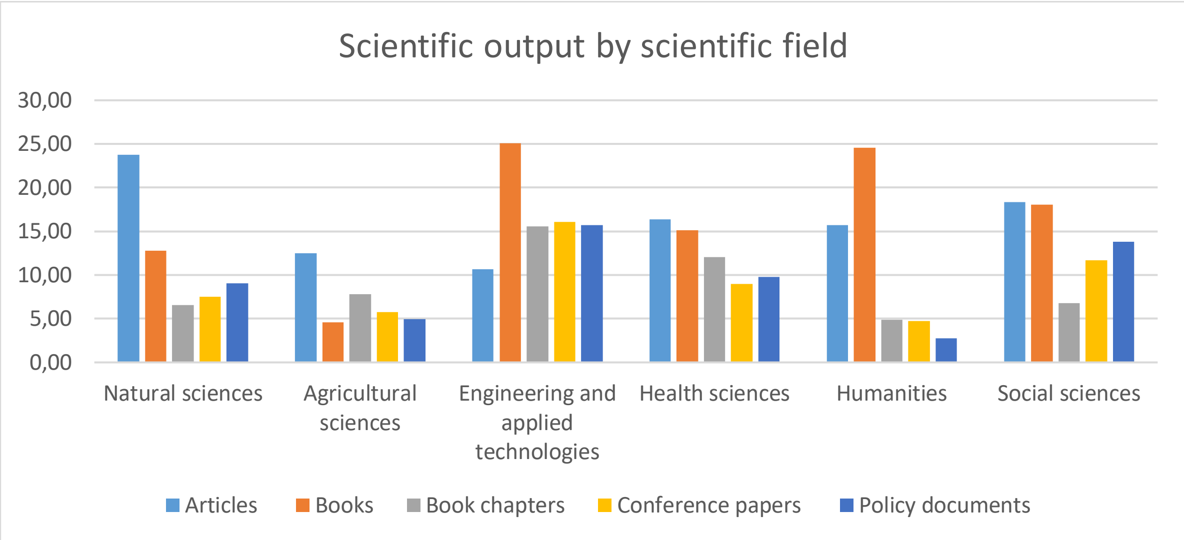
CHA1Re_impacted negatively on your career as academic/scientist - Lack of mobility opportunities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	55	24.6	26.8	26.8
	At least to some extent	150	67.0	73.2	100.0
	Total	205	91.5	100.0	
Missing	System	19	8.5		
Total		224	100.0		

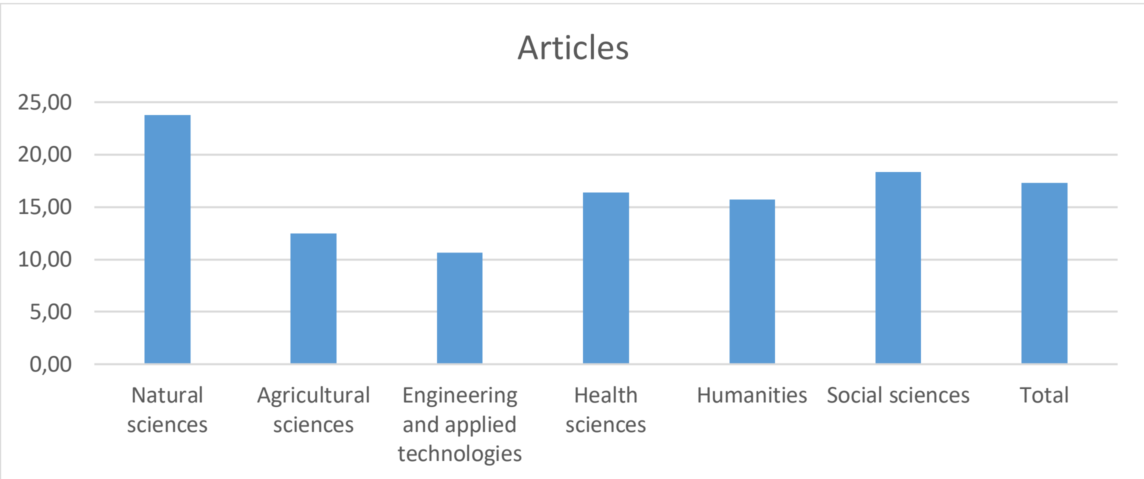
MOB5 Have you ever considered leaving the country where you currently work/reside?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes-often	39	17.4	17.6	17.6
	Yes-sometimes	128	57.1	57.7	75.2
	No-Never	55	24.6	24.8	100.0
	Total	222	99.1	100.0	
Missing	System	2	.9		
Total		224	100.0		

