Research funding and modes of knowledge production: a comparison between NRF-funded and industry-funded researchers in South Africa

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Dissertation presented for the degree of Doctor of Philosophy in the Faculty of Arts and Social Sciences at Stellenbosch University

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DECLARATION

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ABSTRACT

The changing South African policy context since 1994 (new science and innovation policies), and institutional changes at the National Research Foundation (NRF) have had an effect on different funding instruments and related modes of knowledge production. In this study we compare the modes of knowledge production utilized by researchers funded by the NRF and those funded by industry. We also compare the level of scientific productivity of these groups.

This study makes two major contributions: first, we provided a reconstruction of the history of research funding in South Africa from 1918 (through the Research Grant Board – RGB), to date (through the NRF established in 1999 as a result of the merger of the Foundation for Research Development (FRD) and the Centre for Science Development (CSD). The second major contribution of this study concerns the relationship between funding sources and modes of knowledge production and dissemination.

We found evidence that there is an increase in third stream funding for university research in South Africa. The study shows that respondents who received funding from both the Focus Areas and THRIP, concurrently, produced more average annual research outputs than those who received funding from either the Focus Areas or THRIP only. When we compared respondents who only received the Focus Areas or THRIP grant, we found that those who received the Focus Areas grant published more outputs annually than THRIP-funded researchers, despite the fact that those who received the THRIP grant had larger grant amounts, on average, than their Focus Areas-funded counterparts. We also found that industry/THRIP funding is utilised on problem-solving type of research, i.e. applied research, while public/NRF funding is utilised on basic/fundamental/curiosity-driven research.

Overall, the findings show that there is no clear cut conclusion about the influence of funding on the mode of knowledge production. We could not prove that the two factors, that is, funding and mode of knowledge production, are related in a linear fashion. This is a much more complicated situation that requires more investigation.

OPSOMMING

Die veranderende Suid-Afrikaanse beleidskonteks sedert 1994 (nuwe wetenskap- en innovasiebeleid), sowel as institusionele veranderinge aan die Nasionale Navorsingstigting (NNS), het 'n uitwerking gehad op verskillende befondsingsinstrumente en verwante vorme van kennisproduksie. In die lig hiervan vergelyk die huidige studie die vorme van kennisproduksie van navorsers wat deur die NNS befonds word met dié van navorsers wat deur die bedryf befonds word. Die twee groepe se onderskeie vlakke van wetenskaplike produktiwiteit word ook vergelyk.

Die studie lewer twee belangrike bydraes. In die eerste plek bied dit 'n rekonstruksie van die geskiedenis van die finansiering van navorsing in Suid-Afrika, vanaf 1918 (deur die Navorsingstoekenningsraad), tot en met vandag (deur die NNS wat in 1999 tot stand gekom het met die samesmelting van die destydse Stigting vir Navorsingsontwikkeling – SNO – en die Sentrum vir Wetenskapsontwikkeling – SWO). Die tweede belangrike bydrae van hierdie studie is die ondersoek na die verband tussen befondsingsbronne en verskillende vorme van kennisproduksie en -disseminasie.

Die resultate van die ondersoek dui op 'n toename in derdegeldstroom-befondsing wat universiteitsnavorsing in Suid-Afrika betref. Die studie toon verder dat respondente wat befondsing van beide die fokusarea- en THRIP-programme ontvang, se gemiddelde jaarlikse navorsingsuitsette beduidend hoër is as dié van respondente wat slegs binne een van die twee programme befonds word.'n Vergelyking van die navorsingsuitsette van respondente wat slegs fokusarea-befondsing ontvang en respondente wat slegs THRIP-befondsing ontvang, toon dat diegene met fokusarea-befondsing se jaarlikse publikasieuitsette gemiddeld hoër is, ondanks die feit dat die THRIP-toekennings groter bedrae behels. Daar is ook gevind dat befondsing deur die bedryf/THRIP gebruik word vir navorsing wat gerig is op probleemoplossing, d.w.s. toegepaste navorsing, terwyl publieke of NNS-befondsing aangewend word vir basiese/ fundamentele/nuuskierigheid-gedrewe navorsing.

Die algehele beskouing is dat geen duidelike gevolgtrekking gemaak kan word met betrekking tot die invloed van befondsing op die vorme van kennisproduksie nie. Daar kan nie onomwonde gestel word dat die twee kernfaktore van ondersoek, naamlik befondsing en vorme van kennisproduksie, reglynig met mekaar verband hou nie. Die situasie is meer kompleks en vereis verdere navorsing.

"*It always seems impossible until it's done*".

Nelson Rolihlahla Mandela (18 July 1918 – 5 December 2013)

ACKNOWLEDGEMENTS

I would like to thank:

- Professor Johann Mouton, my supervisor, for patiently guiding me through this process and for believing in me,
- Dr Nelius Boshoff for assistance with statistical analysis,
- The National Research Foundation for providing the historical data,
- Ms Marna van Rooyen, NRF Librarian, and the librarians at Stellenbosch University,
- Colleagues at CREST (Centre for Research on Evaluation, Science and Technology), and Department of Higher Education and Training (DHET),
- All the individuals who provided their CVs and those who availed themselves for an interview,
- My husband Nyambeni,
- Family and friends,
- Lastly, my daughters, Anza Tshilidzi and Rofhiwa Vhuthu (to whom this thesis is dedicated) for being my inspiration.

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CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Government funding for basic research is a well-established practice (Salter & Martin, 2001)[1]. However, government spending in Research and Development (R&D), expressed as a percentage of the Gross Domestic Product (GDP) varies across countries. The OECD[2] average spending in 2010 was 2.38% of the GDP[3]. Several countries, including Denmark, Finland, Israel, Japan, Korea, and Sweden, spent over 3% of their GDP on R&D during the same year (2010), much higher than the OECD average (OECD, 2013). While South Africa spends a lot less than the OECD average, the country continues to invest significant amount of funds on research performed at public institutions, i.e. universities and research institutes. The Gross Domestic Expenditure on R&D (GERD) for South Africa was 0.87% during the 2009/10 survey (the latest year available) (CeSTII, 2013), a decrease from 0.92% in 2008/09. This was an expending of R20.9 billion, a decrease of R86 million from the R21 billion spent in 2008/9. The GERD ratio in 2007/08 was 0.93% (CeSTII, 2011) – the highest expenditure on R&D in the history of South Africa. The proportion of HERD[4] as a percentage of GDP increased from 0.18% in 2008/09 to 0.21% in 2009/10. The 2009/10 figure shows a third consecutive decline in the GERD ratio – which continues to leave South Africa well adrift of its last official target, which was to spend 1% of GDP by 2008/09.

Government support for university research in South Africa is channelled mainly through two streams, namely, the National Research Foundation (NRF) – the country's largest funding agency – and the Department of Higher Education and Training (DHET). In addition to the NRF, the South African government invests significant funds in Research and Development through other agencies, including the Medical Research Council (MRC – focusing mainly on the health sciences); and the Agricultural Research Council (ARC – focusing on the agricultural sciences). Government departments such as the Department of Science and Technology (DST) and the Department of Trade and Industry (the dti) also provide research grants. For its part, the NRF provides funding across all broad scientific fields and its sole mandate is to provide research funding to universities and research institutes, whereas other agencies also have a mandate of conducting research.

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[1] For the purpose of this thesis, the term "university" will be used to refer to all forms of Higher Education Institutions (HEIs).
[2] OECD = Organisation for Economic Co-operation and Development.
[3] www.oecd-ilibrary.org (date accessed: 12 July 2013).
[4] HERD = Higher Education R&D.

Alongside the NRF and other sources of government funding, there has also been growth in other sources of funding, i.e. third stream funding. Different sources of funding often place different demands on the researcher, such as different reporting requirements. Previous studies argue that there is a link between sources of funding and modes of knowledge production, and ultimately results in different dissemination modes. This study compares the modes of knowledge production utilised by researchers funded by the NRF and those funded by industry. We also compare the level of scientific productivity of these groups. The study is divided into two broad research foci: sources of funding for university research; and the mode of knowledge production.

1.2. RESEARCH FOCUS 1: SOURCES OF FUNDING FOR UNIVERSITY RESEARCH

1.2.1. Government and industry funding for research

Traditionally, universities are considered as the main producers of public knowledge, as they are in the business of producing and transferring knowledge (Mansfield & Lee, 1996). Around the globe, universities to a large extent rely on government funding for research (Salter & Martin, 2001). One of the benefits of government funding is that results from government-funded research are freely available to the public and thus make scientific knowledge a public good (see Salter & Martin, 2001). Salter and Martin (2001) further note that "increasing the funds available for basic research will increase the pool of economically useful information". This phenomenon was advocated for by early scholars such as Vannevar Bush (1945) in his well-known report *Science: The Endless Frontier*.

According to Ben Martin and colleagues (1996) at the Science and Technology Policy Research Unit (SPRU), government funding for research contributes six types of benefits to the economic growth of a country: increasing the stock of information; new instrumentation and methodologies; skilled graduates; professional networks; technological problem solving; and the creation of new firms. In addition, Narin and colleagues (1997) also demonstrated that most industries in the United States depend largely on government-funded research for new ideas and technological knowledge. They further showed that the research that contributes to industry is "quite basic, quite recent and published in highly influential journals". Funding for basic research is an integral part of knowledge production, and it is therefore crucial for government to continue making funds available to ensure that basic research continues to take place at universities.

1.2.2. Rise in industry funding for university research

Over the past three to four decades, there has been an increase in industry funding of research conducted at universities worldwide, for example in countries such as Canada (Crespo & Dridi, 2007), Korea (Om *et al*., 2007), Germany (Meyer-Krahmer & Schmoch, 1998), USA (Poyago-Theotoky *et al*., 2002) and Norway (Gulbrandsen & Smeby, 2005). This has led Etzokwitz and colleagues to propose what they called the Triple Helix Model of universities-industry-government partnerships (Etzkowitz, 2002). In Germany, for example, Meyer-Krahmer and Schmoch (1998) demonstrated that the number of collaborations between industrial firms and university-based academic researchers has increased, which occurred in response to the high demand for new technologies. The relationship between university and industry is mutual, i.e. universities benefit from industry funding while industry benefits from the knowledge produced by universities (see Mansfield & Lee, 1996). For example, Mansfield (1991) showed that approximately 11% of products produced in some United States firms would not have been possible without academic research.

However, although industrial partners provide financial resources to researchers at institutions, Kruss (2005) notes that they could potentially have a negative impact on the productivity of the institution, particularly in terms of publishing in peer-reviewed journals and in the production of postgraduate theses, due to the restrictions on intellectual property. Furthermore, changes in knowledge production practices could potentially influence policy makers who are more interested in university research that has direct benefits to industrial innovations (Mansfield & Lee, 1996). This was demonstrated by Crespo and Dridi (2007) in an interview-based study done in Québec (Canada). They found that results produced from innovation-orientated research only benefited the researchers, students and the institution, and that publication was restricted by intellectual property constraints. In the United States, Goldfarb (2008) conducted a survey amongst researchers funded by the NASA aerospace engineering program, and found a decrease in the number of publications from this group of researchers. In Norway, however, Gulbrandsen and Smeby (2005) found different results to that of Crespo and Dridi (2007). They found a significant relationship between industry funding and research performance, with researchers receiving industry funding producing more scientific publications than government-funded researchers. Similar results (to those of Gulbrandsen and Smeby) were also found by Harman (1999) in Australia. These contrasting opinions about industry funding show that more research is needed on this topic.

1.3. RESEARCH FOCUS 2: THE MODE OF KNOWLEDGE PRODUCTION

A second focus of this study is the way in which different sources of funding influences modes of knowledge production. In 1994, Gibbons and his colleagues published a book in which they referred to the "the new mode of knowledge production: Mode 2". In the book, they outlined the major differences between this "new mode" – Mode 2, and the "old mode" – Mode 1. Among other things, Mode 1 is governed by the interests of the academic community, it is discipline specific, homogeneous and hierarchical, whereas Mode 2 is socially accountable (being produced within the context of application and responsive to the needs of the community), heterogeneous and transdisciplinary. The authors argue that Mode 2 is the "new" mode of knowledge production, resulting in the shift from the traditional Mode 1.

These shifts in knowledge production are apparently occurring in many countries around the world, including South Africa (Mouton, 2000). According to Mouton (2000), this shift brings about several implications and consequences for the South African science system (and perhaps for science in other countries). Among other things, (1) Mode 2 has resulted in changes in the nature of research institutions as we know them, such as the appointment of different kinds of researchers/knowledge workers. This also affects the way in which teaching at undergraduate and postgraduate levels is conducted. (2) Governments have to manage research institutions (and science in general) differently. (3) The boundary between academic and non-academic science has become unclear. Although the shift from Mode 1 to Mode 2 may bring some benefits to research, e.g. access to more sources of funding in addition to government funding, it is inevitable that there will also be negative consequences, such as those mentioned above. Mouton (2000) therefore supports the view that Mode 2 is not replacing Mode 1, but is supplementing it.

Despite the wide acceptance of the Gibbons thesis, some authors, such as Weingart (1997) believe that the thesis defended by Gibbons and his colleagues is not a new one. Similarly, Rip (1999) pointed out that some characteristics of Mode 2, e.g. the production of knowledge in the context of application, were also evident from the time of Mode 1, especially in fields such as chemistry, pharmacy and electronics. Although there are varying views regarding the emergence of Mode 2, it is evident that the mode of knowledge production is changing, and brings with it different demands on researchers and the science system as a whole.

1.4. RESEARCH QUESTIONS

The main questions of this study can be formulated as follows:

1. Do researchers/academics who receive funding from industry, i.e. THRIP, receive more or less funding than those who receive NRF funding, i.e. Focus Areas funding? What have been the trends in the allocation of funding from both THRIP and the Focus Areas programme over the years?
2. Are there differences in scientific productivity between academics who are funded by the NRF and industry respectively or jointly? And, does large funding result in high scientific productivity?
3. Are there significant differences in the modes of knowledge production undertaken by researchers who receive their funding from different sources (such as those who receive only NRF or only industry funding, e.g. THRIP funding, compared to those who receive both NRF and industry funding, concurrently)?

1.5. METHODOLOGY AND APPROACH

We begin this thesis began an extensive literature review. First, we trace the history of research funding in South Africa by reviewing key historical documents obtained from various sources, including the NRF, the Department of Education (which in 2009 was split to form the Department of Basic Education, and Department of Higher Education and Training), as well as personal documents (including speeches) from individuals who have been key to the development of the country's funding system. Interviews were also conducted with people who held important positions in the funding system, to try and gain a deeper understanding of shifts in the system. These individuals include Dr Chris Garbers (former President of the Council for Scientific and Industrial Research - CSIR), Dr Khotso Mokhele (first President of the NRF), Dr Bok Marais (former Executive Director of the Centre for Research Development – CSD), and Dr Rocky Skeef (former THRIP manager) (see **Annexure 1** for a list of all interviewees). Documents were also obtained from the National Archives of South Africa (NASA) in Pretoria, which show records of research funding dating as far back as 1911 through the Royal Society of South Africa and the Research Grant Board (RGB). The remainder of the literature search was conducted through a desktop study. This included a review of the Gibbons/Mode 2 thesis, as well as studies of the link between funding and mode of knowledge production.

The empirical components of this study employs a predominantly quantitative methodology: first, by conducting a comprehensive bibliometric analysis of the available NRF data on funding in the South African science system over a fifteen year period (1994 – 2008); second, by analysing curriculum vitae of South African scientists on their funding sources, scientific productivity, and postgraduate student supervision; and third, by conducting telephonic interviews with a sample of scientists to determine the link between their sources of funding and their modes of knowledge production.

1.6. POTENTIAL SIGNIFICANCE OF THE STUDY

This study will provide a better understanding of the relationship between two main dimensions of the science system: how differences in funding regimes relate to different modes of knowledge production. The results will also have strategic value and specifically assist the NRF (and other funding bodies) in decisions about resource allocation.

1.7. THESIS OUTLINE

The thesis is structured as follows:

Chapter 2 (Historical overview of research funding in South Africa) discusses the history (and evolution) of research funding in South Africa through funding agencies, from the Research Grant Board (RGB) in 1918, through the Council for Scientific and Industrial Research (CSIR) and the Human Sciences Research Council (HSRC) to the NRF.

Chapter 3 (The “new” mode of knowledge production?) provides a detailed review of the book by Michael Gibbons and his colleagues (*The new production of knowledge*), as well as the broader literature on the emergence of the so-called “Mode 2 thesis”. Literature by both proponents and critics of the Gibbons thesis is presented.

Chapter 4 (Impact of industry funding on the production of knowledge) presents a literature review on university-industry relationships across the globe. The chapter presents reviews of studies that point to the negative and positive consequences of these relationships. Furthermore, it reviews empirical studies on the impact of university-industry relationships on scientific productivity, modes of knowledge production, and collaborations between academics and industrial partners.

Chapter 5 (Data sources and Methodology) details the methodology of the empirical components of this study, including the data collection processes and how the telephone interviews were conducted.

Chapter 6 (Trends in academic research funding in South Africa: 1994 – 2008) presents the results of the analysis of the NRF funding data for the Focus Areas Programme and the Technology and Human Resources for Industry Programme (THRIP). For this analysis, the Focus Areas funding is considered as government funding, while THRIP funding is taken as a proxy for industry funding although this funding is part government and part industry. The analysis compares funding trends through these programmes over the years, including comparisons by average grant amounts and funding by broad scientific field as well as across demographics.

Chapter 7 (Determining the impact of funding on scientific productivity and the mode of knowledge production) provides answers to two main questions in this study. First, are researchers who receive funding from industry, including THRIP, more or less productive than those who receive NRF funding (i.e. Focus Areas)? Second, are there significant differences in the modes of knowledge production utilised by researchers who receive funding from different sources, i.e. from industry as compared to the NRF? That is, do researchers with industry funding engage in different research activities compared to those with NRF/public funding? This chapter therefore makes a link between the source of funding and the mode of knowledge production.

Chapter 8 (General conclusions) concludes the study by synthesizing the main findings and conclusions of the study, and also discusses some possible areas for future research.

CHAPTER 2: HISTORICAL OVERVIEW OF RESEARCH FUNDING IN SOUTH AFRICA

2.1. INTRODUCTION

The South African government has a long tradition of publicly supporting research at public Higher Education Institutions (HEIs). Research support commenced in the early 20th century, although the exact nature of this support is poorly documented. The oldest form of research funding in the country is agency funding, which started as early as 1911 through the Royal Society of South Africa. A few years later, in 1918, a more coordinated funding body called the Research Grant Board (RGB) was established in the Union of South Africa. The RGB offered competitive funding to individual academics in the natural and physical sciences. The human sciences were only supported much later with the establishment of the Council for Educational and Social Research in 1929.

We elaborate on the two modes of funding – agency and subsidy funding – that are found in the South African research system. At the end of the Second World War, in 1945, agency funding for the natural sciences became the responsibility of the Council for Scientific and Industrial Research (CSIR), while such funding for the human sciences was transferred to the National Council for Social Research in 1946, and ultimately to the Human Sciences Research Council (HSRC) in 1969. The CSIR and HSRC had a dual mandate, i.e. funding research at universities as well as conducting research in-house. Later on, each of these councils separated the two functions, and developed a programme to take on the role of research funding. The CSIR established the Foundation for Research Development (FRD) in 1984, while the HSRC established the Centre for Science Development (CSD) in the early 1990s. The FRD and CSD ran parallel for several years, until they were merged in 1999 to form the National Research Foundation (NRF) through the NRF Act (Act No. 23 of 1998). Other large agencies in the country include the Agricultural Research Council (ARC) established by Act No. 86 of 1990, and the Medical Research Council established by Act No. 58 of 1991. The ARC has a mandate to support research in the agricultural sciences, while the MRC provides support for the research in the health sciences. Both the ARC and MRC also have mandates to conduct research in their respective fields, while the NRF has a sole mandate of providing funding for research across all fields of study.

Over the years, the NRF experienced a slow growth in its budget allocation from the government, as well as budget cuts in some cases, making it challenging to provide adequate grants to researchers. At the same time, there has been significant growth in the subsidy funding available from the DHET (which was introduced in 1987). During 2012, the

NRF awarded R1.2 billion to researchers and postgraduate students (NRF 2012 Annual Report), while the DHET allocated around R2.3 billion in subsidies for 2011 research outputs – almost double what was available through the NRF (see section 2.3.6 for a detailed discussion of the subsidy funding).

The remainder of this chapter describes the evolution of research funding in South Africa since 1916. The discussion is organised in terms of three phases (cf. Figure 2.1):

- The development of research funding: 1918 – 1945.
- Research funding post Second World War : 1946 – 1998.
- Research funding under the NRF: 1999 to 2009.

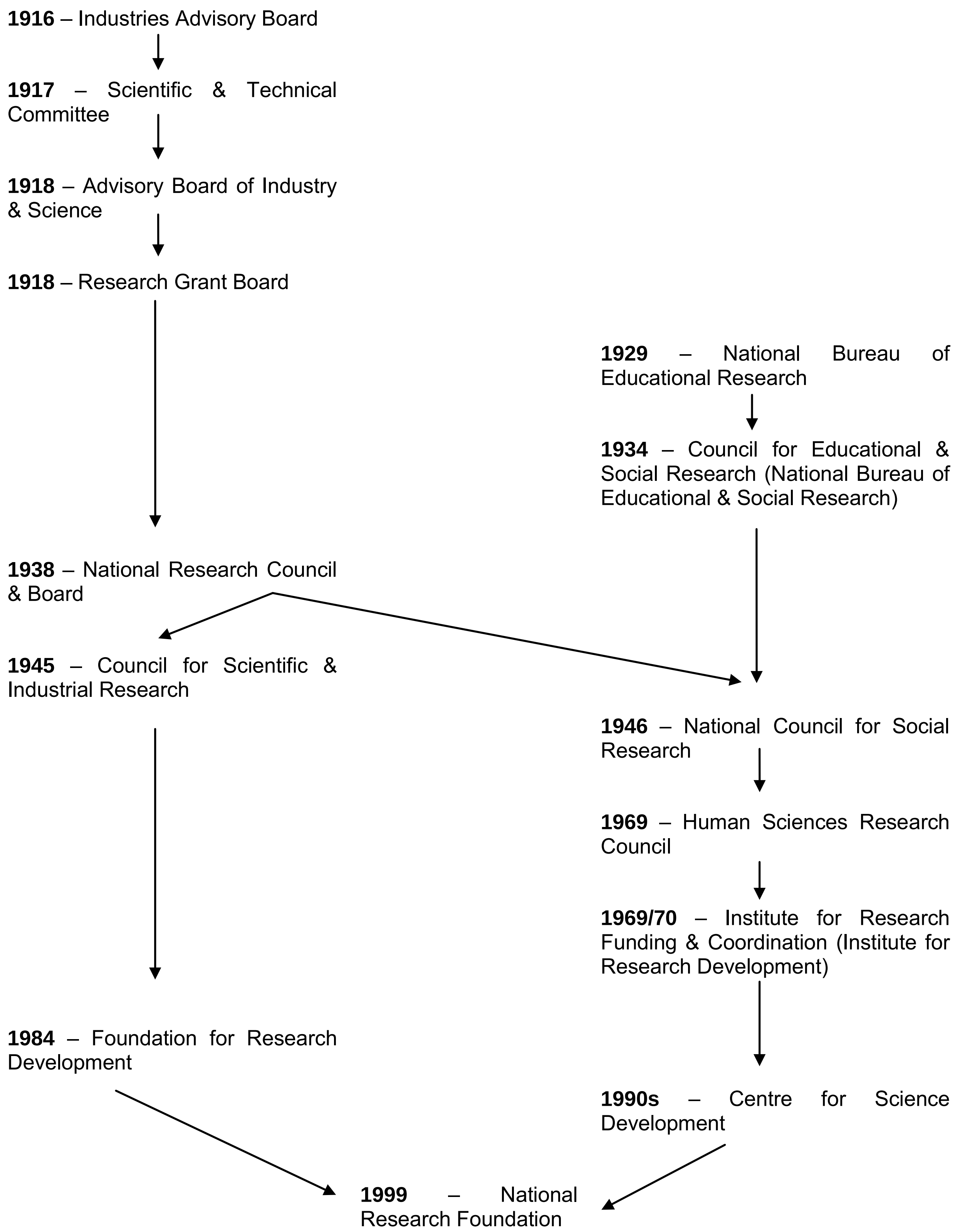


Figure 2.1. The evolution of research funding agencies in South Africa, 1916 – 1999.

2.2. THE DEVELOPMENT OF RESEARCH FUNDING: 1918 – 1945

Scientific activities have been taking place in South Africa from as early as the 18th century. This is evident from the establishment of scientific institutions, some of which have since become prominent, for example the Royal Observatory, established in 1820, as well as the South African Museum, which was established shortly afterwards, in 1825 (Dubow, 2006:36). Scientific activities were nevertheless somewhat unregulated despite the existence of institutions such as the Royal Society of South Africa. The Royal Society of South Africa started in 1877 (NASA, 1910: E18/1) as the South African Philosophical Society (Dubow, 2006: 119) and only received formal status through a Royal Charter in 1908 signed by King Edward VII[5]. Before 1908, an institution called the South African Association for the Advancement of Science, known as the S2A3, had been established (in 1903) to become the regulatory body for all scientific activities in the country (Dubow, 2006:168). As in most countries in the world, during this period research funding was not structured, but some funding for research was available through donations made by prominent individuals or, in some cases, by institutions such as the South African Literary and Scientific Institutions (Dubow, 2006:18).

Because of a perceived lack of co-ordinated research funding the then President of the Royal Society of South Africa, Mr H.H. Hough, wrote to the Prime Minister of the Union of South Africa on 1st July 1910, requesting that the Society be recognised as a research agency (NASA, 1910: E18/1). In his letter, Mr Hough stated that:

> *The Royal Society of South Africa desires to draw the attention of the Union Government to the importance of considering at the present time the best means of promoting methodological scientific research, this being an agency on which, as is well known, so much of the material and moral welfare of a country depends. In the past, unfortunately, there has been no continuity in any such efforts made in our country, with the result that no really adequate return has been obtained for the money thus spasmodically spent.*

Following this plea, the Ministry of Education awarded a grant of £500 (through a budget vote) to the Royal Society of South Africa towards the support of research for the year 1911 (NASA, 1911a: E18/1). In what can be considered as the first case of government funding for research in South Africa five grants totalling an amount of £250 were awarded to the following recipients in 1911: (NASA, 1911b: E18/1):

(a) W.A. Rudge (£40).

[5] http://www.royalsociety.org.za/ The Royal Society of Society – a brief history. Professor Jane Carruthers, Department of History, University of South Africa.

(b) A. Young (£45).
(c) D.T. Bleek (£75).
(d) R.N. Hall (£50).
(e) W.D. Saxton (£40).

The following year (1912), the Society received eight requests for project funding, but only accepted six projects totalling £275 (NASA, 1912a: E18/1). The reason given for the rejection of the two applications, submitted by D.F. Breslin and J. Van Waart, was that “in so far as they involve research, this research has been already completed and it is unsuitable that the fund should be utilized for its exploitation” (NASA, 1912b: E18/1). What is also interesting to note is that the two rejected applications had requested large amounts compared to the other applications, i.e. £250 and £375 respectively. Individual requests for the accepted six projects ranged from £15 to £90 (NASA, 1912: E18/1).

During the first three years that the Department of Education allocated funds to the Royal Society of South Africa (1911 – 1913), the Society received an annual budget of £500, but in 1914 the allocation was reduced to £300, and was further reduced to £50 in 1916 (NASA, 1917a: E18/1). This prompted a delegation from the Society to pay a visit to the Minister of Mines on 23 May 1917 (the mandate of providing funding for research having subsequently transferred from the Ministry of Education to the Ministry of Mines), to lobby for the re-instatement of the original grant of £500. The delegation was led by Dr L Peringuey, secretary of the Royal Society of South Africa. Following their request, government agreed to have the grant to the Society increased in 1917 to £300 (NASA, 1917b: E18/1).

While the Royal Society of South Africa battled with a decreased budget and continued to negotiate for an increase over the following years (see NASA, 1918: E23/10), discussions were taking place within government for the establishment of a national research funding body, later to be called the Research Grant Board.

2.2.1. Research Grant Board

The history of the Research Grant Board dates back to 1916 when the Industries Advisory Board was established on 13 October 1916 (NASA, 1917: B61/1). At the first meeting of the Industries Advisory Board, held in Pretoria on 18 October 1916, the functions of the Board were explained to the eleven members appointed to the Board. As listed in the 1917 report of the Industries Advisory Board (NASA, 1917: B61/1), these functions were to deal with:

(a) Statistics of production,
(b) Scientific and industrial research,
(c) Factory legislation,
(d) Encouragement of industries,
(e) Development and utilisation of natural resources, and
(f) Paper manufacture.

At its inception, members of the Board included only industrialists, but membership was extended in 1917 to include individuals with scientific and technical skills from the Scientific and Technical Committee. The first members of the Industries Advisory Board were:

(a) C.G. Smith (Chairman).
(b) Sir Thos. Cullinan.
(c) E. Chappell.
(d) A.J. Chiappini.
(e) W.R. Jackson.
(f) G.A. Kolbe.
(g) W.J. Laite.
(h) F.T. Nicholson.
(i) J. Pyott.
(j) G.H. Stanley.
(k) A. Canham (Secretary).

In 1918, the Minister of Mines and Industries approved a proposal by the Industries Advisory Board and the Scientific and Technical Committee that the two bodies be amalgamated (NASA, 1918a & 1918b: MM3063/18). The two bodies argued that a consolidation would lead to better coordination of activities. The new institution that resulted from the merger was called the Advisory Board of Industry and Science.

During its first year of existence, the Advisory Board of Industry and Science recommended to the Union Government that they should form a Research Grant Board (RGB), which would be based within the Department of Education (NASA, 1927: MM611/26). The RGB was subsequently established in October 1918 as a sub-committee of the Advisory Board of Industry and Science, reporting to the Minister of Education as well as the Minister of Mines and Industries. In addition to advising the Government on issues of research at universities and museums, the RGB was given the mandate to manage all research grants allocated to universities from Government funds (NASA, 1920: MISC 13). On instruction by the Minister of Education, the RGB also, during the 1920/21 financial year, took over the research funding component of the Royal Society of South Africa, as well as that of the South African Association for the Advancement of Science (NASA, 1919: A668; NASA, 1919: S11/1/1).

The RGB provided Government Research Grants to university-based researchers, mainly those researchers who were “resident within the Union” (NASA, 1936: LA213). The list of individuals who received Government Research Grants includes prominent scientists such as Dr Basil Schonland who was supported for his research projects on atmospheric electricity and on lightning, in 1924 (NASA, 1936: LA213). Dr Meiring Naudé was also funded by the RGB for his research, and so was Dr JLB Smith. Close inspection of the list of grant-holders over the years reveal that the RGB supported research in a variety of topics and disciplines. Examples of projects funded in 1919 include:

- Bushman and other native studies (AM Duggan-Cronin),
- Relative values of locomotive smoke box-char and various wood-charcoals as fuel for suction gas engines (WSH Cleghorne), and
- Flat worm parasites in South African wild and domestic animals and a survey of the trematodes in all classes, vertebrates and invertebrates, of South African animals (CS Grobbelaar).

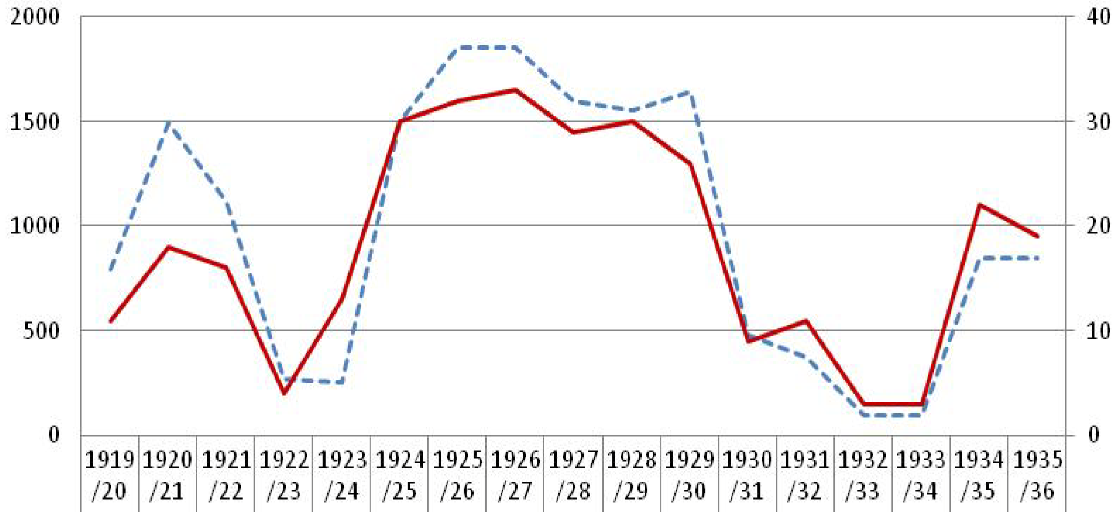
The majority of projects supported through the RGB were in the natural sciences. The social sciences did not have a dedicated source of funding until 1929 when the National Bureau of Educational Research (NBER) was established under the Department of Education (HSRC, 1971). However, the broad social sciences field was represented on the RGB through the inclusion of persons with an Arts background in 1920 (NASA, 1921: MISC 19). Smit (1984: 51) reported that because the NBER was established during the time of an economic crisis in South Africa, some of its functions were compromised. In 1934, the mandate of the NBER was broadened to include the social sciences, and in line with this addition, the name of the institution was changed to Council for Educational and Social Research (HSRC, 1971), later to become the National Bureau for Educational and Social Research (Marais, 2000). The initial funding administered by the Council for Educational and Social Research was obtained from the Carnegie Corporation of New York (HSRC, 1971).

Other grants (and scholarships) managed by the RGB were 1. Carnegie Research Grants (of New York), and Carnegie Travelling Fellowships, started in 1928, 2. University Research Grants and University Research Scholarships, started in 1934, and 3. Mineral Research Scholarships, started in 1935 and managed by the Director of the Mineral Research

Laboratory at the University of Witwatersrand (NASA, 1936: LA213). Thus, in addition to government funding, the RGB administered research funding entrusted to it by the Carnegie Corporation of New York, which made available to it an allocation of £10 000 for the period 1928 – 1932, and a further $30 000 for 1933 – 1937 (NASA, 1936: LA213).

While under the auspices of the Advisory Board of Industry and Science, the RGB was given a significant degree of independence. When the Advisory Board of Industry and Science was dissolved in 1923 (NASA, 1923: A668), the RGB became a separate body aligned only to the Department of Mines and Industries. The RGB was ultimately transferred to the Department of Commerce and Industries in 1933 (NASA, 1936: LA213).

Between 1919 and 1936, the RGB supported 309 projects totalling an investment of over £16 000. The highest number of projects funded within a single financial year was 33 projects, during the 1926/27 financial year (Figure 2.2). For the most part, there was great variation in the number of funded projects between years. Among other factors, the variation in grants awarded can be attributed to the fluctuations in the budget allocated for this purpose, as demonstrated in Figure 2.2. In fact, the 1926 report of the RGB indicated that the Board had been ineffective in some years due to lack of funds (NASA, 1927: MM611/26). The Minister of Mines and Industries is said to have been sympathetic to the financial constraints affecting the RGB (NASA, 1926: MM611/26). One of the consequences of the lack of funding (as reported in the minutes of the sixteenth meeting) was that the RGB was unable to continue with the publication of an annual report beyond 1921 (NASA, 1926: MM611/26). Details of grants awarded up to 1935 were, however, published in the 1936 *Report of the Research Grant Board*.



	1919 /20	1920 /21	1921 /22	1922 /23	1923 /24	1924 /25	1925 /26	1926 /27	1927 /28	1928 /29	1929 /30	1930 /31	1931 /32	1932 /33	1933 /34	1934 /35	1935 /36
Budget (£)	795	1491	1120	275	255	1500	1850	1850	1594	1548	1641	483.5	377	100	100	850	850
Grants	11	18	16	4	13	30	32	33	29	30	26	9	11	3	3	22	19

Figure 2.2. Number of Government Research Grants awarded between 1919 and 1935 (solid, right axis), and the budget allocated each year (dash, left axis).

During the mid-1930s, proposals were submitted advocating for the establishment of a new institution – a National Research Council that would replace the RGB. One of these proposals was addressed to Jan Hofmeyr (then Minister of Education) by Professor MM Rindl, then president of the South African Association for the Advancement of Science. The proposal, which was also published in the November 1935 issue of the *South African Journal of Science*, suggested that "*the new Council should incorporate the functions of the Research Grant Board, and that the moneys administered at present by the Research Grant Board be transferred to the general income of the National Research Council*" (NASA, 1935: R3276/2). Two years later, the Department of Mines issued a memorandum supporting the proposal to establish a National Research Board and a National Research Council that would replace the RGB (NASA, 1937: F8/209). The memorandum suggested that the proposed institution should be placed within the Department of Education (and thus be removed from the Department of Commerce and Industries where the RGB was placed). The move was motivated by the fact that the scope of the RGB had grown over the years, such that it was no longer appropriately placed within the Department of Commerce and Industries. The growth in scope was due to the extension of funding responsibilities of the RGB to include support not only for universities and museums, but other institutions conducting research and, in general, all areas of knowledge production. Furthermore, when the Union of South Africa joined the International Research Council in 1923, later to be known as the International Council of Scientific Union (ICSU), the RGB took on the responsibility of managing the affiliation (NASA, 1936: LA213). Other reasons for the reorganisation of the RGB were that the constitution needed to be changed, and that there was a need for better coordination of research activities by different government departments. Furthermore, the departments concerned expressed the view that, going forward, "*more stable financial provision should be made*" (NASA, 1937: F8/209), as this had not been the case during the many years of the RGB (see Figure 2.2).

A committee was convened to lead the restructuring process, and on completion, recommendations were made and submitted to the Minister of Education. Some of the main recommendations were as follows:

(a) The present Research Grant Board shall cease to function at 31st March, 1938; and in its place there shall be set up a National Research Council [and a National Research Board]. These bodies shall function under the Minister of Education, and

(b) The functions of these bodies shall correspond to those at present exercised by the Research Grant Board (NASA, 1937: F8/209).

The RGB was reorganised in 1938 to form a "larger and more representative body", and was subsequently replaced by two institutions, namely the National Research Board and the National Research Council (NASA, 1941: F8/209). The National Research Board took over the administrative duties of the RGB, while the National Research Council became an advisory body to the Minister of Education offering advice on ways to improve research in the country (NASA, 1938a: R3276/3). These two institutions were collectively referred to as the National Research Council and Board (NRC&B), and were officially inaugurated on 25 July 1938 (NASA, 1938b: R3276/3). In his inaugural speech, the Minister of Education, Jan Hofmeyr, referred to the NRC&B as the "*South African Parliament of Research – its primary function being to consider measures for the improvement of the research position in the Union, and to suggest directions along which research is desirable*" (NASA, 1938b: R3276/3).

Despite the achievements of the RGB and its successors over the years, there were still high levels of dissatisfaction with the state of research in the Union of South Africa, mostly among individuals who were in charge of research development, i.e. those who were part of the National Research Council and Board. For the most part, the dissatisfaction concerned the lack of coordination of research activities, and also the lack of collaboration between researchers. In 1942, members of the NRC&B initiated a discussion that would hopefully improve the state of affairs, through a series of meetings. The first meeting at which the matter was discussed was held in July 1942, followed by a lengthy meeting on 25 – 26 November 1942. It is reported that during the November meeting,

> *a long preliminary discussion took place in the course of which members repeatedly expressed dissatisfaction with the existing state of affairs and stressed the urgent need of reorganization, not only to meet the urgent need for adequate War Time Research but also in preparation for probable post-war conditions. It was generally agreed that whilst a new and comprehensive scheme was urgently needed, the preparation in detail of such a scheme would need careful consideration and would take some time, certain steps to improve the position could and should be taken immediately* (NASA, 1942: R3276/2).

It was clear from this discussion that something needed to be done to change the shape of the research institution. Among the ideas put on the table regarding the new format was that the Union should have an institution similar to the National Research Council of Canada. Early discussions also focused greatly on the calibre of the individual who would be put in charge of managing the institution. It was highlighted that,

> *…in this connection, the Council recognizes that the success or failure of the whole scheme, when established, will depend in great measure on the Executive Officer and that consequently every effort should be made to secure a man with the qualities indicated* (NASA, 1942: R3276/2).

The right person for this job was described as

> *…a man of high scientific attainments who is at the same time energetic, tactful and experienced in negotiations…and his mental horizon should be wide enough for him to take a statesman's view of researches in such diverse fields as, let us say, social anthropology and geophysics* (NASA, 1942: R3276/2).

Following the end of the Second World War, the proposed plan to re-organise the NRC&B came to fruition when the Council for Scientific and Industrial Research (CSIR) was established in 1945 (Smit, 1971), with Dr Basil Schonland as its first Chief Executive Officer.

Dr Basil Schonland was a South African born scientist who spent most of his career in South Africa and the United Kingdom. He also took part in the First World War (Austin, 2001: 306). Before 1945, Dr Schonland was the Director of the Bernard Price Institute (BPI) at the University of Witwatersrand, and was also acting (unofficially) as scientific adviser to the Prime Minister, Jan Smuts (Kingwill, 1990: 8). He returned to South Africa in December 1944 at the request of Jan Smuts to come and head the CSIR (Austin, 2001: 305). Concerns were raised about the Prime Minister's choice, not because the individual he had chosen was not right for the job, but because of "*the very idea that a scientist as eminent as Schonland* *would be lost to research by becoming an administrator, albeit of the body serving the scientific interests of South Africa*" (Austin, 2001). But Smuts was convinced that he had made the right choice. Basil Schonland did not simply accept the Prime Minister's invitation; he had conditions. These conditions were that he would retain his position as the Director of the BPI; that the new institution (the CSIR) would be established outside the civil service; that the institution would receive adequate funding; and that he (Schonland) would be granted direct access to the Minister (Austin, 2001: 306).

The CSIR took over part of the functions of the NRC&B, while the remaining functions, i.e. those falling under the scope of the social sciences, were transferred to a new institution in 1946, the National Council for Social Research (NCSR, 1971). The reason behind the establishment of the NCSR was that the CSIR only supported research in the field of industry and natural science. Therefore there was a need for a similar institution that would support the social sciences post-war. The NCSR also absorbed the responsibilities of the National Bureau of Educational and Social Research (HSRC, 1971), in addition to those that were transferred from the NRC&B.

2.3. RESEARCH FUNDING POST SECOND WORLD WAR

2.3.1. Council for Scientific and Industrial Research (CSIR): 1946 – 1984

The Council for Scientific and Industrial Research (CSIR) was established under the Scientific Research Council Act, Act No. 33 of 1945 (Government Gazette No. 3514, 22 June 1945) and was given a two-fold mandate: first, to conduct scientific and industrial research in its own laboratories (to complement research done at universities) and, second, to support, through the provision of funding, research conducted at universities in the country (Boshoff *et al*. 2000:23; Marais, 2000:71). Funding for university research would thus be through awarding of grants to the academic staff, as well as bursaries to students. For the undertaking of research onsite, the CSIR started off with three laboratories, i.e. the National Physical Laboratory, the National Chemical Research Laboratory, and the National Building Research Institute (Austin, 2001:313). The first head of the National Physical Laboratory was Dr Meiring Naudé, who later succeeded JP Du Toit to become the third president of the CSIR in 1952 (till 1971) (Wagener, 2005). To fulfil its dual mandate, the CSIR received a grant allocation from the Department of National Education (through Parliament).

Supporting and developing research at universities started during the first year of the CSIR's existence. In this regard, Dr Schonland developed the University Research Grants to provide funding for academics and students alike. Research grants were managed under the University Research Division (URD), which supported research of the scientist's own free or self-initiated choice (Kingwill, 1990: 49). During its first year of funding, there was less demand for this kind of support, i.e. £16 526 was requested from a total budget of £27 800. However, the demand for funding increased over the years: in 1962, for example, the CSIR received requests of up to R537 338 from a budget of R299 754 Kingwill (1990: 46). In the mid-1970s, the URD became the Research Grants Division (RGD) and started supporting researchers at museums and technikons as well as at universities (Garbers, 1989).

The CSIR also established several discipline-based Research Units, starting with the Medical Research Unit in the 1950s. By the mid-1960s, nine Research Units had been established. The Research Units were headed by established researchers and were thus based at various universities and research institutes. They included:

(a) Chromatography Research Unit, directed by Prof V Pretorius at the University of Pretoria,
(b) Cosmic Rays Research Unit, directed by Prof P.H. Stoker at Potchefstroom University,
(c) Geochemistry Research Unit, directed by Prof L.H. Ahrens at the University of Cape Town,
(d) Marine Research Unit, directed by Dr A Heydorn at the Oceanographic Research Institute, Durban,
(e) Natural Products Research Unit, directed by Prof F.L. Warren at the University of Cape Town,
(f) Oceanographic Research Unit, directed by J.K. Mallory at the University of Cape Town,
(g) Palynology Research Unit, directed by Prof E.M. van Zinderen Bakker at the University of Orange Free State,
(h) Solid State Physics research Unit, directed by Prof F.R.N. Nabarro at the University of the Witwatersrand, and the
(i) Desert Ecological Research Unit, directed by Dr C Koch at the Namib Desert Research Station (Kingwill, 1990: 47).