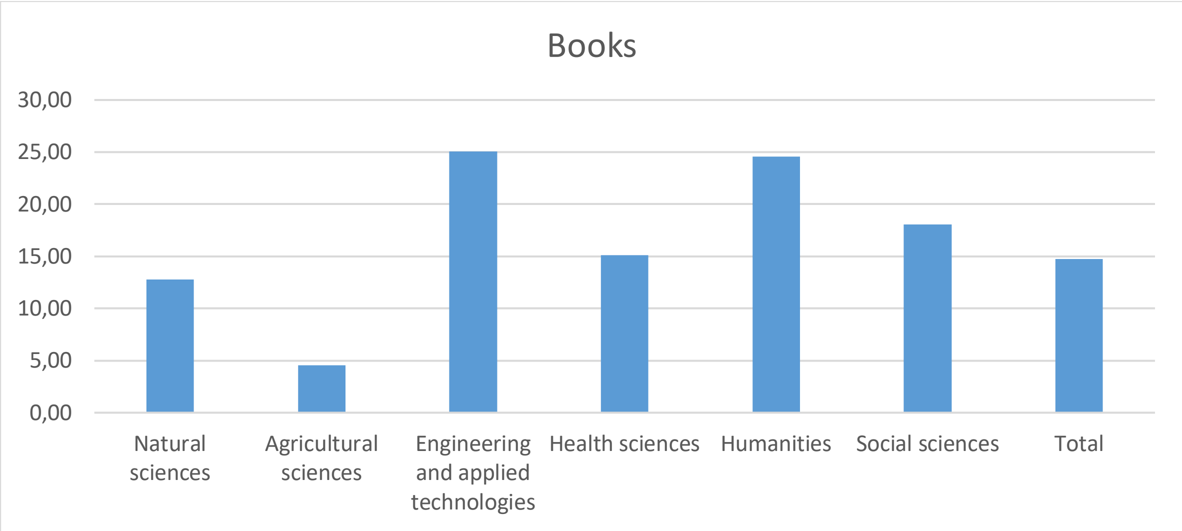
Appendix D: Scientific output mean distribution



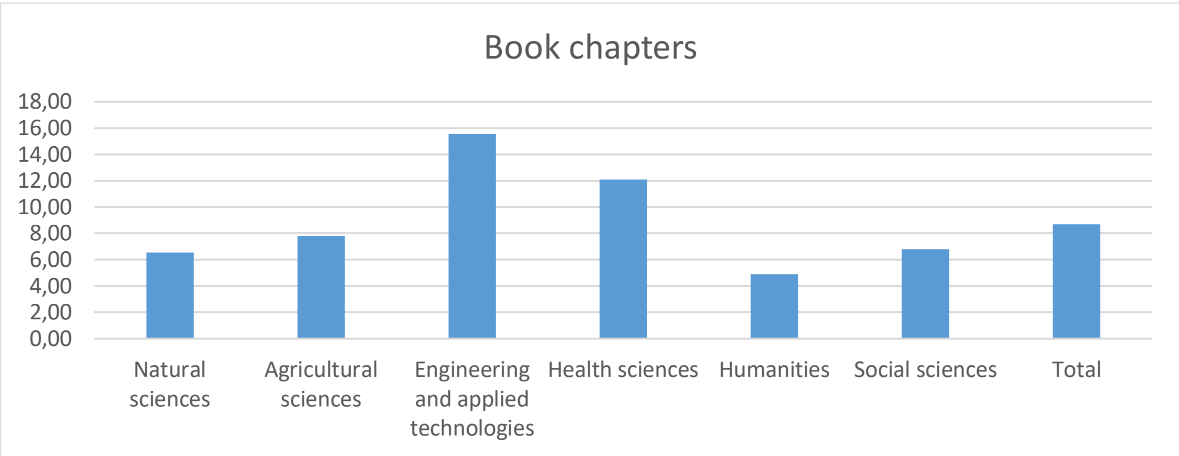
Mean reported article output by scientific field



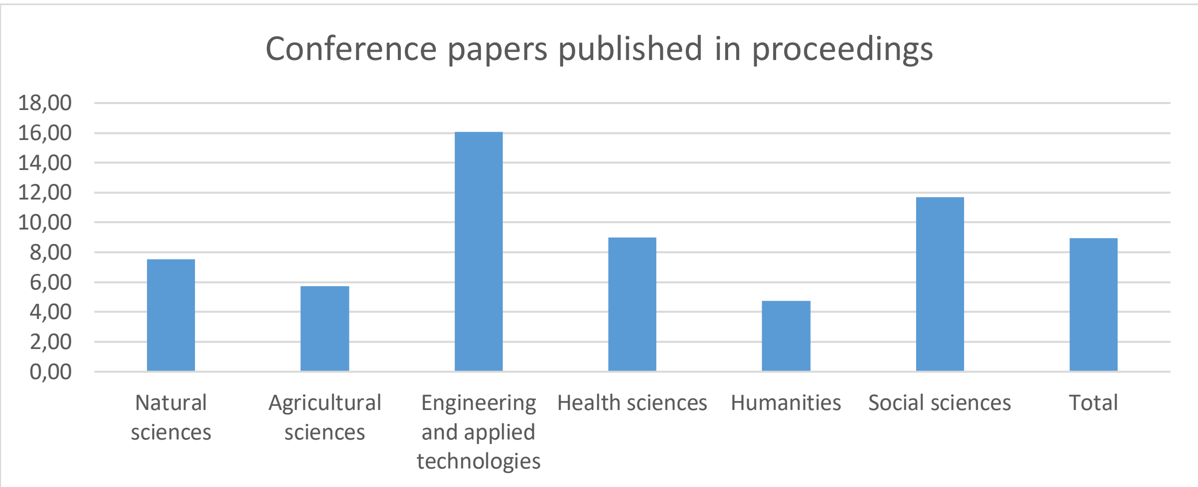
Mean reported book output by scientific field

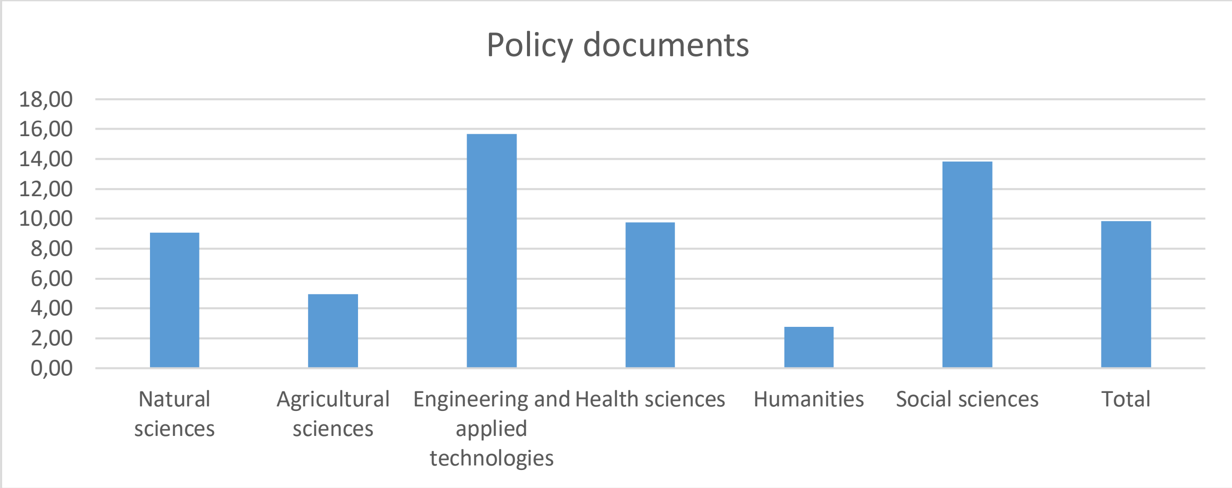


Mean reported book chapters output by scientific field



Mean reported conference papers output by scientific field




Policy documents
18,00
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
Natural sciences
Agricultural sciences
Engineering and applied technologies
Health sciences
Humanities
Social sciences
Total