Alongside the RGD, the CSIR introduced the Co-operative Scientific Programmes (CSP) in 1975, initially referred to as the National Scientific Programmes. The aim of the CSP was "*to identify problems peculiar to South Africa which, because of their magnitude and complexity, required the co-ordinated effort of a number of different organizations in planned research* *programmes*" (Kingwill, 1990: 73). Thus, projects supported under the CSP were aimed at addressing problems of national importance through multi-disciplinary research. Eleven broad scientific fields were supported under the CSP (Kingwill, 1990: 74-81). These were:

(a) Marine sciences
(b) Antarctic research
(c) Geological sciences
(d) Space and atmospheric sciences
(e) Environmental sciences
(f) Aquaculture
(g) Energy
(h) Microelectronics
(i) Materials
(j) Waste management
(k) Renewable feed stocks

The RGD and CSP offered research funding at different levels (Garbers, 1981). The CSP always offered higher average grants across disciplines than the RGD (Garbers, 1985). For example, during the 1979/80 financial year, while the RGD was offering an average grant of R2 902 for biological sciences, CSP was offering R10 742 to its researchers. The difference was even larger for chemistry, with R3 668 and R19 379 average grants for RGD and CSP, respectively. One of the reasons given for this difference was that the CSP grants were larger because the researchers were sub-contracted to conduct directed research with the aim of addressing a specific problem, whereas RGD research was out of the researchers' free choice (FRD, 1987).

2.3.2. Foundation for Research Development (FRD): 1984 – 1999

In 1984, the Council of the CSIR welcomed a recommendation to combine the Research Grants Division and the Co-operative Scientific Programmes to form the Foundation for Research Development (FRD) (de Wet, 1987; Kingwill, 1990: 39), whose mandate would be "*the provision of appropriate human resources in science and technology to meet the requirements of the national economy*" (FRD, 1991). The FRD officially became a funding agency of the CSIR on 1 April 1984. Later that year (during September – October), a new funding programme called the Main Research Support Programme (MRSP) was introduced (FRD, 1984; Garbers, 1986). Jack de Wet (1987) reported that the MRSP was received with great enthusiasm within the local research community, as well as by other funding agencies abroad.

The introduction of the MRSP was an effort to bridge the funding gap that existed between the two previous funding mechanisms, i.e. the RGD and the CSP. This programmme continued with the mandate of the RGD – i.e. – that of allowing researchers to engage in research of their own free choice. The MRSP comprised of several funding categories, i.e. research grants, equipment, postgraduate bursaries, sabbatical support grants and conference attendance. On the other hand, directed research previously catered for under the CSP was supported through the National Programmes.

Accessing funding from the MRSP was done through the submission of a project proposal, which was subsequently put through a two-stage review process (FRD, 1987). First, the proposal would be given to about five to seven reviewers, all experts in the field. Second, all proposals were discussed in discipline-specific panels, comprising of about four assessors and chaired by an FRD Executive. Thus each discipline, for example, animal sciences, chemistry, physics, etc. would have their own panel of assessors. The aim of these panels was to consider the recommendations of reviewers and make a final recommendation to the FRD (FRD, 1987). Panel assessors were appointed on a three-year period. The type of funding awarded on approval of the project proposal was based on a sliding scale, depending on the rating category that the applicant holds. Thus, A-rated researchers would receive higher funding than B-rated researchers and so on (see also below on the rating system).

The MRSP programme enjoyed a steady budget increase over a five year period, from 1982 (under its predecessors) to 1986 (Table 2.1). In its third year of implementation, the allocation to the MRSP increased by 68% from the previous year (from 1983 to 1984). Similarly, the National Programmes also witnessed an increase in budget allocation during the same five year period (Garbers, 1986).

Table 2.1. Budget allocation for the Main Research Support Programme and National Programmes (R'000). Source: Garbers (1986).

Year	**MRSP**	**% Growth**	**National Programmes**	**% Growth**	**Total***	**Total % Growth**
1982	4 657		9 860		14 517	
1983	6 038	30	12 461	26	18 501	27
1984	10 127	68	17 808	43	27 935	51
1985	13 614	34	21 343	17	34 957	25
1986	18 631	37	24 223	12	42 854	23

* MRSP plus National Programmes.

The FRD proceeded to become the main research support programme within the CSIR, until it was awarded an autonomous status in 1990, through the Research Development Act (Act No. 75 of 1990). The Act identified the mandate of the FRD as research development. This included not only providing financial support to higher education institutions and museums, but also managing some expensive national facilities, namely: the National Accelerator Centre (NAC) (now iThemba Labs), the South African Astronomical Observatory (SAAO), the Hartebeeshoek Radio Astronomical Observatory (HartRAO), and the Hermanus Magnetic Observatory (HMO). FRD thus became the largest research support agency in the country, although supporting only the natural sciences and engineering.

In addition to the MRSP and National Programmes, the FRD introduced “research development” funding programmes, i.e. the Technikon Research Development Programmes (TRDP) and the University Research Development Programmes (URDP) (van Vuuren & Haag, 1991). Furthermore, a partnership programme between academia and industry, called the Technology and Human Resources for Industry Programme (THRIP), was launched in 1992.

The TRDP and URDP were introduced in 1990 and 1992 respectively, to develop research capacity at technikons and historically black universities (NRF, 2003). These institutions were supported within the Research Development Initiative of the FRD with a focus on three goals (NRF, 2003), i.e.:

- *Human resource development: Support will focus on women, black and new researchers as well as quality postgraduate students.*
- *Building the research environment: Support will focus on [developing] the capacity of technikons and historically black universities (HBU’s) and support for research infrastructure in the form of equipment.*
- *Development of research/knowledge areas will focus on the design and implementation of appropriate strategies based on the identification of weak disciplines, national strategic research areas and gaps in the national research system.*

Unlike with other FRD programmes, academics did not need a rating to be awarded funding within the TRDP and URDP (von Gruenewald, personal communication, 7 November 2008).

2.3.3. The rating system

In 1985, the FRD introduced a new framework, called the Evaluation and Rating System (hereafter simply referred to as the rating system). This framework was not only new within the CSIR context, but in South Africa and elsewhere in the world. According to Dr Reinhard Arndt and some of his former colleagues who were at the FRD when the rating system was developed, the system was developed to help identify the best researchers in the country at that time (but only in the field of natural sciences and engineering) (Arndt, personal communication, 29 October 2008). The person who assisted the FRD in developing the rating system was Prof Jack de Wet (De Wet, 1987) who had returned to South Africa after spending many years at Oxford University. At the time, Prof De Wet was based at the University of Cape Town's Faculty of Science.

The rating system involved a peer review process, which also included international reviewers. The review process focused on the applicant's research history, i.e. what s/he had done in the past, and not on what the applicant planned to do. This thinking was based on the premise that "*a researcher with an excellent recent track record is likely to continue producing high-quality research outputs*" (Facts & Figures, 2005). That is, the quality of the researcher was more important than the proposed research (Krige & Morrell, 2007). This was the first hurdle that researchers had to overcome before they could access funding from the FRD. The second step was to apply for project funding after being awarded a rating. Failure to obtain a rating once the process has been completed meant that no research support could be obtained from the FRD. Access to FRD funds was therefore composed of two stages: application for rating, and application for project funding (which was guaranteed if the applicant was successfully rated).

At the end of the evaluation process, researchers could obtain any one of several ratings depending on the recommendations of reviewers and the assessment panel. Four rating categories were used in 1984/85 when the system was introduced, i.e. A, B, C, and Y[6] (see **Annexure 2** for a description of rating categories). The difference in the funding received between different categories was exponential, i.e. A-rated scientist received more comprehensive grants than B-rated scientists, while B-rated scientists received more than C-rated scientists and so on (FRD, 1987). The plan was that A-rated researchers should receive every cent that they requested from FRD, but this was not realised due to budget constraints (Mokhele, personal communication, 2 December 2008).

[6] Two other categories, D and E, were used (awarded to) for researchers not qualifying for support at the time of applying for the rating.

The rating system caused a fair amount of tension within the scientific community, mostly because it was seen to be discriminating against some study disciplines. Moreover, there was also "discrimination" within the same discipline. The evaluation criteria for rating were also at the centre of the debate. As Dr Reinhard Arndt recalled during our discussion:

> *We had a lot of people in zoology that said that we are discriminating against systematists and we are going for too much molecular zoology. Also, the Afrikaans-speaking botanists said that the English-speaking botanists were discriminating against them when they are called in as reviewers (Arndt, personal communication, 29 October 2008).*

The outcry on the "unfairness" of the rating system continued, but despite this, the FRD continued to award funding on the basis of the possession of a valid rating.

In 1996 the FRD decided to de-link rating from funding. Thus, researchers were allowed to apply directly for project funding without having to apply for a rating. Obtaining a rating from this point onwards became a matter of choice, not a prerequisite. Critics argue that it is from this point onward that the rating system lost its appeal and became a mere recognition factor with no direct monetary reward. To ensure that academics continued to apply for rating, the FRD introduced a criteria that rated researchers would be funded for a period of five years without re-applying, while unrated researchers had to re-apply after two years of funding. For several years to follow, this became the only benefit of having a valid rating.

Around the same time of the de-linking of rating from funding, rating categories were revised, with the retention of some categories as well as the introduction of new ones. The A, B, and C categories were retained, while an L category (late entrants) was introduced. The Y category was changed into a P category (for Presidents' Awards) and a new Y category was introduced (see **Annexure 3** for a description of rating categories). These categories were further divided into sub-categories, e.g. A1, A2, B1, B2, B3 etc.

2.3.4. Technology and Human Resources for Industry Programme (THRIP)

The Technology and Human Resources for Industry Programme (THRIP) started as a result of a proposal submitted by members of the South African Engineering Association (SAEA) to the government, requesting funding towards developing engineering skills in the country, in partnership with industry (Skeef, personal communication, 11 November 2008). This proposal was referred to Treasury where it was accepted. The national Department of Trade and Industry (dti) became the line department responsible for THRIP, and the FRD was given the mandate of managing this newly established programme. The dti and FRD operated on a Memorandum of Understanding (MoU), as well as a Service Level Agreement (SLA). In addition, an Advisory Board with specific Terms of Reference (ToR) defining its functions was established. The main function of the Board was to advise and make recommendations to the FRD at a strategic level, without making any decisions for the programme.

THRIP operated, and continues to operate, as a partnership between government, industry, and academia, with industry and government (through the dti) playing the financing role, and academia fulfilling the performance role. The FRD played a largely administrative, non-financial role in this partnership. The aim of the programme is embedded in its mission statement: *to improve the competitiveness of South African industry, by supporting research and technology development activities and enhancing the quality and quantity of appropriately skilled people*. This mission has been realised through three specific objectives:

- To contribute to the increase in the number and quality of people with appropriate skills in the development and management of technology for industry;
- To promote increased interaction among researchers and technology managers in industry, higher education and SETIs[7], with the aim of developing skills for the commercial exploitation of science and technology. This should involve, in particular, promoting the mobility of trained people among these sectors; and
- To stimulate industry and government to increase their investment in research, technology development, technology diffusion, and the promotion of innovation.

As THRIP progressed over the years, and as the country experienced the challenges of democratisation from 1994 onwards, the dti was continuously pushed towards making high level strategic changes that would translate into criteria needed to address recent issues and needs, particularly industrial and governmental strategies. THRIP struggled with some of these challenges, for example with the geographical distribution of funds between provinces. There was (and still is) a strong bias of funding distribution towards the stronger, Historically White Institutions (HWIs), versus the weaker, Historically Black Institutions (HBIs), e.g. the Universities of Cape Town and Stellenbosch continue to receive the bulk of THRIP funding. Getting black women to participate as project leaders has also been a persistent challenge over the years. Some of these challenges were exacerbated by the fact that each project

[7] SETIs = Science, Engineering and Technology Institutions.

had to have an industrial partner willing to invest in it. It is possible that even where black institutions and black females were interested in applying for THRIP funding, they lacked an industrial partner willing to partner with them.

In an effort to address some of these challenges, THRIP introduced a funding formula that included targeted thrust areas intended to receive funding. Project proposals that could demonstrate their contribution to these areas would receive more government funding than those that did not. Therefore, while the default funding formula was R1 (dti contribution) for every R2 (industry contribution[8]), the new formula for projects addressing these areas would be R1:R1 (in that government would now match industry funding in the drive to address the challenges. These thrust areas are:

- Support of an increased number of black and female students who intend to pursue technological and engineering careers. The project should have a minimum of five students, half of whom are black or female.
- Promotion of technological know-how within the small, medium and micro enterprises (SMMEs) sector, through the deployment of skills vested in higher education and SETIs. The SMMEs involved should contribute to the project a minimum of 25% of the total support by industry.
- Facilitation and support of multi-firm projects in which firms collaborate and share in the project outcomes.
- Support for Black Economic Empowerment (BEE) and Black-owned enterprises[9]. The BEE company should also invest financially into the project.

Another one of THRIP initiatives towards addressing industry challenges is the TIPTOP scheme (Technology Innovation Promotion through the Transfer of People) which provides an opportunity for researchers and students to be part of an exchange programme between industry and academia, as well as participating SETIs. Four schemes are available, also affording industry managers the opportunity to spend some time at the partnering academic institution. The TIPTOP scheme is only applicable within the context of a THRIP project, i.e. researchers must have a THRIP approved project to be able to participate in the scheme.

[8] One of the most recent changes is the increased ratio for large companies, from R1:R2 to R1:R3 (www.thrip.nrf.ac.za. Date accessed: 9 July 2013).
[9] This focus was added on five years after the first three were introduced, as part of the THRIP Strategic Plan 2003-2007.

Although THRIP was approved in 1992 with a budget of R1.5m from the dti, it took two years for the first grants to be released to researchers (THRIP, 1997). At the time of releasing the first grants in 1994, the dti had committed to additional funding of R6.7m.

The selection of THRIP projects was done through a simple evaluation process different from that utilised by the MRSP. THRIP management operated on the premise that the best people to judge the potential value of a project proposal are the industry partners themselves. This was motivated by two issues. Firstly, because THRIP projects were designed to provide both the skills and technology to industry, industry is therefore best placed to make the judgment on projects. Secondly, the fact that industry is willing to invest money into the project should also be an adequately strong indicator that they have applied their minds to the project.

More than a decade after the FRD was launched, the organisational structure was revised with the ultimate introduction of a new structure that will allow for better integration of activities in order to address the corporate goals of the organisation. To achieve this, three categories (each with its own focus and objectives) were introduced to guide the activities of all FRD funding programmes. These categories would play a crucial role in determining the level of support for individuals, i.e. individual applicants had to demonstrate in their proposal how these categories will be addressed in the project.

These categories were:

- *Competitive research in Science, Engineering and Technology (SET)*. This category would focus on research excellence so as to enhance South Africa's international competitiveness in SET fields of research.
- *Corrective actions*, to correct past imbalances caused by the apartheid era. This category will emphasise support for the previously disadvantaged communities and enable them to participate fully in SET research.
- *Academic-industry co-operative research*. Support in this category would go toward enhancing the human capacity required to effectively develop and employ new technologies that will enhance the competitiveness of South African industry.

The table below summarises the main attributes of the Main Research Support Programme and the Technology and Human Resources for Industry Programme.

Table 2.2. Attributes of the MRSP and THRIP programmes.

	MRSP	**THRIP**
First grants issued	1985	1994
Budget during first year	R13.6m	R8.2m
Aim of programme	Develop research at universities and museums	Support research between industry and academia, with a focus on engineering research
Target group	University and museum researchers	University researchers and industry managers
Type of research funded	Applicant's free choice, i.e. all research types supported	Applied research
Project selection process	Two-stage review process, i.e. postal review followed by panel review	Endorsement by industry partner
Type of funding	Commensurate with rating category of the applicant	Based on R1:R2 ratio with contribution from government and industry respectively

2.3.5. Human Sciences Research Council: 1969 – 1990

Running parallel to the CSIR was the National Council for Social Research (NCSR) (Marais, 2000: 76), established in 1946 to support the social sciences. The NCSR was resuming the functions of the National Bureau of Educational and Social Research, which had been closed at the onset of the Second World War. Unlike the CSIR, the NCSR did not have a statutory status. This would only change when the Human Sciences Research Council (HSRC) was established on 1 April 1969 through the Human Sciences Research Act (Act No. 23 of 1968). Before 1969, the NCSR served as an advisory body to the Minister of Education (Dubow, 2000: 244). Over the years, the mandate of the HSRC has remained "*the promotion of research in the human sciences*".

It is alleged that the HSRC was highly politicised and also succumbed to pressure from the apartheid government. Chisholm and Morrow (2007), for example, report that in the period before 1979, "*no black people had any part in running or conducting research in the HSRC*". It has also been alleged that during the pre-1979 years of the HSRC, individuals who were in high positions, e.g. executive directors, had an influence on who should get funded. However, no evidence supporting this claim has been put forward. This era supposedly came to an end when Dr Johan Garbers became president of the organisation. Dr Johan Garbers was instrumental in ensuring that the HSRC was separated as far away from politics as possible, so that it could become a scientific agency of repute (Marais, 2000: 78).

The HSRC was comprised of two main sections, the Research and Development (R&D) section, which was the research performing side, as well as the Research Development (RD) section, which was the agency or the research funding section. Similar to the CSIR, funding for HSRC activities as well as for research at universities was received as a parliamentary grant. The R&D section was funded through the I-budget (internal budget), while the RD section was funded through the A-budget (agency budget) managed under the Institute for Research Funding and Coordination (IRF&C). As one of the nine Institutes of the HSRC, the IRF&C was responsible for distribution of the A-budget to universities through the awarding of grants to researchers, scholarships to postgraduate students, as well as grants for conference attendance, both national and international (HSRC, 1970; White, 1992). The I-budget, on the other hand, was used to support research which was considered to be of national importance and conducted within the HSRC's research institutes. The IRF&C later, in the mid-1970s, became the Institute for Research Development (IRD). During the 1969/70 financial year, the HSRC comprised of the following Institutes (HSRC, 1970):

- Institute for Historical Research.
- Institute for Communications Research.
- Institute for Manpower Research.
- Institute for Research Funding and Coordination.
- Institute for Educational Research.
- Institute for Psychometric Research.
- Institute for Sociological Research.
- Institute for Statistical Research.
- Institute for Language, Literature and Arts.

By mid-1980s, the R&D section was experiencing severe financial pressures as government announced that the HSRC would have to find ways of financing its in-house research, although the funding arm of the organisation, i.e. the Institute for Research Development, would still receive government support. The resulting situation was that there was pressure to try and get some funds from the agency side of the business to finance the R&D section (Marais, personal communication, 11 March 2009).

During the early 1990s, the HSRC was re-organised such that there was better management of the two sections, i.e. the R&D and RD sections. Most importantly, the intention was that the research funds intended for university research (managed under the IRD) would be secured from the rest of the activities of the HSRC. One of the staff members who was involved from the start in the restructuring process was Dr HC (Bok) Marais, then Deputy

President of the HSRC (Marais, personal communication, 11 March 2009). Dr Marais was also the previous Executive Director of the Institute for Research Development.

The reconstruction process consisted of a series of consultations with key stakeholders, including a consultative workshop to which the executive management of all universities in the country, i.e. Vice-Chancellors and Deputy Vice-Chancellors, as well as some international scholars, were invited (Marais, personal communication, 11 March 2009). Among the things discussed at the workshop was what the proposed institution should be called or referred to. One ideas was to call it a "Foundation of…", but management at that time was not in support of this suggestion. Allowing this institution to be called a "foundation" would have implications such as assigning to it a statutory status and thus total independence from the HSRC. It would also have meant that the institution would be incorporated into the existing Foundation for Research Development. A second suggestion was to call it a "Centre of…", which is a commonly used term in countries around the world. The word "centre" found favour with management, and the institution was thus called Centre for Science Development (CSD). This created yet another debate over the "science" part of the name. For many people, science refers to the natural sciences and excludes the social sciences and humanities. Therefore some social scientists felt that the name was inappropriate for an institution supporting the social sciences and humanities. Dr Bok Marais maintained, however, that "science" in this case was used in a broader sense, and that using it would also affirm the position of the social sciences and humanities as sciences just like the natural sciences. The proposal to establish the CSD was passed through the Scientific Advisory Council (SAC)[10].

2.3.6. Centre for Science Development (CSD): 1990 – 1999

The CSD was officially formed in 1990 (taking over the responsibilities of the Institute for Research Development), with Dr Bok Marais as its first Executive Director. Although the CSD never gained an autonomous status, it had a great degree of autonomy in terms of executing its agency mandate. Before the CSD was established, however, there had already been talks (in the 1980s) about whether its predecessor, the IRD, should join the FRD. When Dr Bok Marais and Dr Johan Garbers assessed the situation, they realised that the social sciences and humanities in the country were not nearly as developed as the natural sciences, and therefore it would be unfair to combine the two fields given the situation. If

[10]The SAC (established in 1962) was an advisory body which provided advice to government on issues relating to, amongst others, scientific and technological infrastructure; manpower; and the overall functioning of the South African science system.

combined, the social sciences and humanities would be the junior partners in the organisation. They then agreed, based on certain analyses and extrapolations, that the social sciences and humanities should be given time (a period of about ten years) and support to develop themselves before they can join the natural sciences. Individuals who were doing good research in social sciences and humanities were identified at institutions and supported to fast track their development.

The CSD received its funding allocation directly from Parliament, separate from that of the HSRC, until the mid-1990s. From the mid-1990s onwards, Parliament allocated funding for the HSRC as a whole, and the Council of the HSRC would then distribute funding for each of its organisational activities. The direct impact of the change in allocation mechanism was that any change in the HSRC allocation would affect the subsequent allocation to CSD and all the other components of the HSRC. For example, during the 1997/98 financial year the CSD allocation was lower than it had been in the previous year, due to a two percent reduction in the HSRC parliamentary allocation (CSD, 1997). The CSD made efforts to leverage funding from other sources to supplement the parliamentary grant.

Project funding from the CSD was awarded on a competitive basis, through submission of research proposals. The CSD however, placed more emphasis on the project itself than on the researcher (as done by the FRD). Thus, if the project was methodologically sound and feasible, CSD would fund it. The capability of the researcher to execute the project was also taken into consideration, but to a lesser extent. Project proposals went through a peer-review process in the form of a panel meeting. These panels were discipline specific, and would comprise of a group of between eight and twelve experts, mostly Afrikaans speaking individuals (Marais, personal communication, 11 March 2009). The panel would make recommendations on which projects should be funded. The executive Director also had to look at all the proposals. Once the panel had made its recommendations, they would go to an Advisory Committee of the CSD followed by the Exco of the HSRC council. The HSRC council did not have the power to change any recommendations from the review panel and the board, and its main task was simply to authorise funding for the projects.

The CSD had four directorates (CSD, 1997), namely:

- Research and Scholarship Funding Directorate. This was the main funding directorate for both researchers and postgraduate students. In addition to funding individuals, this directorate also funded groups of researchers working on a common theme at South African universities. These were called CSD Research Units, and there were about ten of them. These Research Units were also an effort to fast-track the development of researchers in the social sciences and humanities, by getting those individuals who were already experts in the field to work with developing researchers.

- Research Capacity Development Directorate. This directorate provided mechanisms and resources to ensure development of researchers as well as institutions, such as the Women-in-Research programme, which was developed to address the shortage of women in research.
- Research Information Directorate. This directorate, housed projects such as the NEXUS database containing information on projects funded by the CSD.
- Informational Scientific Collaboration. Through this directorate, the HSRC entered into agreements with organisations in other countries. When the Nationalist Party was in power, many countries refused to enter into partnerships with South Africa due to its apartheid policies. Nevertheless, the HSRC managed to foster agreements with the Science Academy of Egypt, the Academy of Sciences in Moscow, as well as the CNRS in Paris (the Human and Social Sciences Library Paris), to name just a few. These forms of agreements are currently referred to as Bilateral Agreements.

To a large extent, the operational processes of the CSD were similar to those of its counterpart, the FRD, such as with regard to the peer review process. One major difference was the rating system used in the FRD but not in the CSD. Another significant difference between the two agencies was their budget allocation for research, which was always higher for the FRD than the CSD. For example, during the 1990/91 financial year, the research budget for the FRD was R45 million, while only R3.5 million was allocated for the CSD (van Vuuren & Haag, 1991).

Following the establishment of the CSIR and HSRC, several other science councils were established, some with a dual mandate (of conducting and funding research), e.g. the Medical Research Council (MRC) and the Agricultural Research Council (ARC), and others only conducting research, e.g. the Council for Mineral Technology (MINTEK). In 1988, science councils were awarded more autonomy, which allowed them to have greater control over the day-to-day business as well as the utilisation of funds, through the system of “framework autonomy” (DNE, 1988). For many years, research support in South Africa was available primarily from science councils/agencies until the mid-1980s, when government introduced an additional funding framework.

2.3.7. Government subsidy-based support of research

In 1986, the Department of National Education (now DHET) introduced a funding framework that would support research by awarding a subsidy grant to institutions for the research outputs produced by their academics. This funding framework was and is unique to South Africa, and was introduced to encourage academics to increase their publication rate. Initially, only universities were eligible for the subsidy, but this was changed in the early 1990s when technikons could also receive subsidy for their research outputs.

Prior to the introduction of subsidy funding, the Department of National Education supported research indirectly through the General University Fund (GUF) (Pouris, 2007). Universities received the GUF as a block grant for the running of the institution, and a portion of the funding (about 15%) was meant to go towards research. However, there was no accountability system in place to ensure that universities would indeed utilise 15% of the funds on research, and anecdotal evidence suggests that some institutions used the funding for something other than research (for example, staff salaries).

The new funding framework was developed during the time when South Africa was facing sanctions imposed by the international community due to the apartheid regime. South African science, for example, was excluded from the rest of the international scientific community (Mouton, 2003), and South African scientists could not participate in scientific activities such as scholarly conferences, hosted by other countries. In addition, they could not access funding from anywhere other than locally. The aim of introducing the funding framework in 1986, therefore, was to encourage academics to engage in research (and produce publications) despite the isolation, by offering them an incentive in the form of a research output subsidy (Mouton, 2009). The types of publications that could receive subsidy funding were journal articles, books, chapters in books, and conference proceedings. Patents and artifacts were also subsidised in the 1990s (see DoE, 1997a & 1997b), but were later removed from the list of qualifying outputs. To qualify for funding, all these publication types had to have undergone a peer review process, and for journal articles, they had to be published in journals appearing in either the ISI (Institute for Scientific Information) list or the list of South African journals.

The 1986 subsidy policy was revised in 2003, when the Department promulgated a new policy on subsidising research outputs, titled: Policy and Procedures for Measurement of Research Output of Public Higher Education Institutions. One of the changes brought about in 2003 was the introduction of a third list of journals that would be eligible for subsidy, the

International Bibliography of Social Sciences (IBSS) list. The Department of Higher Education and Training (DHET) manages the list of South African journals. The Department also oversees the process of journal accreditation for inclusion in the list, ensuring that those journals that make it onto the list meet certain criteria. Currently, the DHET list of South African journals contains about 270 journals. The list is reviewed annually to ensure that all journals contained therein still meet the criteria. The 2003 policy is currently (in 2013) under review. Among the several proposed changes to the policy is the inclusion of two additional international journal lists. This will bring the total number of lists eligible for subsidy to five.

The journal accreditation process itself leaves much to be desired. The accreditation process is two-fold. First, DHET officials who are not necessarily experts in the field in which the journal is published, assess the journals and make recommendations on whether the journals should be accredited. Following the first round of evaluation at the DHET, the journals are sent to the Academy of Science of South Africa (ASSAf) for a second opinion. Once ASSAf has submitted its recommendations, the same group of DHET officials that evaluated the journals initially, look at both recommendations (their own recommendations and those of ASSAf) and make a final decision. That is, while the DHET does consider the recommendations by ASSAf (on whether to award accreditation to the journal or not), the Department makes the final decision on the outcome of the application. The criteria used to assess these journals are also not very detailed. For example, one criterion (in the 2003 policy framework) states that "*the purpose of the journal must be to disseminate research results and the content must support high level learning, teaching and research in the relevant area*". The decision on whether the journal submitted satisfies this criterion rests with the DHET official assessing the journals, which in some cases can only be determined by an individual in the same field of research. This challenge can be addressed by involving more experts from the respective academic fields when considering a journal for accreditation.

There are also other parts of the 2003 policy that are not very clear. The policy states that its purpose "is to encourage research productivity by rewarding quality research output at public higher education institutions". However, it does not indicate what is considered as quality research. For example, the only quality measure for journal articles seems to be that the articles should be published in journals listed in any one of the three journal lists. This is of course based on the assumption that those lists contain high quality journals, but again, it is not stipulated why those lists are considered to be of high quality. Factors such as the length of the article are not considered, meaning that a very short article, for instance, would receive the exact same subsidy amount as a very lengthy article.

The subsidy amount which is paid to institutions is determined by publication units. Over the period between 1987 and 2003, the monetary value of a publication unit, which is equivalent to a single journal article (and divided by the number of authors at different institutions[11]), was approximately R22 000 (Mouton, 2009). The unit value for a publication increased significantly during the years to follow, with the latest (2013) monetary value per unit being just over R119 000[12]. As a result, the Department awarded about R2.4 billion in research subsidies across South Africa's 23 public higher education institutions in 2013 (for 2011 research outputs) (DHET data).

While it was hoped that the subsidy grant would help increase South Africa's overall research outputs from HEIs, this was not the case. As Mouton (2009) demonstrated, the number of journal articles published remained constant from 1987 until around 2003 when the funding framework was revised (Figure 2.3). It is possible that the sudden increase in research outputs from 2003 onwards coincided with the significant increase in the monetary value of a publication. In addition, it needs to be investigated whether there have been any changes in the length (and quality) of publications, particularly journal articles, before and after 2003. In other words, has there been any reduction in the average length (number of pages) of a journal article from 2003? It could very well be that academics are still doing the same amount of research as they did prior to 2003, but in order to get more money from the DHET, they would publish results from one study in two or more journal articles. Mouton (2008) also argues this point, and stresses that researchers have resorted to publishing more, shorter articles rather than fewer longer articles, because they can get more money from more articles. This form of publishing, where a researcher would publish more than one article from work that could very well be one article, has been termed "salami publishing". The general feeling is that salami publishing has become a way of getting money from the DHET and, as such, could be detracting from the quality of the research outputs.

[11] If two authors based at two different institutions submit an article for subsidy, each institution will receive half a unit, while a third of a unit will be awarded to each institution if three authors from three institutions contributed etc. If however, all two or three authors are from the same institution, the institution will be awarded a full (one) unit.

[12] The formula used to allocate subsidy grants is n – 2, where n is the current year. That is, if n = 2012, then the subsidy grant released to HEIs in 2013 is for publications produced in 2011.

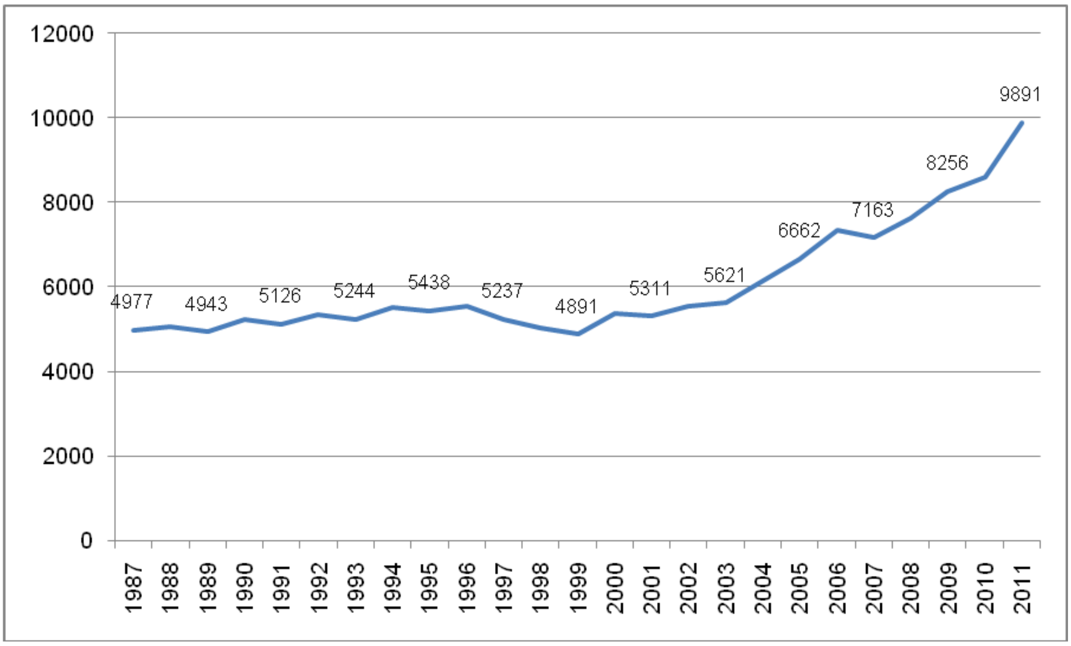


Figure 2.3. Higher Education journal article output units (1987 – 2011). *Data source*: DHET (2012); (Mouton, 2009).

When institutions receive their share of the subsidy funding, it is up to them as to how to spend this money. Anecdotal evidence suggests that most institutions re-invest this funding back in research by depositing a portion of the funds into the research accounts of individual researchers who published in the claiming year. It is also a well known fact that some institutions do pay a portion of the subsidy into the researchers' personal bank accounts as a salary. Whatever the mechanism used, it seems that institutions have their own way of encouraging their academics to publish.

Whether or not this is a fair system remains widely debated within the scientific community. Some scientists argue that a one page article in disciplines such as mathematics, for example, may contain a ground breaking formula, and therefore there is no need for it to be a fifty page document. Another hotly debated issues relates to where an article is published. Some feel that an article published in the journal *Nature*, considered a top journal particularly in the natural sciences, should receive a higher subsidy than articles published in other journals. On the other hand, academics in the social sciences and humanities (SS&H) disciplines feel that the current system favours the natural sciences by making it easier to publish journal articles rather books, which are the preferred mode of publishing in many SS&H disciplines. The system is also considered discriminatory to disciplines such as the performing arts and engineering: outputs of an artistic nature such as sculptures and art exhibitions are not recognised for subsidy purposes by the DHET, and nor are engineering related patents and artefacts (although these used to be subsidised in 1997 (DoE, 1997a, 1997b).

While there may be merit in these and other arguments, there still remains some level of disagreement about what quality research output is, more so because there is a monetary reward involved. It is also clear that there are differences are along disciplinary lines, and perhaps the DHET should not use a "blanket" approach in addressing these issues. Considering that the largest portion of subsidy funds goes towards journal articles, one would expect that the DHET would put stringent measures in place to ensure that (public) money is well spent. At the same time, the DHET needs to assess whether the current system is working in terms of pursuing quality research.

2.4. RESEARCH FUNDING UNDER THE NRF: 1999 – 2009

The mid-1990s marked a new era for South Africa. The country witnessed the end of apartheid[13] and elected a new government headed by the African National Congress (ANC). One of the greatest challenges for the ANC was to bring equity to and across the country's systems, including the science systems, and in the process to move away from forms of governance along racial lines.

To begin the process of reorganising the science system, the ANC together with COSATU (Congress of South African Trade Unions) and SANCO (South African National Civic Organisations) commissioned the International Development Research Centre (IDRC) of Canada to conduct a review of South Africa's Science and Technology (S&T) policy. The IDRC also provided financial assistance towards the review. The major finding of the IDRC review was that South Africa has an S&T policy which is scattered across institutions and these institutions were operating in silos. The system was highly fragmented and lacked proper coordination. The report summarised this finding as follows:

> *Our impressions are of a highly fragmented group of institutions. These were often trying to define a role for themselves in the new South Africa, but were not quite sure how to go about it. These institutions also exist within an overall system which was most frequently described, by officials, as 'dysfunctional'. What was clear is that South Africa badly needs a wide-ranging*

[13]Apartheid can best be described as a form of governance which was characterized by the segregation of people according to their race, discriminating against all non-whites, particularly Africans. The apartheid period started in 1910, but was consolidated in 1948 and after following the election which was won by the National Party (Lipton, 1985:14-15).

> *discussion of S&T Policy options of the kind which the Democratic Movement proposes to launch* (IDRC, 1993).

The IDRC review provided a much needed baseline for a national debate on S&T policies. It did not in any way dictate what South Africa needed to do to change the situation, but merely offered recommendations and points of departure for the future of the S&T policy. Following the publication of the IDRC report, government started the process of developing a new science policy, which kicked-off with the publication of the Green Paper on Science and Technology in 1996. The Green Paper raised several questions relating to the previous science policy, and it was distributed to stakeholders who were afforded the opportunity to respond. One of the questions was regarding the funding structures in the country, and was posed as: how should agency funding be organised in South Africa? Three options were provided to this question[14], but the majority of the respondents suggested option 3 (Mokhele, personal communication, 2 December 2008), that government must “create a single agency funding instrument for all university science, engineering and technology human resource and capacity development activities”.

Later that year (September 1996), government published its first S&T policy, i.e. the White Paper on Science and Technology. The White Paper indicated that South Africa will establish a National Research Foundation “responsible for support to research and research capacity building through funding”. The proposed funding institution would be a consolidation of several funding agencies, namely, the Foundation for Research Development (FRD); the Centre for Science Development (CSD, the agency arm of the Human Sciences Research Council); the agency mandate of the Medical Research Council (MRC); and the agency mandate of the Agricultural Research Council (ARC).

The process of establishing the National Research Foundation (NRF) as a statutory body was a highly debated one. Not all the stakeholders within the scientific community were in favour of the formation of the NRF. Of the four agencies that the White Paper proposed would merge into the NRF, i.e. the FRD, CSD, the agency mandate of the MRC and the agency mandate of the ARC, only the FRD was in favour of consolidating, with the other three were opposed to the idea. The greatest fear amongst these later three agencies was that if they merged, their portfolios would suffer (von Gruenewald, personal communication,

[14]The three options were: Option 1. Continue with the present arrangements; Option 2. Separate the agency funding aspects of the current NSI more clearly from the performance function and create a small number of larger agencies (natural science and engineering, health and social science); Option 3. Create a single agency funding instrument for all university science, engineering and technology human resource and capacity development activities.

7 November 2008). Dr Khotso Mokhele recalls an event where a group of individuals, comprising of the head of the HSRC, MRC, ARC, MINTEK and some Ministers visited the then Minister of Arts, Culture, Science and Technology, Dr Ben Ngubane, to lobby against the creation of the NRF (Mokhele, personal communication, 2 December 2008).

Dr Ben Ngubane was considered by some as a conciliatory Minister. In an effort to resolve the situation, he (the Minister) came up with what seemed to be a reasonable way of satisfying all the parties concerned. His suggestion was that the NRF should consist of four divisions, i.e. natural sciences and engineering, the social sciences and humanities, the health sciences, and agricultural and environmental sciences. Therefore each of the disciplines involved would be taken care of by their respective division. This looked like it would be the end of the consolidation debate, and the NRF Act (No 23 of 1998) was passed recommending that the NRF should be divided into the four divisions outlined above. However, the struggle was far from over.

After it became clear that each of the disciplines would be represented in the new agency, the focus of the debate shifted to the leadership of the proposed institution. Each of the four agencies had a president, so who would be the president of the NRF? The same group of individuals who were opposing consolidation started the discussion around the leadership issue. The main fear was that, if the FRD took charge of the new agency, natural sciences and engineering would dominate and discriminate against the other disciplines.

After a consultative and competitive process of selecting the president (by advertising the position and interviewing all potential candidates, overseen by the NRF Board), Dr Khotso Mokhele was appointed as the first president of the NRF.

During the period of resistance and fighting for leadership, two of the four agencies (MRC and ARC) opted out of the merger, leaving only the FRD and CSD to merge. The MRC and ARC retained their agency mandates and continue to award research grants to university-based researchers to date, in the health sciences and agricultural and environmental sciences respectively.

The NRF was officially established on 1 April 1999 through the NRF Act with the mandate of

> *supporting and promoting research through funding, human resource development, and the provision of the necessary facilities in order to facilitate the creation of knowledge, innovation*

and development in all fields of science and technology, including indigenous knowledge, and thereby to contribute to the improvement of the quality of life of all the people of the Republic.

Under the Act, the organisation would also focus on human resource development by developing novice researchers as well as providing support for post-graduate students.

The NRF is composed of three business clusters, i.e. Research and Innovation Support and Advancement (RISA – formerly Research Support Agency), the National Facilities, and the South African Agency for Science and Technology Advancement (SAASTA). Research funding is managed under the RISA cluster, while the provision and support of research facilities is done separately, under the National Facilities cluster[15]. SAASTA coordinates all activities relating to science and technology education, communication, outreach and advancement for all the components of the NRF.

The NRF is governed by a Board appointed by the Minister of Science and Technology. Funds are received as a parliamentary core grant, which is part of the science vote, via the Department of Science and Technology (DST). Thus, the NRF provides government funding in support of proposal-driven basic and applied research within a competitive environment (NACI, 2006). Over the years, the NRF budget allocation from the DST grew significantly, from R251 million in 1999/00 to R779 million in 211/12 (NRF 2000; 2012). Despite the growth, the demand for NRF funds remains very high across all programmes. However, the *Quo Vadis* (2006) document of the NRF claims that the NRF is improving because the demand for funding has decreased. They attribute this improvement to several factors, such as the new multi-year funding mode, which the NRF adopted in 2003. The new funding mode ensures that researchers only need to re-apply for funding after three years. These researchers would therefore be out of the system until the end of the funding period. On the other hand, it could also be that the number of applicants to the NRF has decreased due to the small size of the grant.

The NRF is also under threat from the development of other funding opportunities offering higher grant amounts, including the DST. Compounding the issue is the lack of growth in new funding available to the NRF which would enable the organisation to fund new

[15]Initially, the NRF managed three National Facilities, namely: the National Accelerator Center (now iThemba labs); South African Astronomical Observatory (SAAO); Hartebeesthoek Radio Astronomy Observatory (HartRAO); and the JLB Smith Institute of Ichthyology (now South African Institute for Aquatic Biodiversity). Currently, there are seven National Facilities under management of the NRF, with the addition of three to the original list, namely: Hermanus Magnetic Observatory (HMO); South African Environmental Observation Network (SAEON); and the National Zoological Gardens of South Africa (NZG).

applications, as well as the stagnant parliamentary core grant. One of the functions of the NRF as mandated by the Act is to “obtain funds for research, both locally and abroad” (NRF Act, section 4.1 (c). However, over the past ten years, the organisation has not been very successful in leveraging additional sources of funding. In this regard, the NRF launched a fundraising strategy in 2008. The goal of the strategy was “to lead and facilitate the growth of the NRF income to R4 billion by 2014/15” (NRF, 2008a). The organisation aims to direct its fund-raising efforts to other sources outside the DST, which currently provides the majority of its funds.

The first two years of the NRF were a “phasing out period” for the activities of the FRD and CSD. FRD and CSD continued to operate under their existing frameworks so as to honour their financial commitments to academics. In January 2001 a new strategy titled: Research Promotion and Support Beyond 2000 was launched, providing a single funding framework for both the natural sciences and the social sciences and humanities.

The new strategy (Research Promotion and Support Beyond 2000) was developed from a consultative process which involved the relevant stakeholders, both internal, i.e. within the NRF, and external, i.e. outside the NRF. The strategy became a vehicle through which the mandate of the organisation would be carried out. Researchers would be supported to conduct either basic or applied research, which would contribute to the country’s knowledge base.

One of the significant changes that the new strategy brought into the funding system was the introduction of what was called “a strategic landscape for intervention”. This was the introduction of a new funding mechanism called the Focus Area Programme (FAP). The FAP would bring about a shift from self-initiated research to more focused research that would address national strategic priorities. The programme was managed alongside several other programmes of the NRF (see the detailed discussion of the FAP later in the chapter).

2.4.1. The NRF funding mechanism

As indicated earlier, the FRD had a two-step review system: first, apply for a rating and, second, submit a project proposal for a research grant. Under the NRF, project funding was no longer linked to rating. Researchers could apply for funding from any NRF programme without a rating, but they could still apply to be rated out of choice. The rating system was therefore reduced from being a “reward mechanism” to becoming a form of “status”. The only advantage that rated researchers had over unrated researchers was that they were awarded funding for five years, i.e. once the project had been approved, they only had to submit progress reports annually for funding to continue to the next year, for a maximum of five years. On the other hand, unrated researchers had to submit new project proposals every two years (Facts & Figures, 2005). This situation lasted for about 10 years, until 2008 when rating was once again linked to funding. The award system was different this time, however, because researchers still had to apply for project funding, but would receive additional funding based on their rating category, over and above the project funding awarded (see later in the chapter).

The second part of the review system, i.e. subjecting the project proposal to peer-review, involves two processes: a postal review followed by panel review. For postal review, a proposal is sent out to about six to ten reviewers in the applicant's field of study. The choice of the reviewer is determined by the NRF's administrative staff using a database of reviewers. Sometimes proposals are also sent to reviewers that were selected by the applicant. Ideally, a minimum of three reviewers' reports per proposal is required to make a funding decision. Given the small pool of reviewers in the country, it is often a challenge to get sufficient number of reports for each proposal in the first round of sending the proposals out, requiring that the proposal be sent out to more reviewers. Once the reviewers' reports have been received, a panel meeting is arranged comprising of academics in a particular field of study as well as NRF staff. Members of the panel are different to those academics who were involved in the postal review process. The purpose of the panel meeting is to reach consensus on the funding decision. The panel members have to review the project proposals as well as the reviewers' reports and give their own report on whether or not they concur with the reviewer's reports (whether positive or negative). The panel may override the decision by postal reviewers. Although the panel can advise the NRF on the applicant's budget request, i.e. whether the budget is accurate or inflated, the NRF makes the decision on the final budget allocated to the applicant.

2.4.2. Rating system under the NRF

When the rating system was developed in 1984, it was only meant to be applied to researchers in the natural sciences and engineering, not across all study disciplines. However, when the FRD and CSD merged there was a need to consolidate the strategies and processes of the two separate agencies into one. This also included applying the rating system to the social sciences and humanities, which caused tension among the scientific community from this point onwards (Mokhele, personal communication, 2 December 2008).

In 2005, the NRF and all its processes were reviewed, and the following recommendations were made on the rating system:

- a sector-driven task group should reconsider the rating system, in terms of its fundamental purpose and utility, and
- the higher education sector should convene this task group, invite input from all stakeholders, and report to the NRF.

Following this recommendation, the NRF together with HESA (Higher Education South Africa) commissioned five reviews of the rating system in 2007, each review focusing on a different aspect of the system. The studies were as follows:

- **Krige, S. & Morrell, P** (2007). An historical review and analysis of the rating system: 1983-2005.

This study looks at the birth of the rating system, its conceptualisation and the people behind the system. It also looks at operational processes such as the peer review process used to allocate ratings to individuals, as well as changes to the rating categories over time, including the addition of new categories.

- **Lombard, C** (2007). Report on mapping the formal and informal use of the rating system over time by various institutions.

Lombard assessed the way in which institutions (HEIs, science councils, museums, national facilities, and other research institutions, e.g. the South African Biodiversity Institute) make use of the rating system for their own internal processes. These uses are divided into formal use, i.e. where the institution has included the use of the rating system in their policies, such as the recruitment policy; and informal use, i.e. where the institution values the rating system (and encourages staff members to be rated) but does not include this in their policies.

- **Madikizela, M** (2007). Review of processes used to manage the rating of individual researchers.

The report by Madikizela assessed the review process followed by the NRF from the moment individual applications arrive at the NRF right to the time that the outcome is communicated to the applicants. It also includes the appeal process that applicants can follow if they are not satisfied with the outcome of their application.

- **Marais, HC** (2007). Impact of the NRF evaluation and rating system: a review.

The Marais report looked at the impact of the rating system on the science system with regard to, amongst others, the research community; researchers' output productivity; and the impact of the rating system on the various fields of knowledge production. The report indicates that a fair portion of the research community believe that the rating system has had a positive influence on the research system. On the other hand, there is still some dissatisfaction various aspects of the rating system, for example, the delinking of rating from direct funding.

- **Pouris, A** (2007). The NRF evaluation and rating system in the world context.

The aim of this review report was to compare the NRF rating system with similar systems elsewhere in the world. The author describes how the NRF's rating system works, i.e. the process of awarding a rating, and also reviews other comparable processes elsewhere in the world, e.g. the Research Assessment Exercise (RAE) used in the UK and the Performance-Based Research Fund (PBRF) in New Zealand.

A synthesis of the five studies was provided by Thomas Auf der Heyde and Johann Mouton (2007).

Many of the doubts that people have about the rating system, as Cheryl Lombard discovered during the interview stage of the review, relate to the objectivity, validity and transparency of the system. While one could argue that some of these reasons are based purely on perceptions, it also seems that the FRD/NRF has not made some aspects of the rating system clear enough. For example, Sue Krige and Penny Morrell (2007) reported that, during the review process, they could not get clarity regarding certain aspects of the system, particularly with regard to:

- The development of the rating categories assigned to applicants,
- The criteria used to allocate applicants to these categories, and
- The way in which the applicants would be assessed for rating.

The fact that Krige and Morrell could not get answers to these questions after (presumably) going through every available document about the rating system shows that there is a serious deficiency in the system, which supports the lack of transparency that has been raised as a concern.

Some of the general concerns that academics have with regard to the rating system are the following:

- During the evaluation process, there tends to be more emphasis on journal articles than any other form of publication. This is discriminatory of disciplines that publish other types of publications. For example, engineers engage in contract research which results in technology transfer, and which often has restrictions with regard to the distribution of outputs. The highest form of research output emerging from contract research is a patent. However, patents were not recognised in the application for rating (see FRD, 1987). Academics in the social sciences and humanities are said to focus more on publishing books than on journal articles. Books take longer to publish, sometimes years to complete one book, but the rating system does not take this into account. Therefore academics who concentrated on writing books lagged behind those who were publishing journal articles, and it would take longer for them to build a good enough profile to obtain a good rating status.
- Although the NRF presents the rating system as a quality-driven process, the system does not take into account other outside processes that could negatively affect the process. One such process is the research subsidy funding of the DHET, which rewards institutions for the actual number of publications. The only quality check that the DHET has in place before awarding the subsidy is that journal articles should be published in one of the three lists of accredited journals. Factors such as the length of the article play no role in the awarding of subsidy money. The length of books, however, is considered, and subsidy is allocated on the basis of the number of pages in the book.
- More value is attached to publications in ISI-indexed journals as opposed to local journals. The SS&H research often deals with issues that are relevant to the local community, and it only makes sense to publish the output from this research locally as it may not be relevant elsewhere in the world.

As things stand, there are deeply entrenched opposing views within the scientific community about the rating system. This highlights the urgent need for the NRF to consider a new way forward for the system, whether this involves a complete restructuring or doing away with the rating system. Over the years the rating system has retained pretty much the same format despite indications that a portion of the scientific community is unhappy with the system. Currently, there are over 1900[16] researchers with a valid NRF rating, not only in South

[16]In 1984, there were 881 rated researchers at South African universities, museums, and research institutes (FRD, 1987).

African HEIs, but also in science councils, museums and research institutes as well as in institutions outside South African borders (NRF data). About 1700 of these rated researchers are employed at South African public HEIs, comprising approximate 10% of the total staff complement in the higher education sector (based on the latest DHET data for 2007). The question that arises from this statistic is: what percentage of the remaining 90% is rate-able? By answering this question, one could be able to determine how the rating system is perceived by the scientific community, and ultimately decide if the system should continue, and in what format.

Over time, the rating system was adopted by some HEIs as well as the science councils in their operational activities. This is what Cheryl Lombard focused on during the 2007 review of the rating system, to assess the areas where institutions are utilising the rating system. Among other things, Lombard found that institutions were using the rating system for research management (North-West University); promotion (Nelson Mandela Metropolitan University); performance management (University of Pretoria); and remuneration (Stellenbosch University). Some institutions even go to the extent of holding annual events to celebrate rated scientists, e.g. University of KwaZulu-Natal. The areas of application of the rating system vary between institutions, and in some cases it also varies within an institution, i.e. different faculties within a university or research units within a science council may use the rating system in various ways. Institutions make use of the rating system without the influence of the NRF. At the individual level, rated researchers indicated that the only benefit they got from being rated is an improved profile as a researcher, which gives them a better status. This has a positive impact on their career advancement. However, rating does not improve their chances of getting funding outside the NRF, nor does it give them better access to the local and international research communities (Lombard, 2007).

The fact that the NRF has re-introduced the linking of funding to rating (although in a different format) could be seen as an indication that the organisation is set on having the rating system as part of its policy. The question is whether or not this was as a result of the recommendations of the 2007 review (see, for example, the Lombard and Marais reports); or whether the NRF had already taken the decision to again link funding to rating prior to the review. The answer to this question can only be provided by the management of the NRF, given that there was no official institutional response to the findings of the five commissioned studies. Starting from 2008, rated researchers are receiving funding (termed “glue funding”) from the NRF just because they are rated. The maximum amount of funding is t R100 000 per annum, depending on the level of rating. That is, A-rated researchers will receive

R100 000, R80 000 for B-rated, R40 000 for C- and P-rated researchers (also see McKune, 2009). This was in response to the perception (or perhaps the findings of the review) that academics are no longer interested in the rating system because there is nothing in it for them anymore except for the mere status of being rated. Some of those who were rated allowed their ratings to lapse because of lack of monetary reward. More concrete data, however, is still needed to prove (or disprove) this perception.

In a way, the glue funding has given false hope to researchers by making them believe that once they are rated they are guaranteed some money. Already in its first year of implementation, the NRF is faced with a challenge of not being able to allocate funding to all the rated researchers. In 2009, only the A, B and P-rated researchers received glue funding, although not all B categories were funded (McKune, 2009). In a disgruntled correspondence to the South African Journal of Science titled: New to science and already disillusioned, a newly rated researcher at one university expressed his shock at not being awarded any glue funding by the NRF despite his rating (Anderson, 2009).

2.4.3. NRF funding programmes

The NRF has managed several funding programmes to date, some inherited from the FRD and CSD, and others developed within the NRF. The programmes are supported through either ring-fenced or core grant funding. Ring-fenced funding is contract-based, and the NRF can only utilise that funding for the specific programme. For example, the Department of Labour allocates money to the NRF for masters and doctoral scholarships, and this money cannot be utilised for anything other than the intended purpose. Core grant funding, however, is part of the allocation received as a parliamentary grant, and can be allocated to funding programmes according to their budgetary needs. In many cases, the ring-fenced funding is made available for strategic programmes that would address a particular issue within a study discipline. An example is the THRIP programme, introduced earlier in this chapter.

Over the years, the THRIP programme retained much of its structure, but one of the changes that were introduced when the programme was transferred into the NRF related to the proposal review process. Under FRD management, THRIP projects were not subjected to the two-stage peer review process (the postal review followed by panel review). All that was required was a proposal endorsement from the host institution, and the industrial partner also had to submit a statement confirming that they had looked at the proposal and were committed to funding the project. This changed when THRIP management (under the

NRF) negotiated with the line department, the dti, that they should introduce some form of peer review for THRIP project proposals. Although it took some convincing, the suggestion was given the go ahead, and THRIP began implementing expert panel reviews of proposals, although this was not preceded by postal review.

The THRIP programme has been hailed as one of the most successful funding instruments in the country, and has received accolades from several reviews, both internal and external. For example, the OECD (Organisation for Economic Co-operation and Development) review of South Africa's Innovation Policy states that "the Technology and Human Resources for Industry Programme has been very effective in integrating the development of research-capable human resources with industry-university co-operation in R&D, and the programme has been recognised internationally as particularly successful when compared with similar schemes in other countries" (OECD, 2007). THRIP remains the oldest programme under management of the NRF, and also boasts the largest budget for a single funding programme. The most recent THRIP allocation for the 2009/10 financial year from dti was R164m (NRF data).

A full list of the most recent NRF funding opportunities is provided in Annexure 3. For the purpose of this study, only the THRIP and the Focus Areas Programmes are discussed.

2.4.3.1. Focus Areas Programme

The Focus Areas Programme (FAP) was launched in 2001 with nine focus areas. The NRF would hence support research conducted within these focus areas (NRF, 2008b), although researchers would be allowed to make suggestions on other research areas that should be considered for funding. Research proposals in other funding programmes, such as Thuthuka and the Institutional Research Development Programmes, also had to be aligned with one of the nine focus areas. All the study disciplines were eligible for funding, and this provided the opportunity for researchers to work on multi-disciplinary projects. The idea was that the Focus Areas would offer fewer research grants but of larger monetary value (in comparison to other funding programmes within the NRF). As such, the FAP was the second largest funding programme within RISA in terms of its budget (following the THRIP programme).

The nine Focus Areas introduced at the start of the programme were:

- Unlocking the future: advancing and strengthening strategic knowledge,
- Distinct South African research opportunities,
- Conservation and management of ecosystems and biodiversity,

- Sustainable livelihoods: the eradication of poverty,
- Economic growth and international competitiveness,
- Information and Communication Technologies (ICT) and the information society in South Africa,
- The socio-political impact of globalization: the challenge for South Africa,
- Indigenous knowledge systems, and
- Education for the knowledge era.

Two additional focus areas were also planned but were ultimately dropped:

- Arts and culture, and
- Health and well-being.

In a way, the FAP was regarded as the programme for established researchers because most rated researchers submitted their project proposals to the FAP. Novice researchers participating in developmental programmes such as the Thuthuka programme were encouraged to apply for funding from the FAP once they received a rating.

In 2007, the NRF commissioned a review of the Focus Area Programme, undertaken by Dr HC Marais (Marais, 2007b). Marais reviewed the entire spectrum of the Focus Areas, i.e. the context within which they were established as well as the implementation of the programme and its contribution to research in general. Consequently, he identified the strengths and weaknesses of the FAP as well as the challenges that lie ahead for the NRF as a whole. Some of the issues that Marias raised, particularly the weaknesses, affect not only the FAP but also other NRF programmes. For example, the lack of sufficient funding for researchers is a problem for all NRF programmes, particularly those that rely on the parliamentary core grant. Below is a summary of the strengths, weaknesses and challenges of the FAP as identified by Marais (2007).

Strengths:

- The move from self-initiated curiosity driven research to multidisciplinary research that's more focused on national imperatives.
- The ability to sensitise institutions (and researchers) on the need for relevant research and not merely research for the sake of knowledge production.
- The ability to demonstrate to the research community and all relevant stakeholders that the agency is willing to steer the research system.

Weaknesses:

- The low level of funding available for researchers in the FAP.
- The very small pool of researchers available to conduct peer review for the large number of applications submitted to the FAP. This could compromise the quality of review reports received in that some “not so experienced” academics may be requested to review proposals.
- The high staff turnover within the programme, resulting in the discontinuity in the service offered to the research community.
- The poor quality feedback that is sent to applicants, particularly with respect to unsuccessful applications.
- The challenges associated with two of the nine focus areas, namely, Distinct South African Opportunities and Indigenous Knowledge Systems. The former has too wide a scope, such that any project that does not fit well within the other focus areas can be accommodated here, while the later has a very high success rate of project proposals, creating an impression that it is easy to access funding from this focus area.

Challenges:

- Developing or improving on the already existing relationship between the NRF and the DST, which is critical for the development of future research initiatives.
- Developing research management capacities necessary to drive the system in the right direction.
- The establishment of institutions such as the Technology Innovation Agency (TIA) that will direct the country’s research efforts in a strategic direction.
- Going forward, the NRF needs to be able to draw from the past experiences of the FAP for future reference, i.e. when designing the programme that may replace the FAP.

Following the review, the FAP was phased out in 2008 and in its place the NRF has introduced several funding programmes, which include: incentive funding for rated researchers; competitive support for unrated researchers; Blue Skies Research Programme; Blue Skies Research Programme; African Origins Platform, Education Research in South Africa, and International Research Grants (Nthambeleni, personal communication, 1 October 2013).

Currently, the greatest challenge (and threat) to the NRF is lack of adequate funds available for allocation to researchers. This is despite the slight increase in its budget over the years. The demand for NRF funding has increased at a much faster rate than the increase in its allocation from the parliamentary grant.

In as much as more money is needed for research funding, proper management of the funding already available is even more necessary. There are large sums of money flowing through the science system annually, and a portion of this money is not utilised. The bulk of unspent funds come from student bursaries, which were allocated to students who subsequently fail to register for the intended postgraduate degree within that particular financial year. The remaining portion of unspent funds is from academics who applied for and received but did not utilise funding. Academics often claim that they were not able to utilise the funds because they were awarded a lot less funding than they had requested from the NRF. While this may be dismissed as an excuse, there is actually some truth in the claims. For example, in previous years researchers received an average of only 20% of what they had requested from one of the NRF's developmental programmes. For some study disciplines, it is possible to use the little funding awarded, but in other disciplines researchers can do very little with R100 000 if they needed R400 000.

The way that the NRF arrives at a situation where only a portion of the funding is allocated is through budget cuts. When budget requests from academics are assessed during the proposal review stage, funding is allocated according to whether the request is realistic or not. At the end of the process, the total request from all the proposals is tallied and matched against the available budget for that funding programme. It is almost always the case, particularly in recent years, that the requested amounts far exceed the available budget. This is when budget cuts are introduced at the discretion of management. The budget cuts are done step-wise, until the funding requests fit the available budget. First, one category of funding, say the request for international conference attendance, will be removed for everyone. Thus, for that particular funding year, no academic will be awarded funding to attend an international conference. If this cut is not sufficient, another category will be removed, and so on, until the budget fits. The cuts are done at programme level and may differ between programmes depending on the demand for funding from that programme (personal observation)[17].

[17] N Luruli was employed by the NRF between April 2007 and December 2008, and participated in meetings where funding decisions were made.

Of course, the NRF continues to look at ways to improve its funding allocations. In 2007 for example, the Institutional Research Development Programme (IRDP) issued a “closed call” for funding. The IRDP supports groups of researchers who are working together under a common theme, say on the topic of Wine Biotechnology. These groups are referred to as Research Niche Areas (RNAs). Given this closed call, only a few RNAs were invited to apply for funding, the IRDP having realised that the available budget will not be sufficient to fund everyone in the programme. A closed call was issued again in 2008 for funding in 2009.

The postgraduate bursaries model is also being restructured to ensure better utilisation of funds. Previously, the NRF had two types of bursaries, namely, grant-holder linked bursaries and free-standing bursaries (NRF, 2007). A grant-holder linked bursary is awarded to a researcher (also known as a grant-holder) who holds a grant within a specific funding programme, and the researcher subsequently allocates the bursary to a student working on a project with him/her. The challenge with the grant-holder linked bursary (and the most common complaint from grant-holders) is that the NRF releases the bursary money far too late, sometimes in the second or third quarter of the academic year, and students often give up on waiting and therefore leave their studies. This leaves the grant-holders without the students and hence unable to claim the bursary money. The free-standing bursary is competitive, and students have to apply directly to the NRF. The monetary value of the free-standing bursary is higher than that of the grant-holder linked bursary. Moreover, students are not linked to any specific researcher and can claim the bursary to study at any South African HEI. The NRF is considering a shift towards a system where only free-standing bursaries will be offered, and grant-holder linked bursaries are phased out.

2.5. CONCLUDING REMARKS

The review of South Africa’s funding instruments and mechanisms presented in this chapter shows that research funding in the country has developed and advanced. Most importantly, the review revealed an increasing differentiation in funding instruments, starting after the Second World War. This began with the establishment of separate structures for supporting research in the natural sciences (through the CSIR) and the social sciences (through the (NCSR, which eventually became the HSRC), respectively. Thus the first point of differentiation in the system was along scientific fields. The CSIR contributed significantly to the development of research in the country. Furthermore, it is from this institution that other prominent research agencies such as the Medical Research Council were formed.

Funding continued to be allocated from within the CSIR and HSRC (although they both had dedicated programmes introduced in the 1990s, namely the FRD and CSD, respectively) for more than 50 years, until the NRF was established in 1999 with the mandate of providing funding across all fields/disciplines. However, differentiation continued within the NRF, with the allocation of funding by funding programmes, each with its own set of criteria. The Focus Areas programme, for example, was introduced in 2001 to provide funding for strategic projects that would fit within any one of the identified "focus areas". The Focus Areas funding therefore promoted research of a multidisciplinary nature.

Given the country's history of apartheid, It seems the NRF would also be used as a vehicle for addressing past systemic challenges, such as a science system that had not been representative of the demographics of the country. This was done by introducing programmes such as Thuthuka, to provide support to those considered "previously disadvantaged", including blacks and women. This constitutes another form of differentiation within our system.

A further interesting shift in the system has been the introduction of the THRIP programme - a partnership between academia and industry. THRIP was established to provide funding for researchers in engineering, engaging in industry-related research. Thus the research conducted with THRIP funding can be classified as applied research conducted within the context of application. In most cases, the industry partner decides on the scope of the research, and also determines how the results should be published. On the other hand, public funding through the NRF, for example, allows researchers a great deal of freedom with regard to both the choice of research and the dissemination mode.

This review therefore leads us to an interesting question about the sources of funding and their impact on the science system. Taking the NRF funding as proxy for government funding, and THRIP as proxy for industry funding, what has been the impact of these funding sources on various aspects of the science system, particularly the type of research conducted or the mode of knowledge production, the level of scientific productivity by academics, and student training in research?

CHAPTER 3: THE “NEW” MODE OF KNOWLEDGE PRODUCTION?

3.1. INTRODUCTION

The history of knowledge production shows that people have been producing knowledge for millennia. In his comments on the history of science in South Africa, Saul Dubow (2006) refers to developments in knowledge production in South Africa in the early nineteenth century. For example, the Royal Observatory was established in Cape Town in 1828, becoming the “first major scientific institution” of its time (Dubow, 2006: 25), which, moreover, was located outside of a university. Since then, however, knowledge production has increasingly being based within the boundaries of academia, with the rules being determined by academics themselves. Dubow (2006: 25) also mentions that private funds were invested in public institutions, which shows that researchers have not always relied only on government funding.

The primary motivation for engaging in knowledge production activities has been for one of two reasons: (a) to add to the pool of knowledge, or (b) to seek s solution to an existing problem. However, knowledge production has evolved in recent decades, and as Arie Rip and Barend van der Meulen (1996: 343) state: “the landscape of science is changing radically”. These changes include expectations by peers, which impact on the way knowledge is judged, as well as where and by whom knowledge is produced. In 1994 a group of academics, namely Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott and Martin Trow, published a (now popular) book titled *The New Production of Knowledge: the dynamics of science and research in contemporary societies*, which elaborates on how the forms and production of knowledge as we know it are changing.

The New Production of Knowledge is based on the principle that “*a new form of knowledge production is emerging alongside the traditional, familiar one* (1994: vii). The book makes a distinction between the traditional mode of knowledge production (labelled Mode 1) and the new mode (labelled Mode 2). Furthermore, it claims that “*the new mode of knowledge production affects not only what knowledge is produced but also how it is produced, the context in which it is pursued, the way it is organised, the reward systems it utilises and the mechanisms that control the quality of that which is produced*” (1994: vii). From this description, it is clear that Mode 2 does not mean that research is being produced differently, or that the methods being followed are different. Rather, it is the “social characteristics”, as the authors call them, of knowledge production that are changing. For example, the composition of research teams may comprise individuals from different disciplines. In some cases (as will be demonstrated later in the chapter), Mode 2 is interpreted as referring to applied research while Mode 1 refers to basic research, although some may view this as an over-simplification of the thesis. The central thesis of the book, i.e. the Mode 2 thesis, is sometimes referred to as the Gibbons thesis, and these terminologies may be used interchangeably throughout the chapter.

3.2. PROPOSITIONS OF THE MODE 2 THESIS

The Mode 2 thesis consists of five "sub-theses" or propositions, which are described in Table 3.1. A Mode 2 project therefore, would demonstrate a combination of all or some of these propositions.

Table 3.1. Propositions of the "new" mode of knowledge production (Mode 2), versus the traditional mode (Mode 1)

Proposition	Description
Knowledge produced in the context of application	In Mode 1, knowledge production is governed by the academic community, and is comprised largely of fundamental research without the intention of practical application in the future. That is, "*knowledge production is carried out in the absence of some practical goal*". Mode 2 knowledge production, on the other hand, "*is intended to be useful to someone whether in industry or government, or society more generally and this imperative is present from the beginning*" (1994: 4). Furthermore, "*knowledge production in Mode 2 is the outcome of a process in which supply and demand factors can be said to operate, but the sources of supply are increasingly diverse, as are the demands for differentiated forms of specialist knowledge*" (1994: 4).
Transdisciplinarity	Transdisciplinary knowledge extends beyond disciplinary boundaries in terms of the composition of the research team, thus the individuals involved in a particular project come from different disciplines; the intellectual agenda is also multidisciplinary; resources are obtained from different sources; research is not organised around one particular discipline; and the dissemination of research results takes various forms. Further, within a transdisciplinary context, boundaries between fundamental and applied research are less rigid, and boundaries between institutional types such as university and industry, are less strict.

Proposition	Description
Heterogeneity and organisational diversity	Mode 1 knowledge production is largely homogenous – the teams of researchers working in a particular problem are largely from a single discipline, and the papers published focus on one particular discipline. Thus, homogeneity entails "the production of more of the same thing". Mode 2 knowledge production, on the other hand, is more heterogeneous – there is greater differentiation and rearrangement of processes and activities, and also multidisciplinary teams working on a single project. The multidisciplinary nature of teams involved in Mode 2 projects is evident in the increasing number of research papers co-authored by academics from a variety of disciplines. The individuals in these projects are often located at different sites, both geographically and in terms of institutional types (universities, private companies, research institutes etc). As a result, constant communication becomes critical to the success of the project. Communication in knowledge production happens at three levels: between science and society; among scientific practitioners; and with the entities of the physical and social world. During the past decades, perhaps even centuries, knowledge was communicated by scientists to the general public. That is, society was merely a recipient of knowledge and had no influence on the knowledge they were receiving. This has changed over the years, with increasing demand for scientists to be both socially accountable in the knowledge they produce, and to be financially accountable for the resources received. Furthermore, scientists are faced with pressure from political authorities to communicate science in a "vernacular" that society can understand. The change in society's attitude towards knowledge production can be attributed to the higher level of education within society. Communication among scientific practitioners is influenced by mobility and also by the way they set research priorities and select problems. Scientists working on collaborative projects have to move between different sites of knowledge production. In instances where mobility is not possible for one reason or the other, scientists have to rely on Information and Communication Technologies (ICT) such as telephones, fax, e-mails, and the rapidly expanding internet.
Social accountability and reflexivity	Knowledge produced in Mode 2 does not only focus on the advancing of science and adding to the pool of knowledge, as is the case in Mode 1, it has to be socially accountable and respond to the needs of the community. In Mode 2 knowledge production, "*sensitivity to the impact of the research is built in from the start, and forms part of the context of application*" (1994:

Proposition	Description
	7). Furthermore, the process of knowledge production is reflexive – thus it involves a constant 'back and forth' interaction between the fundamental and the applied areas of the project.
Quality Control	Under disciplinary, Mode 1 knowledge production, scientists determine the parameters for what should be recognised as good science, how it should be produced and in what format the results should be reported. Quality control of Mode 1 knowledge is maintained through peer review processes, managed by academics considered experts in the relevant field. In Mode 2 however, quality control involves a wider range of criteria, and it is dependent on two main components: the *institutional space*, and the *social organisation of research*. Unlike in Mode 1 where knowledge production happens primarily within universities and research institutes, knowledge production in Mode 2 can happen anywhere outside these types of institution, for example in industry and consulting companies. Mode 2 knowledge has to be socially relevant. Thus, while the work must still be considered good science by peers in the field, a Mode 2 project must go a step further by having an element of application in it. It has to be useful to a wider audience beyond the producers themselves, i.e. scientists.

The Gibbons thesis identifies a number of key trends that have given rise to Mode 2. These trends include: the marketability and commercialisation of research (pp. 46-69); the massification of research and education (pp. 70-89); reconfiguring institutions (pp. 137-154); and managing socially distributed knowledge (pp. 155-166). Our discussion of the Gibbons thesis is organised according to these four trends.

3.3. KEY DRIVERS OF MODE 2 KNOWLEDGE PRODUCTION

3.3.1. Marketability and commercialisation of research

Knowledge production has become an important factor for economic development, and knowledge has become a commodity in its own right. The private sector, i.e. industry, has an increased focus on making scientific activities or research outputs, more marketable. Furthermore, there is a rise in the amount of knowledge produced for commercialization purposes, exacerbated by the intensification of international competition in business and industry. To gain the competitive edge in the market, companies must possess specialist knowledge, which in most cases is obtained through collaborations with universities or other companies. As a result, the number of knowledge production sites outside the traditional university, has increased. Efficient collaboration between the various sites is made possible by having strong ICT infrastructure in place, ensuring that constant communication and the exchange of information is maintained between partners. In a different publication, Nowotny *et al*. 2001 state that

> *The rapid development of new information and communication technologies has created the technical preconditions for far-reaching social changes (such as the erosion of the boundaries between different forms of rationality). Most obviously it has provided the means by which global capitalism has been able to transcend particularities of all kinds – national, cultural, social, even individual. But it has also had more radical effects that tend to dissolve existing forms of systemic differentiation. These new technologies are themselves technically transgressive as demarcations between the mass media, voice and data transmission are eroded. The loosening of bureaucratic restrictions has led to the convergence of the telecommunications industry with the computer and entertainment industry. But, in a more fundamental way, these technologies have helped to undermine national and institutional boundaries; they have undermined established social hierarchies, moulding these hierarchies into lean organizational shapes and flat, geographical dispersed, structures* (2001:32).

The advantages of collaborations include the multidisciplinary set of skills that individuals bring to solving a particular problem. Collaboration with industry also brings with it much needed funding. In countries such as Germany, Japan and the USA, industry funding increased (in real term) between 1980 and 1988, with the USA showing the highest investment (from US$305 million in 1980 to US$816 million in 1988).

Understanding the dynamics of knowledge production under the new mode requires that one makes a distinction between economies of scale and economies of scope. Economies of scale are defined as "*the gains made possible by the combination of technology and organization in which the number of units of production or distribution increases while unit costs fall*"; while Economies of scope are defined as "*gains arising from repeatedly configuring the same technologies and skills in different ways to satisfy market demand*" (Gibbons *et al*. 1994: 51). Knowledge produced in Mode 2 is considered an economic good driven largely by competition. The authors argue that competition is good for knowledge production in Mode 2 as it leads to innovation. Furthermore, companies have to constantly improve their processes and skills in order to deliver a competitive product to the market. The authors also warn, however, that too much competition can lead to high volatility and uncertainty within the system. While economies of scale and economies of scope are distinct, the two are not totally independent of each other, as stated: "*increasingly economies* *of scale depend upon obtaining economies of scope which embody knowledge produced in Mode 2 in different parts of the production chain*".

Knowledge has therefore become an important aspect in wealth creation, to an extent that at times knowledge is considered more important than money in wealth creation. Gibbons *et al*. argue that there is a need for a theory that can explain this trend, i.e. "*how knowledge behaves as an economic resource*". Such a theory, they argue, can explain things such as "*economic growth, innovation, how and why the Japanese economy works, and also why newcomers, especially in hi-tech fields, can, almost overnight, sweep the market and drive out all competitors*" (Gibbons *et al*. 1994: 57).

3.3.2. Massification of research and education

The second driver behind the rise in Mode 2 is what has been called "massification of higher education", which became evident after the Second World War. Gibbons and his colleagues claim that "*a profound transformation of knowledge production inside and outside of universities is currently underway, one which both depends on and contributes to the progressive massification of higher education*". Some of the changes brought on by the transformation of higher education include the change in university curriculum, the modes of governance, sources of funding, the relationship between university and society, as well as the relationship between university and industry. Furthermore, research is no longer an activity for university professors only, but also involves people outside universities, such as those in the business sector. Thus, universities are losing monopoly over the production of knowledge. There are ten shifts in particular, that are becoming prominent within higher education since nineteen forty-five. These shifts are summarised below:

- **Diversification of functions**: universities no longer focus only/mainly on undergraduate teaching and postgraduate supervision as they take on non-traditional functions that are considered utilitarian in nature.
- **Social profile of student populations**: unlike in previous decades, universities are no longer dominated by male students who come mostly from privileged backgrounds, but have seen an increase in the enrolment of female students from various socio-economic backgrounds. The growth in female participation in higher education has played a major role in the reshaping of disciplines such as the human and social sciences. There is also greater diversity in the nature and types of jobs that graduates are taking up after leaving university.
- **Education for the professionals**: there has been a growth in disciplines that have a particular focus on business, such as management and accounting subjects.

- **Tensions between teaching and research**: universities are shifting their focus from teaching to research, forcing academics to also shift their ambitions if they wish to remain in academia. As a result, academics' number of scientific publications, such as journal articles and books, and the number of technological innovations, are valued more highly than the number of students trained, particularly undergraduate students.
- **Growth of problem-oriented research**: the character of research has changed, from the typical curiosity driven programmes to more specific focussed ones dedicated to solving a pre-identified problem. Specific research programmes are often funded privately, instead of by government, and may require both specialised equipment and skills.
- **Decline of primary knowledge production**: there is a decline in the production of primary data and ideas across research fields, and an increase in the re-configuring of existing knowledge. In the social sciences and humanities, for example, academics are moving away from publishing monographs to works of synthesis, such as edited books, which costs less to produce than monographs. Besides the high cost associated with the primary production of knowledge, academics are finding the process of re-configuration knowledge to be challenging and exciting.
- **Broadening of accountability**: because universities are now part of a bigger network which includes other research institutes, industry, government, and even the media, so too have their lines of accountability broadened. Universities are less autonomous than before, although they still retain important features such as the peer review process.
- **Technology for teaching**: historically, the teaching of (mostly undergraduate) students happened in a classroom with an academic physically present. The increasing use of ICT in higher education presents both an opportunity and a threat to the traditional method of face-to-face teaching: on the other hand, teaching via computers, videos and other technologies might encourage independent learning, but on the other hand, might create an "*alienating anti-humane environment or lead to mechanistic forms of learning*".
- **Multiple sources of funding for higher education**: for most countries, government will remain the main source of funding for research, while at the same time encouraging universities to obtain or leverage additional funding from the industry. Such a shift will contribute further to the "*growth of problem-oriented research*", and also escalate (unfortunately) "*tensions between teaching and research*".
- **Efficiency and the bureaucratic ethos**: the organisational structure, as well as the roles of faculties within the university, has changed. For example, university departments have large amounts of administrative duties and may no longer serve as intellectual centres.

3.3.3. Reconfiguring institutions

It has been successfully demonstrated in previous sections that the role of the university, most significantly its functions, is changing. University functions are now influenced by the society that the knowledge produced is meant to benefit, in other words its clients. Following the "massification of higher education", there has been an increase in the number and types of knowledge production sites in addition to traditional universities. For example, most governments in many countries have invested in the establishment of research institutes; companies are increasing their spending on R&D; and think tanks are becoming the norm. Universities are also creating small, spin off companies in disciplines such as electronics, telecommunications and biotechnology. Further, most of these sites, including universities and research institutes, have begun to sell their specialist knowledge to the market, as a way of earning extra funds for their research. In most cases, this is done through providing consulting services to the private sector.

Under the current changes, institutions, including those concerned with the funding of research, have to broaden their mandates. For example, in the early 1990s, the then president of the United State's National Science Foundation (NSF), Walter Massey, proposed that the NSF should "*expand its role, to play an even more dramatic role in improving society*". Thus, the NSF was to move away from supporting only researcher-initiated proposals, towards funding projects that are socially relevant and which will boost the US economy. Like in many situations, any proposal for change is often met with positive and negative reactions from those who will be affected. Some individuals and organisations supported the proposal, while the strongest objection came from academics who felt that such a change would "*shift resources toward development of new technologies*", which is the opposite of what NSF aims to achieve through its mission.

Another institutional-level change is the growing number of collaborations between scientists in different countries, and also between academics and the industry. As a result, individuals have faster and easier access to information or knowledge due to their cross-country and/or cross-sector networks. Universities are also beginning to participate in exchange programmes, which involve the movement of university staff and students between countries and also to private companies. In this arrangement, academics and/or students spend some time in another university of a different country or at a company, enabling them to gain more knowledge and skills. An added advantage of these collaborations, particularly with industry, is extra funding for the university.

Boundaries between university disciplines are becoming increasingly blurred, with disciplines such as biotechnology working together with biochemists, microbiologists and chemical engineers in addressing problems. The social sciences are another example where addressing problems require the involvement of more than one discipline. Universities are affected more by this shift compared to non-university institutions because university departments are often organised according to specific disciplines. Thus, the lack of clear boundaries affects the organisational structure of the university. This change, i.e. the collapse of disciplinary boundaries, is evidence of the emergence of a new mode of knowledge production, Mode 2, alongside the traditional mode, Mode 1.

The dynamics of knowledge production, some of which have been discussed here, present certain challenges to the universities. First, the university is losing the monopoly of being the primary site of knowledge production, and also for determining competence or quality in research. Second, due to the increasing number of individuals gaining access to universities, some of whom want to participate in the production of knowledge, universities are unable to meet the demand for funding. However, universities can overcome these challenges by, among other things, letting go of the monopoly over knowledge production, and thus welcoming and encouraging other sectors in terms of both producing knowledge and the funding thereof.

Quality control is an important characteristic of knowledge production. In Mode 1, the quality of research is judged by peers in the relevant discipline. However, with increased diversification and the collapse of disciplinary boundaries as discussed above, there are new dimensions of quality control, involving a variety of standards, as well as individuals from outside the university. This does not imply that quality in research is being compromised; instead, "*traditional scientific criteria will have to be qualified by other criteria which can claim equal legitimacy*". The issue of quality control under Mode 2 is a crucial one, and necessitates policy changes within the science system globally, which takes us to the final "driver" of Mode 2 knowledge production, namely "managing socially distributed knowledge".

3.3.4. Towards managing socially distributed knowledge

The implication of the diversity in knowledge production institutions is that the style of management and the criteria for quality control also had to change. The type of knowledge produced, thus the content of Mode 2, requires a different management style because it has also gone through transformation and differs from knowledge produced in Mode 1.

Individuals, particularly students, have to be advanced in their methods of accessing and selecting useful information from these various sources.

For a period lasting several decades, starting in the 1940s, science and technology policy went through different phases. The focus of the first phase was developing a "policy for science", and ensuring the growth of the "scientific enterprise". During this phase, scientists were the main authority over scientific matters. Further, different disciplines were treated and decided upon separately, with minimal to no transdiciplinarity. The 1970s ushered in a second phase, with scientists and policy makers both advocating for a policy shift, from "policy for science" to "science in policy" – where science formed a part of the strategy/plan to achieve policy objectives. Lastly, a third phase in the 1980s saw a growth in the connection between science and industrial innovation and competitiveness, through the development of a "policy for technological innovation".

The management of distributed, socially relevant, Mode 2 knowledge should be grounded on two factors: increasing permeability of boundaries, and brokering. Academics and institutions of knowledge production, particularly universities, should become more open to permeability and becoming a part of the broader network of knowledge production. "*The process of increasing permeability of boundaries weakens the centralising tendency of bureaucracy*" (Gibbons *et al*. 1994: 161). Brokering should become the responsibility of governments, given that they already have relationships with other governments or government agencies. In addition, governments will be able to provide the resources to support the process as "*brokering will demand exceptional skills because the individuals involved in the innovation process will come from different institutions and organisations, they will often be dispersed geographically and may only be able to work on a problem or project part-time*".

Over the years, governments have moved towards supporting innovation policy, rather than supporting science for its own sake. As a result, the development of a policy for innovation involves a more diverse team of people beyond politicians and civil servants, such as economists, marketing experts and industrialists. The "new" policy is people- and competence-centred, and requires different types of institutions of management. Gibbons and his colleagues emphasise:

> *The importance of developing policies that promote interchange among scientists and technologists and the general connectivity of innovation systems, possibly using information technology to exploit its knowledge base. The competence – the new skills and perspectives that emerge from these interchanges – is at least as important an outcome of this mode of*

> *knowledge production as the problems solved or the artefacts created. This implies policies that promote transdisciplinarity and provide for the possibility that unusual modes of organisation may be required: policies that promote international collaboration and that seek to be aware of, and be able to interpret, knowledge wherever it may be produced. People as the carriers of competence will constitute the main resource* (pp. 163-164).

The issues raised by Gibbons *et al*. (1994) provide a basis for the evaluation of research systems across countries, i.e. for determining the emergence of Mode 2, and its implications. The authors also provide some questions which will need to be addressed by countries individually and "implemented locally". Of most relevance to this study is the question of "the future of funding". Gibbons et al. claim that "*sources of funding will become increasingly diverse*". The current study, acknowledging that sources of funding for research have become more diverse, i.e. universities are no longer relying solely on government for support, will therefore take the further step of investigating the relationship between these diverse sources of funding and modes of knowledge production among academics.

In 2001, co-authors Helga Nowotny, Peter Scott and Michael Gibbons published the sequel to "*The New Production of Knowledge*", titled "*Re-Thinking Science – knowledge and the public in an age of uncertainty*". The central message of "*Re-Thinking Science*" is that "*Mode 2 knowledge production is emerging in the context of a Mode 2 society…*". The authors make the point that science and society no longer exist in parallel, that they have evolved in recent decades such that they benefit each other, or rather they "*speak back*" to each other. Other factors indicating the co-evolution between science and society include the emergence of many more parties than academics who are interested in scientific activities, for example industry and political authorities. In addition there are forces outside academia that can influence the direction of science, such as social, economic and political forces.

Besides the forces already mentioned above, the authors discuss other parameters that play a role in the "co-evolving process of science and society". These are "*the inherent growth of uncertainties, the growing influence of new forms of economic rationality, the transformation of time into the extended present, the flexibilization of space, and an increasing capacity for self-organization in both scientific and social arenas*". "Re-Thinking Science" did not receive as much attention within academia as "*The New Production of Knowledge*" did.

3.4. REACTION TO THE MODE 2 THESIS

Since the publication of the first book in 1994, the Mode 2 thesis has become popular within academia. Shinn (2002) conducted a study to determine the reaction of academics to the Mode 2 thesis by taking into account the citation count of Gibbons *et al*.'s book over an eight year period (1995 – 2002). From the citations of the book, Shinn determined who is citing the work (thus the audience and their respective disciplines), where the citations are taking place (geographical locations, and the journals where the work is published), as well as the impact that the book has had within the academic community. Up to July 2002, the publication had received 266 citations from regions such as Western Europe, United States and Canada. The journals within which the work has been cited include education, psychology, science policy, and the sociology of science and technology.

Among the main criticisms of the Gibbons thesis by Shinn are that: "*it lacks a theoretical referent, and it is not specifically connected to any conceptual framework such as that of Bourdieu; the approach is anti-differentiationist – it seeks to minimize or deny demarcations between academic, technical, industrial, political and social institutions. In this regard, the authors also do not acknowledge that academia, industry, and the state operate within a national setting; the book and concept seems tinged with political commitment (instead of theory or data)*". Shinn further states that *The New Production of Knowledge*, and its sister publication, *Re-Thinking Science*, "*can be likened to political manifestos, whose expository form is rhetoric*". Shinn concludes by stating that if publications of this nature are to "*contribute something enduring to scholarship and practice"* (Shinn, 2002: 612), authors should ensure that concepts and conclusions are well grounded in empirical studies. Otherwise, the publication will "*simply nourish an unproductive frenzy, and be little more than fleeting fads*" (Shinn, 2002: 612).

For the current study, a search was conducted on Thompson-Reuters's Web of Science and produced 20 relevant publications on the Mode 2 phenomenon. A similar search of the Scopus database produced 26 relevant papers[18]. All twenty articles listed on the Web of Science were also listed on the Scopus database. The search on both databases was restricted to papers that mention "Mode 2" in their titles. Inevitably, other publications with "mode 2" in their titles also came up during the search of both Web of Science and Scopus, although they were not referring to the "Gibbons Mode 2". Most of these papers were in the engineering discipline, such as a paper titled "Bi-layer, mode 2, four-arm spiral antennas",

[18]The searches were conducted on 12 August 2011.

published in *Electronics Letters*. The twenty-six publications listed on the Web of Science and Scopus databases are not a true reflection of the amount of publications on the Gibbons thesis, as revealed in additional searches from other sources such as library archives, journal websites, reference lists within published articles and, discussions with individuals. Using key words other than “Mode 2”, such as “modes of knowledge production”, also produced additional literature.

A closer look at the available literature revealed that some of the publications merely mention Mode 2 without making it the focus of the study, for example an editorial by Dr Stephen J Childe in the journal *Production Planning & Control* (2001). The one-page editorial titled “A *view of Mode 1 and Mode 2 knowledge production*” provides a summary of the main characteristics of Mode 1 and Mode 2, and concludes by inviting contributions from a wide spectrum of disciplines, including engineering, management, ICT, and industry in general, as well as contributions that focus on “*the policy debate on the future of our universities and the links between industry and academia*”. Only a small portion of publications present empirical evidence, while a larger number consists of reviews or commentaries.

While all twenty six papers (from Web of Science and Scopus) were reviewed for this study, detailed discussions are limited to studies that provide empirical evidence and those whose debates or critiques stayed close to the Gibbons thesis throughout the discussions. In cases where the article was written in a language other than English, only the English abstract was reviewed. In general, the literature on Mode 2 can be classified into (a) proponents and, (b) critics of the Mode 2 phenomenon. There are also studies that do not fit perfectly into either of the two groups, such as studies that show evidence of Mode 1 and Mode 2 co-existing within a single discipline, which will also be discusses. The remainder of this chapter examines this literature (all published between 1994 and 2011) in detail, in the same order below.

3.4.1. Proponents of the Mode 2 thesis

Most of the studies that support the Gibbons thesis are of a general nature in that they do not provide empirical evidence. An article by Fujigaki and Leydesdorff (2000), for example, focuses on the quality control characteristic of Mode 2. At the beginning of the article, the authors ask questions such as: *does Mode 2 differ from Mode 1 epistemologically or is the difference only contextual*? In addition, *how could it be possible for a different context to change the validity of a knowledge claim*? The article further introduces the concept of validation boundaries, which the authors indicate enables us to understand the issue of the quality criteria of different audiences.

Fujigaki and Leydesdorff (2000) argue that before conducting quality control in both Mode 1 and Mode 2 knowledge, it is important that a system of reference is specified. In Mode 1 knowledge production, quality control involves peer review, usually during the process of submitting a manuscript for publication in a journal or in a book. During the peer review process, the manuscript can either be accepted or rejected, and "*this accepted-rejected action recursively constructs the validation boundary of knowledge-production*". The peer review process is maintained by the scientific community. The validation boundaries in Mode 1 (which involves the peer review process maintained by the scientific community, and hence pertain to scientific excellence), "*play a role in controlling quality in scientific work at the level of the disciplinary fields and specialities*". Scientific excellence can therefore be judged independently of "relevance for users", which is important in Mode 2.

On the other hand, Mode 2 knowledge production does not have to follow the strict peer review process used for Mode 1 knowledge. In this case, quality control or the validation boundary for Mode 2 knowledge involves a different community, i.e. the public, and knowledge is produced to solve a pre-determined problem. In some cases, quality control for Mode 2 is first based on the criteria used for Mode 1 research, such as the peer review process. However, the authors warn that "*this arrangement can lead to serious problems in the case of Mode-2 research. For example, Mode-2 researchers may be eager individually to produce publications in order to earn Mode-1 credit. Their achievements in terms of the numbers of publications may still function as a key to their future careers*".

Quality control in Mode 2 has to consider two points of reference: market forces, and problem solving in the public sphere. Market forces involve the commercialisation of scientific knowledge and thus the evaluation of knowledge by the market. The success of the product, i.e. knowledge, may depend on how well the Mode 1 aspect of scientific excellence is combined with the user orientation under Mode 2. In some parts of the globe, public funding is increasingly directed at projects that demonstrate this combination (scientific excellence and user orientation), and such projects can be found in chemistry and biotechnology, to name just a few. Problem solving in the public sphere, on the other hand, is concerned with providing solutions to problems that affect the general public, such as setting standards for the disposal of harmful chemicals in ways that will not harm the environment.

Since quality control in Mode 1 and Mode 2 knowledge is done by different communities with different validation boundaries, it is important to foster communication between the two to ensure that both modes deliver quality knowledge to their audiences.

Jacob (2001) believes that recent changes within the science system, such as the lack of adequate public funding for research and the pressure on academics to produce socially relevant research, is a cause of the rise of the Mode 2 phenomenon. However, the author cautions that while most of the Mode 2 attributes are genuine, they should be accepted with reservations. The study investigates the “institutionalisation” of the Mode 2 thesis in European universities, and the challenges thereof. Two case studies were conducted, titled “the emergent Mode 2 institute (Case A)” and “the policy assisted Mode 2 institute (Case B)”.

Case A is based on a small, seven year old research institute. The institute is used as a think tank for policymakers from academia, government and international organisations. The institute has no external source of funding and thus derives its funding from the research conducted in-house. The management and leadership functions for the institute take place both at the university with which it is linked, and the institute. For example, the majority of the administrative work is done at the university, while the institute manages the daily activities.

Case B concerns a four-year programme focusing on research and education in the field of management. Funding for the programme is provided by a public funding agency and industrial partners. The main focus of the programme is the provision of doctoral education to part-time students. Unlike Case A, Case B is a short-term programme with a fixed timeframe. The paper further looks into some of the challenges encountered in the management of both the research institute and the research programme.

First is the challenge of leadership which was evident in both cases. Jacob reminds the reader that leadership in academia has always been secondary to what is considered the core business of the sector, i.e. teaching and research. Generally, academics have a fear of compromising their research career by taking up leadership/management positions. While this can be true in some cases, sometimes it is simply a matter of perception by colleagues. An example used by Jacob to demonstrate this point occurred in Case B, where an academic-turned-manager was faced with resistance from colleagues as a research manager because he was not considered an experienced enough researcher to give directions. On the other hand, the same individuals who refuse to be managed by someone "inferior" did not want to accept management positions because they "are not interested in the day-to-day management" of the programme. This creates a dilemma for those who would like to see the programme succeed.

The second and third challenges were the interface between the institute/programme and the university, on the one hand, and funding agencies, on the other. For example, institute-based and university-based researchers engage in relationships that benefit both parties with regard to the supervision of post-graduate students. However, the success of the relationship may depend on the reputation of the individuals involved, such that if an academic has a poor reputation (as a researcher), other academics may not want to work with him/her. The relationship between researchers and their funders is an important one for Mode 2 projects, where funding is tied to pre-determined conditions agreed upon by both parties (the funder has as much interest in the success of the project as the researcher). Furthermore, academics need to become good entrepreneurs to attract funding from sources other than government.

Harloe and Perry (2004) add to the body of literature that suggests that the university has transformed in recent years, partly as a result of social and political pressures, and that the "new" university has taken on roles in addition to teaching and research. Key characteristics of this new university, which the authors are calling "a Mode 2 university", are that: "*it is closer to government and the market and is more directly responsive to national and regional needs in teaching, research and specific enterprise activities; it conducts research in an interdisciplinary fashion and according to new criteria such as economic and social relevance; it is innovative and interacts in a number of different networks and it is a key player in evolving systems of regional and local governance; changes in mission and practice are accompanied by internal turmoil, reorganisation and restructuring*" (Harloe and Perry, 2004: 217).

Market demands also add to the social and political pressures facing universities, as they need to add the commercialisation of research and teaching activities to their mandate. The growing need for commercialisation adds to competitiveness in the system. Another development in the system is an increase in the share of private funding for university research, partly due to diminishing public funding. However, in most cases private or industry funding is linked to the production of knowledge which is socially relevant; involves partners from outside the university, i.e. from industry, government or the community; and involves different criteria for quality control from that of traditional, Mode 1 knowledge production. In this regard, Harloe and Perry (2004) state that "*the increasing recognition of science's capacity for economically productive innovation involves a movement from support for 'basic' or 'pure' scientific research whose evolution is determined by the 'advancement of knowledge' and whose direction is controlled by (mainly academic) scientists, to support for research that is closely linked to societal priorities*". The article also highlights that there is division among the academic community on the issue of commercialisation. On the one hand, there are studies that support commercialisation of research and argue that this has benefits for disciplines such as informatics and biomedical research, and also benefits the university as a whole. On the other hand, some studies highlight the negative impact of commercialisation on the quality of research; on academic freedom; and on "*the loss of the uniqueness of the university as an institution*". These studies argue that some researchers tend to focus on the commercial benefits of the project rather than the academic contribution to the advancement of knowledge.

In addition to the expanding role, the university is no longer the main site for knowledge production. Government research institutes and the private sector are growing as sites of knowledge production alongside the university. Therefore the university is beginning to lose the monopoly it once had in the system. These changes within universities affect the culture and internal organisation of the institution, and require both academic and administrative staff to possess a different set of skills.

Having acknowledged that more empirical work is still needed to fully understand the dynamics of the Mode 2 thesis, the authors conclude their debate with questions such as: "*are scientific practices being transformed by changing socio-economic conditions? Are universities actually becoming 'Mode 2' institutions? Is 'Mode 1' science being eclipsed or is there some new accommodation between 'pure' and 'contextualized' research? Can investing in the knowledge base really make the difference to wealth creation and growth that is anticipated and, if so, at what cost*"?

Harvey *et al.* (2002) present findings of a case study that looked at the characteristics of research groups in the United Kingdom (UK), and determined if these characteristics could be categorised as Mode 2. While universities and public research institutes in the UK are the main sites of knowledge production, not enough work has been done to determine how research is organised inside these institutions, particularly universities. Furthermore, public funding for research is awarded selectively to a small number of universities which are deemed to be the most productive in terms of research outputs. This form of selective funding has resulted in an increase in academic entrepreneurship in recent decades. Consequences of academic entrepreneurship include what the authors call "shop windows", which they define as "*configuring expertise to meet funding opportunities*" (also see Mitev & Venters (2009).

The article presents exploratory case studies of research groups in the health sciences. Data was collected by means of a questionnaire-based survey. Participants were requested to provide details on "*grants and fellowships generated from regional sources and their outcomes and impacts in terms of such factors as: generation of subsequent grants and fellowships, publications, contribution to individual career and research group development, and scientific impact*". Based on the outcome of the survey, "high impact groups" with a high number of articles in refereed journals, as well as a high number of high profile academics, were selected for case studies. The most recent UK Research Assessment Exercise (RAE) ratings, and the amount of competitive research funding obtained by the group, were also considered as criteria for inclusion of the group in the study. Four case studies were conducted in the following areas, all of which have a university link or affiliation: Endocrinology Department, Genetics Department, Primary Care Department, and Orthopaedic Hospital.

The study found that there are at least five factors that determine the success of a high-achieving/high-impact research group. These are: *strong leadership; finding, motivating and retaining talent; strategies of related diversification; strongly linked theory and practice; and network connectedness*. Strong leadership was found to be critical in terms of providing strategic direction for a research group, both within and outside of the group (see also Ferlie and Wood, 2003). The group leader is also key in establishing a vision for the team, and developing new ideas. In addition, good leaders ensure that there is innovation within the team, and also pursue different avenues for generating much needed funding. It is also the role of the group leader to build collaborative relationships (what the authors call network connectedness) both nationally and internationally. The study also found that a strong leader has to be able to adapt his/her leadership style as and when the situation or environment demands. For example, strong leadership in the current era demands that a leader be an entrepreneur because they "*now have to interface with a more business-oriented and complex environment*".

The second factor is *finding, motivating and retaining talent*. The study found that high performing research groups comprise "hand-picked" individuals. Targeted individuals are also used as "product champions" within a group, particularly within Endocrinology and Primary Care, and these champions take the lead in developing thematic groups in both departments. The availability of adequate research funding (or the lack thereof) was cited as a critical component of finding, motivating and retaining talent in research groups. In recent years, researchers are spending a significant number of hours preparing funding proposals.

Third, *strategies for related diversification*, are understood to ensure continued coherence in the research portfolio, maintains critical mass in addressing research problems and facilitates effective research outputs under the UK RAE. It is important, however, that organisations that seek to diversify should identify their strength and capabilities in the area they wish to venture into. In Endocrinology, for example, diversification happened during the search for additional funding, when this group of researchers had to search for funding from donors outside their area of specialisation.

Forth, *strongly linked theory and practice* makes reference to the positive collaborations between scientists (academics) and practitioners (clinicians). The relationship between scientists and clinicians is symbiotic, and thus benefits both parties by allowing them to work in areas they would otherwise not be able to.

The final factor determining the success of research groups is *network connectedness*, or building collaborations both nationally and internationally. The benefits of networks include: the opportunity to create social and intellectual capital; the opportunity for academics to access additional research and skills that they do not have within their own group/department; the opportunity to work in inter-disciplinary projects, presenting even greater opportunities to innovate; and the opportunity to share technical knowledge with others. These five factors are interrelated, and further research is needed to explore the nature of their relationship to one another.

Heimeriks and colleagues (2008) investigated the role of ICT in facilitating characteristics of the Mode 2 phenomenon in eight scientific fields across European universities. The study, which contained web-based data on the size, content and outlinks of university websites, had the following three hypotheses: Hypothesis 1 – Mode 2 sciences make more extensive use of internet and web applications; Hypothesis 2 – Mode 2 sciences are characterised by a greater variety of outputs disseminated through the web; and Hypothesis 3 – Mode 2 sciences address a greater variety of audiences through the web. The eight fields considered for the study were divided into Mode 1 and Mode 2, with Mode 1 fields being

Astrophysics, High Energy Physics, Literature Studies, and Psychology, while Mode 2 fields were Biotechnology, Computer Science, Genetics, and Information Science. The authors conclude that "*the web does play an important role in facilitating the Mode 2 characteristics of knowledge production: in sharing data and information, in showing the network of the research organisation, in supporting the interaction with non-academic partners, and in the dissemination of output*" (also see Costa, 2000). Data revealed the following results: half of the scientific fields made use of the internet to a large degree, i.e. Astrophysics, High Energy Physics, Computer Science, and Information Science, while the other half makes lesser use of it; there was no direct relationship between the website content and Mode1/Mode 2 fields; and there were differences between fields in terms of their linked organisations i.e. whether they were linked to private companies or universities (their audience), but again, the differences were not along the Mode1/Mode 2 line. For example, while it could be expected that fields such as Biotechnology, Computer Science, and Information Science would have greater links with private companies than with universities (due to their economic role), the study also found similar links with the field of High Energy Physics. All three hypotheses were therefore not supported by the data.

3.4.2. Critics of the Mode 2 thesis

The critics of the Gibbons thesis comprise of those that present a general argument and those that present more specific arguments that are supported by empirical evidence. One of the earlier, more general critiques of the Mode 2 thesis was by Peter Weingart (1997). While Weingart (1997) agreed that changes are taking place in science, he argued that authors of the Mode 2 thesis do not give substantial depth to their claims (backed by empirical data) and therefore tend to "dramatise" them. Weingart's argument is that the Mode 2 thesis is not a new thing, and that the so-called new mode of knowledge production has been in existence since long before the nineteenth century. In his review, Weingart made reference to the German and French science systems, to determine if they exhibit any signs of Mode 2 attributes, and in what format they might manifest.

On the issue of heterogeneity, Gibbons *et al*. state that more sites of knowledge production are emerging alongside traditional universities, and that these sites, such as research institutes, industrial laboratories and think tanks are becoming important sites of knowledge production. However, Weingart (1997) argued that this is not true. He also made the point that Gibbons and his colleagues fail to indicate which national science system they used as a reference for their claims. For Weingart, "*historically, universities were relatively late in becoming the most important institutions of research*". Germany and France, for example, had both witnessed an increase in research taking place outside university structures since the mid-nineteenth century and beyond. Furthermore, two-thirds of the total research produced in Germany can be attributed to industrial research. Asking whether the increase in industry research for the university will affect the way university research is conducted, he found that some universities that were concerned by this development, e.g. Harvard and Stanford (when they established their first industrially funded laboratories), have since observed "*a surprising resilience of traditional academic forms of knowledge production and, on the other hand, a growing competence on the part of the universities in marketing that knowledge*".

As for the "new" sites of knowledge production such as think tanks, Weingart concluded that they have a place in which they operate, which he calls "the transfer zone", but have no capacity to take over the role of the university. According to Weingart, what has been interpreted as a change in the organisation of research is "*primarily an indication of the expanding role of knowledge in social, political and economic areas of activity*".

Gibbons and his colleagues define a transdisciplinary project as one that involves researchers from more than a single discipline, and that disciplinary boundaries are becoming less rigid. However, Weingart indicated that "*the enormous specialization and recombination of specialties is a process which has been unfolding within the framework of Mode 1, i.e. academic science, and within the traditional disciplines ever since the emergence of disciplines in the 19th century*". Weingart further indicated that the Gibbons thesis lacks a definition of disciplines and their operationalisation, which is important in determining the degree of specialisation. Similarly, Lenhard *et al*. (2006) argued that "*the relevance of Mode 2 science does not imply the weakening of its disciplinary structures, and that transdisciplinarity and robustness may involve strong disciplines"*.

Quality control is yet another criterion which is apparently changing within the new mode, bringing with it a wider range of criterion than it was the case in the traditional one. The quality of Mode 2 research is determined by factors such as social relevance, political relevance, marketability and others. However, the criteria of marketability and cost effectiveness, for example, have always been considered as important in judging the quality of industrial research. In an article entitled "*The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations*", Etzkowitz and Leydesdorff (2000) supported Weingart's argument, pointing out that "*the so-*

called Mode 2 is not new; it is the original format of science before its academic institutionalization in the 19th century".

Godin and Gingras (2000) also contested the claim that, due to the emergence of other sites of knowledge production such as think tanks and the growth of the private sector (as a knowledge producer), the university will become a less significant partner. Gibbons and his colleagues state that "*in the future the institutions of higher education, the universities, in particular, will comprise only part, perhaps only a small part, of the knowledge producing sector. They are no longer in a strong enough position, either scientifically, economically or politically, to determine what shall count as excellent in teaching or research*" (Gibbons *et al*. 1994: 85).

The authors conducted an analysis of the Canadian bibliographic database over the period 1980 to 1997. Journal articles, reviews and research notes were reviewed and assigned to various sectors on the basis of the authors' address, i.e. university, industry etc. While it is accepted that the sites of knowledge production have diversified over the years, the results do not support the Gibbons *et al* claims. The bibliometric study revealed that there had been an increase in collaborations between the university and other sectors from 1980 to 1995, and that the university was an important part of these collaborations. In fact, it was the other sectors that relied on collaborations with the university (to benefit from the scientific research), and not the other way round. The authors conclude that "*universities are thus more than ever at the heart of the system of knowledge production*", and that none of the other partners are sidelined in any way. This finding was also supported by Fujigaki and Leydesdorff (2000), who state that "*the university provides a 'laboratory' of knowledge-intensive development, while being at the same time the main reproductive 'function' of this system*".

MacLean *et al*. (2002) provide a review of the mode of knowledge production in the management sciences. They argued that argue that management research has been in Mode 2 format for many years, even longer than some disciplines in the natural sciences. Attributes such as problem solving are said to have been evident in management research before the Mode 2 debate started. The authors considered a project in which all five Mode 2 characteristics occur, i.e. knowledge produced in the context of application, transdiciplinarity, heterogeneity and diverse organisation of research capability, social accountability and reflexive processes, and, a diverse range of quality control. They called this a 5mode2 project. The project was conducted on behalf of the Scottish Health Advisory Service

(SHAS), an organisation dealing with the auditing of healthcare provision to care groups in Scotland. The care groups include those dealing with mental health, the elderly and people with learning disabilities, and audits are led by a member of a small core team together with 6-8 reviewers. The auditing process involves a day of orientation for the team and a week-long visit to the healthcare provider being audited and is followed by the writing of a report to be submitted to the relevant health board.

Although the workings of SHAS were considered to be successful, the management processes of the organisation, which were considered "*informal and person-dependent*", were coming under scrutiny. Furthermore, it is reported that the Chief Executive Officer of SHAS "*felt that there was a clear need to transform working practices so that key decisions and initiatives were less critically dependent on her direct involvement*". As a result, there was a consensus among the team that there should be changes in terms of the external identity and internal processes. The focus of the project was therefore "*the strategic transformation of SHAS, both internally in terms of its management processes, and externally in terms of its desire to leverage core capabilities, enter new areas and increase the breadth and depth of its service delivery*". The authors investigated evidence of Mode 2 attributes in the project, as shown in Table 3.2 below.

Table 3.2. Evidence of Mode 2 attributes within the Scottish Health Advisory Service (SHAS) project

Mode 2 Attribute	Evidence of Mode 2 in SHAS project
Context of application	There were continuous negotiations between the role players in the project, ensuring that the project continues to meet practical objectives.
Transdiciplinarity	Research for the project incorporated three theoretical frameworks, i.e. management theory – concerned with *what* SHAS did previously; complexity theory – concerned with *how* the changes within SHAS came about; and psychoanalytic theory – trying to answer *why* these changes occurred.
Heterogeneous	The project team comprised of individuals with different skills and areas of specialisation. For example, it included people specialising in IT, team-building, public relations and business planning.
Social accountability	The project had several lines of accountability, through formal and informal structures. The project reported to the senior Minister of the Scottish Executive, and was constantly under public review through the media.
Quality control	Mode 2 projects involve a diverse range of quality control. In the case of the SHAS project, the authors considered "*the willingness of practitioners to pay directly for [the] research as one sensible diagnostic of the value which they attach to the process. Receiving full payment usually signals that the detailed terms of a problem-solving contract have been met*".

The presence of these five attributes in the SHAS project revealed three things: first, that Mode 2 attributes are "*overlapping facets of a single dynamic*", and therefore occur simultaneously in a single project. Second, it became clear as the project evolved that its success would be dependent on a heterogeneous team bringing different set of skills. Lastly, the project revealed that "*there is a cumulativity of issues and outcomes at work across projects...and it is precisely this cumulativity which provides both the academic and practical benefits which derive from Mode 2 research at the level of substantive content (as opposed to process)*" (MacLean *et al*. 2002: 201). The authors conclude by stating that "*we believe that 5mode2 has much to offer both the academic and practitioner communities, but that a serious debate about the epistemological nature of management knowledge, with a more open embrace of constructionist perspectives than has been the case to date, should increase in priority*" (MacLean *et al*. 2002: 203).

In Canada, Albert (2003) studied the research pattern of academics in sociology and economics at two Quebec universities, i.e. Université de Montréal and Université du Québec à Montréal. A further aim of the study was to test two models, i.e. the Entrepreneurial Science and the Mode 1/Mode 2 models. Two cohorts of academics were considered, those who were granted permanent professorship during the period 1974 and 1983, and those granted the same between 1989 and 1998. The first time period considered in the study marked the onset of the need for university professors to collaborate with industry, while the pressure to collaborate in this manner started to manifest in the second period.

The author collected data through interviews, and supplemented this with information from the professors' Curricula Vitae (CVs). The CVs, as the author points out, gave insight into the academic's publication pattern prior to being awarded the professorship, and thus enabled the author to determine if there had been any change in the pattern after being awarded the professorship, as well as the direction of the change. The findings of the study revealed that researchers in economics engage in what the author called "Production for Producers". Research in economics is therefore aimed at peers in the field and is subjected to the peer review process typical of academia. There was no evidence that economics research was moving towards the problem solving side (Mode 2). Instead, data showed that quality control measures have become more stringent regarding research produced for peers. In addition, those researchers who wished to make their research socially relevant seemed to focus first on Mode 1 type research (production for producers) to ensure their scientific legitimacy. Only after they had secured their position as scientists did they move towards research that responds to the needs of society, but without neglecting the research for peers in the discipline. In a similar fashion, researchers in sociology showed an increase in knowledge production for producers.

While Dominique Pestre (2003) agreed with both Gibbons *et al*. (1994) and Nowotny *et al*. (2001) that there are changes in the way knowledge is produced, i.e. that science is increasingly taking into account the interests of society, and in some cases, society is involved in the production of knowledge, his view was that the comparison between Mode 1 and Mode 2 as presented by Gibbons *et al.* "*may not be the most interesting contrast in historical terms*". Furthermore, the contrast between Mode 1 and Mode 2 attributes paints "*an overly-optimistic vision of the changes affecting science and society today*".

While the Gibbons thesis implies that changes associated with the new mode are recent occurrences, Pestre pointed out that scientists have been engaging in what can be classified as Mode 2 knowledge production for many centuries. For example, during the sixteenth century, the knowledge produced from disciplines such as mathematics, astronomy, navigational science, surveying and geography was used to respond to social, political and economic challenges. Similarly, European researchers have been producing socially relevant knowledge since as early as the eighteenth century, particularly in disciplines such as natural history and agronomy. The most significant changes in the system started in the late nineteenth century (and continued well into the twentieth century) during the emergence of the techno-science era. Scientific disciplines such as chemistry, pharmacy, bio-technologies, electronics, and materials science formed a large part of solving societal problems during the twentieth century. Other shifts that occurred during the twentieth century included the establishment of new sites of knowledge production outside the university, such as industrial laboratories, followed by increasing collaborations between the university and these sites.

The author also argues that science has formed a part of decision making in many developed states such as Europe and the United States of America. For example, science has been central to national security and economic development for these countries.

Pester (2003) identified two critical features of current society and science, which the Gibbons thesis does not consider: first, "*the reassertion of power by big business and financial capital, resulting in the reversal of many processes of social protection that have taken a century and a half to develop*"; and second "*the emergence of new, influential social groups (generally composed of younger, educated people), which have developed new* *values and modes of social action*". These features bring other elements to the way we interact with our environment, for example, the increasing use of technology (such as ICT), which often leads to a faster pace of work resulting in the risk of engaging in projects "*prior to an analysis of their long-term consequences*".

The author further argues that debates around knowledge production are not only technical and organisational, but also political. 'Political authorities' are central to ensuring social accountability in knowledge production. In addition, there is a call to involve the 'laymen' in the entire process of producing knowledge. Pestre qualified this call by adding that "*knowledge benefits by being tackled from various angles; that collective elaboration outside the confines of academic or industrial science is a guarantee of plurality and promises a better social outcome; and that the point of the exercise is not just to have a pronouncement of true scientific knowledge and then work to have this 'understood' by ordinary people*".

Another study found no evidence of a shift in mode of knowledge production among researchers. Surveying Norwegian researchers based at a university, in industry and at research institutes, Gulbrandsen and Langfeldt (2004) tested three hypotheses.

Hypothesis 1 was: "*criteria governing research are changing as academic researchers find themselves confronted by new demands and expectations*". Data was collected via interviews, and academics were requested to define their research as basic, applied or developmental. Some of the interviewees felt that there is a clear division among these three modes of research, with scientists in industry being associated with development research, institutes associated with applied research, while the university is associated with basic research. These three modes were also found to utilise different evaluation criteria in judging quality research. Applied research, for example, has to have a "practical utility" to be considered good research, while practical orientation is not as important in basic research. Industrial and institute scientists felt that academics produce good research that do not have any practical application, and pushing for practicality "*could lead to a lowering of originality and poorer research training*". Some of the academics interviewed, however, indicated that their research has to have some level of "utility value". Academics holding this view included social scientists and anthropologists working in collaborations with private companies. The majority of respondents agreed on what constitutes good science, namely, solidity, which incorporates well founded conclusions, thoroughness and patience; originality, which incorporates novelty; and scholarly or social relevance, incorporating cumulativity and generality. The findings of the study thus did not support the hypothesis but, while there was not enough evidence to demonstrate significant changes in the criteria used to govern research, it did seem that scientists are beginning to re-think the way they do research, particularly at universities.

Hypothesis 2 stated: "*there is increasing convergence between the criteria for the support and justification of basic research, industrial research and applied research*". Results in this regard showed no evidence of convergence, with differences between the three sectors. In particular, the differences were on how each of these sectors define and place emphasis on relevance and focus. In the university sector, for example, scholarly relevance takes precedence over any other criterion, while practical application and social relevance is important to industry and research institutes. Industry and institutes showed more similarities to each other than either of them did to the university. For both these sectors, good research is defined by how well they meet the demands of their clients. This, however, seem to be as far as the convergence between industry and institute go. Scientists expressed a concern that there could be an emergence of a "forced convergence" particularly on the part of the university sector, through factors such as inadequate government funding, which would force academics to conduct research for industry in pursuit of financial gain. The authors also suggest that "*the current trend in Norway is a slow increase in funding for basic research, accompanied by cuts in user-controlled programmes*". Furthermore, academics in tapplied fields question the reasons behind government spending on basic research, which does not have any immediate benefit to society, while practical research does not receive the same support. Applied research in Norway continues to rely primarily on private funding.

The third and last hypothesis was: "*without the construction of new criteria for research assessment, new modes of knowledge production will not take place*". Interviewees from all three sectors were asked to outline the criteria they use for reviewing a paper for publication in a scientific journal, for evaluating a project proposal (for funding), and for assessing a candidate for promotion into a senior position. While there was no difference in the way these sectors reviewed papers for publication, applied sectors, i.e. industry and research institutes, allocated more weight to the practical outcomes of the project and less to scholarly relevance and theory. Expert opinion in the evaluation of project proposals was considered important across all sectors, while there were differences in the criteria used to select individuals for senior positions. Social and communication skills were among the qualities required to hold a senior position in both industry and research institutes.

Joan Ernst Van Aken (2005) published a paper following a proposal by academics in management sciences that the discipline should incorporate Mode 2 attributes. Of particular concern for management researchers, as for marketing and accounting researchers, was the aspect of relevance, which had been a problem for many years. The aim of Van Aken's study was "*to support the call for more Mode 2 research in management by articulating the nature of the resulting Management Theory and its use in actual management practice*".

The author pointed out that previous discussion on the use of Mode 2 knowledge production in management research focused on the research process and less on the knowledge produced, i.e. the product. Furthermore, some studies have reported tensions between collaborating partners, i.e. academics and practitioners, regarding the way projects should be conducted in the management sciences (Burgoyne & James, 2006; see also Mitev & Venters, 2009; Swan *et al*. 2010). Three approaches are suggested through which management research can be made relevant: (a) by improving communication with practitioners (about the products), (b) by looking at the production process, and (c) by looking at the nature of the products. To illustrate the point further, Van Aken split the management science discipline into two, i.e. design sciences (medicine and engineering), and the explanatory sciences (natural sciences and sociology). Research in design sciences is aimed at enhancing understanding and improving human performance. It is also solution oriented. On the other hand, research in explanatory sciences is pursued in the quest for truth. The study concludes that the field of management research is not yet a design science, i.e. research conducted in this field is not solution oriented. This is not to say that the situation cannot change, and that management research cannot aim at providing practical solutions; all it takes is a change in attitude of knowledge producers in the field, and time.

3.4.3. A mix of Mode 1 and Mode 2 knowledge production

Among studies that are neither largely supportive nor critical of the Gibbons thesis is that by Ferlie and Wood (2003), which investigated "*how [academics/researcher] produce knowledge and how they link to consumers*". The study aimed to address four issues: *whether university-based health services research in the UK resembles Mode 1 or Mode 2*; *the linking strategies of research group leaders*; *how the flow of finance shapes knowledge production*; *and, development and dissemination strategies in use*.

The primary source of funding for health services research in the UK is the National Health Service (NHS), and research in this field is produced by academics. Ferlie and Wood (2003), used qualitative and quantitative methodologies, i.e. semi-structured interviews; attending meetings and symposia; analyzing archival material, documents and field notes, to collect data for case studies on four research units/groups: health and social care; cardiovascular investigation and research; primary care research; and health informatics. Three of the four units were university-based, while the fourth, i.e. cardiovascular investigation and research, was based within a teaching hospital.

Results were divided into four themes. First, the study found that health services research in the UK comprises a mix of Mode 1 and Mode 2 output criteria. Academics still worked according to strict protocol, and published peer reviewed journal articles (Mode 1). In addition, research that would add to the pool of knowledge was viewed as very important. On the other hand, Mode 2 attributes were evident in terms of the managerial authority and consumer demands, among other things. Furthermore, academics in health services viewed factors such as liaison with users; improvements in service delivery; collaboration; and incorporation (of research) into policy guidelines, as being very important.

Second, the study showed that it was important for academics in health services to build relationships with individuals and institutions outside academia (Mode 2). All the directors of the units surveyed were collaborating with external stakeholders, such as health care practitioners and private companies. Furthermore, the units obtained some funding from the non-academic partner. In this regard, the authors indicate that "*partnering secures access to different forms of knowledge and finance as well as non-academic endorsement*".

Third, the study looked at external funding as a powerful driver of research in health services. There is increasing demand for public funding of research groups in the UK. The panels reviewing proposals for funding from the NHS consist of academics and practitioners, hence the proposals need to demonstrate both academic quality/good scholarship, as well as relevance to policy and practice. In addition, the 'funder' tends to influence the research agenda for the projects, rather than allowing the researcher to determine the goal for the project. Mode 1 outputs, such as the number of publications in peer reviewed journals, are also considered for the awarding of private funding.

Lastly, some respondents to the survey indicated that the dissemination of health services research is very important. Dissemination activities included here are: *building local ownership for research findings; customisation of feedback for different user groups; the employment of multiple engagement strategies; and academically led dissemination*. The authors further add that "*in Mode 1 terms, health services research may be a high-input, low-output form of research*". In terms of the five Mode 2 attributes, the findings can be summarised as demonstrated in Table 3.3.

Table 3.3. Attributes of Mode 2 in the health sciences

Does research in health sciences demonstrate…	Yes/No	Mode 1	Mode 2
Research problems framed in the context of application	Yes		√
Trans-disciplinarity	No	√	
Diffusion occurring in the context of production	Yes		√
Heterogeneous teams of researchers	No	√	
Socially and politically accountable knowledge production process and output	Yes		√

The study concluded that "*there is a mix of Mode 1 and Mode 2 in university-based health services research in the UK, and any mode 2 pattern is as yet only partially evident*".

Prpić (2007) studied the Croatian research system to determine the changes (if any) in the mode of knowledge production as well as changes in the scientific productivity of Croatian researchers. In particular, the author examined three dimensions of knowledge production, namely, "*the division of research work and the distribution of influence on research projects and in scientific institutions; the commercialization of research; and researchers' social networking or capital*". The Croatian research system is said to be in a "transitional" stage. Compared to developed countries within Europe, transitional countries such as Croatia have a far less developed science system, which is evident in the (inadequate) level of public funding available. However, Croatia seems to be in this "less developed" position as a result of historical events. As Prpić puts it, "*the transformation of the Croatian research system started in extremely unfavourable social conditions which are made even worse, compared to other transitional countries, by war destruction, the dramatic erosion of economic activities, socially problematic and insensitive privatization, and the formally democratic political system whose level of democratization was nonetheless insufficient*". The research system of the country not only suffers from low funding, but also a low number of researchers.

The survey-type study was based on data collected via questionnaires during 1990 and 2004. The participants' research productivity was assessed over two time frames – throughout their career and the most recent five years. The findings of the survey showed that the Croatian research system experienced an increase in applied research and a decrease in basic research during the period 1990-2004. Eminent researchers tended to engage in basic research more than other groups of researchers, for example young researchers. On the distribution of research projects, the study found no significant difference between young researchers and other groups, including eminent researchers. On the commercialisation of research, results revealed that there is very little commercialisation taking place within the Croatian system, with "*just one commissioned project per researcher in the course of five years*". Furthermore, the amount of commissioned research had decreased between 1990 and 2004 (thus, there was more commissioned research in 1990 than in 2004).

The third component investigated Prpić (2007) study was researchers' collaboration efforts (i.e. social networking). The survey considered collaborations with both local and foreign researchers. The number of collaborations between Croatian researchers increased since 1990, with a mean of 3.35 in 2004 (from 2.54 in 1990), while the mean for foreign collaboration was lower at 1.33 for 2004. No significant differences were found in researchers' productivity throughout their career as well as during their most recent five years. The productivity level of Croatian researchers is much less than that of researchers in developed countries, with an average of 1.7 publications per year compared to 3 on average per year for Norwegian researchers and 2.2 for American researchers, for example. Other significant changes that have taken place over the fourteen years period include the rise in the number of co-authored publications, and also the average number of publications on the international platform such as journals and books. The author attributes the increases to "*the introduction of more demanding criteria into the system of researchers' scientific promotions, as well as legal provisions on the termination of employment in the event of failure to advance to a higher scientific rank within a set timeframe*".

Based on the findings of this study, the Croatian research system shows some evidence of a change in the mode of knowledge production, for example through the increase in the number of collaborations, which could lead to increased heterogeneity of projects. On the other hand, aspects such as the de-commercialisation of Croatian research show that the opposite is also true. It is perhaps safe to conclude that the Croatian research system is still in a transitional phase and the focus is more on the production of knowledge and less on how it is produced.

3.5. IMPLICATIONS OF MODE 2 THESIS

There are several implications of the new mode of knowledge production for the science system and, most importantly, for the role of the universities. Several authors argue that the traditional role of the university, that of teaching and conducting research, has undergone certain changes in recent years. However, it can also be argued that the role of universities is not changing fundamentally, but simply diversifying. Thus, universities are adding on new roles such as increased interactions with industry and a focus on intellectual property rights (which ultimately lead to the commercialisation of research products) while keeping their teaching and research responsibilities. The issue therefore becomes whether or not universities can maintain quality teaching and research while at the same time developing the emerging "focus areas", or if the new roles are developing at the cost of the traditional ones. The commercialisation of knowledge, for example, can be both positive and negative. The positive aspect of commercialisation is that it brings in much needed funding, while the activity can be negative if it denies the public access to knowledge, i.e. most research outputs in this regard are not published in the public domain.

3.5.1. The changing role of universities

As highlighted in a previous section, the Mode 2 thesis prompted a discussion on the so-called "new mode" in many parts of the globe. In South Africa, a group of academics organised a seminar entitled "New modes of knowledge production". One of the papers presented at the seminar was by Johann Mouton (2000), whose presentation was on the main features of the Gibbons thesis. He also discusses the implications of the shift in the mode of knowledge production for the science system. Mouton indicated that some of the evident changes in the system that are a result of Mode 2, include, first, changes in the nature of research institutions as we know them, for example, institutions are appointing different kind of researchers/knowledge workers, such as "*scientists who have an entrepreneurial spirit*". This also affects the way in which teaching at undergraduate and postgraduate levels is conducted. Second, institutions are producing new forms of knowledge, which is in turn disseminated to a wider social spectrum of individuals. Third, consumers of knowledge are also involved in the production process, and fourth governments have to manage research institutions (and science in general) differently due to the "*socially distributed nature of Mode 2 knowledge*". Furthermore, Mouton discusses the implications of Mode 2 and its relevance for "*the organisation of science in South Africa today*".

Among the changes that were already becoming evident within the South African science system (during the late 1990s to early 2000) was that knowledge production was increasingly taking place in sites other than the university, such as in government departments, parastatal organizations; private research organisations; and large science councils such as the Council for Scientific and Industrial Research (CSIR) and the Human Sciences Research Council (HSRC). Moreover, the way that research is managed at universities is changing. For example, academics have to learn to leverage additional funding from private sources, and thus become "fund-raisers"; the issue of research ethics is becoming more complex, partly due to having to manage private funding as well as the working relationship between academics and their non-academic partners, and academics have to learn new skills in research management such as entrepreneurial skills and managing a team comprising individuals from different disciplines.

In a case study of the Faculty of Engineering at the University of Durban Westville (UDW) Jonathan Jansen (2002) examined the university's response to the challenges posed by the emergence of Mode 2. In 1999 the UDW had to undergo a restructuring process, led by Jansen. The Faculty of Engineering was one of the faculties that required major changes as it was a candidate for closure. The main reasons for the impending closure were low student numbers, high failure rates and, high staffing costs. In order to rescue the situation, some university leaders proposed the introduction of the Warwick Model.

- *The Warwick model represented a partnership between business and industry, a South African university (UDW), the Morgan University Alliance (a South African group acting as facilitator of faculty exchange programmes and university-business partnership), the MUCIA Global Group (a partnership of several top North American Universities offering modular-based engineering and business training on demand), and the Warwick Manufacturing Group (offering technical assistance, consultancy support and accreditation).*
- *The model brought together the UDW Graduate School of Business (GSB), the Faculty of Engineering, and the Faculty of Science.*
- *The model required that engineering education be offered strictly on the basis of a business venture between UDW and the facilitating partner, the Morgan University Alliance.*
- *The model was based on complementary functions and specialisations offered by different partners in what is called "the partnership Programme".*
- *The model meant that a UDW professor, who could previously assume tenure for life, now had a career shaped by the availability and relevance of his or her expertise to modules influenced and shaped by the demands emerging from industry.*

- *The model also assumed that engineering students are working employees of a particular industry, and was based on intensive and ongoing negotiations between the different partners.*

The features of the Warwick Model as outlines above provide a clear description of Mode 2 knowledge production.

The proposal to introduce such a model at UDW was, however, met with a lot of resistance by the engineering professors. This resistance was motivated by the fears that:

- Academics would have to abandon the four main engineering disciplines in which they were trained and socialised, i.e. chemical, civil, electrical, and mechanical engineering.
- The Engineering Council of South Africa (ECSA) would not be supportive of such a model.
- Some academics may have to be retrenched should they fail to reach the profit margins set (due to the business style of the model).
- Academics would have to be more active in recruiting students and leveraging additional funding from private sources.

Adding to the academics' lack of enthusiasm was the absence of any form of incentives for engaging in partnerships, or for venturing into transdisciplinary projects. Furthermore, first year students would be based at the firm in which they would receive training, and would not experience everyday campus life. All these issues made it difficult to implement the Warwick Model at UDW, as Jansen indicates: "*the more we tried to force cohesion and conversation between the two models (i.e. the campus-based model and industry-based model), the more we realised that their base assumptions about engineering education, the identity of the engineering academic, and their assumptions about students were so radically different, that the models could only exist in isolation from each other*" (Jansen, 2002: 517).

Jansen also highlight an important part of engaging in Mode 2 knowledge production, which the Gibbons thesis does not address, which is the "readiness" of both partners to engage in the "new" mode of knowledge production. Hence, while the author acknowledged the emergence of a Mode 2 type of knowledge production in some South African Universities, he found that this was not the case at UDW's Faculty of Engineering.

3.5.2. Commercialisation of research

Scott (2003) investigated the ethical implications of Mode 2 in the European science system. In Europe (and perhaps elsewhere in the world), the Mode 2 phenomenon has not only manifested itself within the academic community, but also within the intermediary level comprising of research councils. Similarly, the evaluation panels of the Research Assessment Exercise (RAE) have also been changed such that they include representatives of the user community. Scott (2003) highlighted three aspects within the system that have been brought about by the transformation of the way knowledge is produced, i.e. the steering of research priorities, the commercialisation of research, and the accountability of science. The steering of research activities takes place at three levels: first at the continental (across Europe) level – with research programmes that are developed to meet social and economic need; second at the national level – with a focus on addressing the short-term political agenda; and third at an intermediary level – where funding is increasingly directed at identified research priorities versus a common practice where funding goes to the best research proposals.

The commercialisation of research is often attributed to the lack of adequate public funding of research, which has pushed researchers towards other sources of funding outside government. The picture is no different for European academics. Another consequence of "commercialisation" is that academics treat research outputs as intellectual property, no longer as public goods. The accountability of science is concerned with management as well as quality assessment. In Europe, this task is the responsibility of the RAE conducted by funding councils for higher education. However, Scott argues that quality control measures such as those of the RAE "*are doomed to failure because they damage the creativity of the research system*". Furthermore "*they encourage researchers to espouse industry-style production*", with the tendency to rush the release of outputs and be less concerned about quality. An ethical consequence of these transformations within the system, as suggested by Scott, is the impact they have on the freedom of academics to conduct research of their choice. There is increased interference by non-academic "stakeholders" such as industry funders, and also by society wanting to benefit from research.

Similarly, Tijssen (2004) found evidence of increasing commercialisation of research outputs between 1996 and 2001 in a worldwide survey. The statistical data for the study was based on an analysis of publications (produced by industry researchers) appearing in international peer reviewed journals. The primary source of data was Thompson's Reuters Science

Citation Index. The analysis was conducted using a tailor-made programme by the Centre for Science and Technology Studies (CWTS), using the author's address at the time of publishing the work. The analysis included "*all research papers listing at least one author affiliate address referring to an organisation that CWTS classified as belonging to the corporate sector, which the OECD defines as – all business enterprises, organisations and institutions whose primary activity is the commercial production of goods and services (other than higher education and medical care) for sale to the general public at an economically significant price*".

The organisations where divided into public enterprises, public-private consortia, private non-profit institutions, government-owned non-profit companies, and private non-profit companies. These companies were grouped into two industrial sectors, i.e. bio-pharmaceuticals and semiconductors. Results showed that while as many as 290 000 research articles had been published by researchers in the corporate sector during the period 1996-2001, this represented a 12% decline compared to previous years. On the other hand, the percentage of articles jointly published by researchers in both the public and private sectors increased from 57% to 68% during the same period. The study also demonstrated an increase in the number of patents accompanied by a decline in the number of research articles published. Different regions such as Asia, Europe and North America experienced a similar drop in research articles from corporate researchers.

The author attributed the decline to the following reasons (among others): the increased pressure on companies to commercialise research outputs; companies contracting their research projects in order to minimise costs; reduced funding for in-house research; and the reduction in the amount of laboratory space available for research. Furthermore, corporate researchers are "pulled" into publishing in other forms, particularly patents, due to the recognition and reputation that comes with it. Tijssen also indicated that the "decline" in research articles does not necessarily mean a decline in the amount of work being done by corporate researchers. He concluded that "*based on the findings presented in this paper we cannot rule out the possibility that science-based companies might well still be doing the same magnitude of long-term research (or maybe even more than before), but their R&D labs and research managers now operate in different organisational and managerial structures that are governed by rules and regulations aimed at maximising the efficiency of knowledge creation processes and broadening the opportunities for commercial gains of research activities*".

Dana Holland (2009) examined the "*implications of Mode 2 knowledge production*" in the developing country of Malawi. The University of Malawi had been greatly affected by the country's financial crisis, to the extent that the institution was not receiving full funding as per budget request. Salaries for academics had not increased at the pace they should, i.e. to keep up with the increased cost of living; the university's Research and Publications Committee (RPC) received very little (if any) funding; and the government research funding agency, i.e. the National Research Council (NRC) was unable to keep up with requests for funding from academics. For example, a few years prior to the survey by Holland, the NRC was only able to fund 8 out of the 180 research proposals. This has resulted in an increase in the proportion of donor funding from international agencies in Malawi. An official of the NRC reported during Holland's interviews, that "*donors fund roughly 80% of the research conducted in Malawi*", and that some donors tend to "*shape the agenda and terms of research production through their patronage*".

Data was collected between 2003 and 2004 through interviews with 42 academics affiliated or previously affiliated with the University of Malawi. Additional data was obtained from historical documents produced between the 1960s and 1980s, containing information on the establishment of the University of Malawi. The majority of individuals that were interviewed were from the social sciences: economics (n = 9)[19]; sociology (n = 8); political and administrative studies (n = 6); history (n = 5); and psychology (n = 3). Individuals in the natural sciences were also interviewed (n = 7), as well as in anthropology (n = 2), the arts (n = 1) and education (n = 1).

Findings revealed that, to a large extent, academics are drawn towards consultancies for monetary gain, both personal and to support their research due to diminishing public funding for research in the country. Although academics expressed the desire to maintain a balance between their academic obligations – that of teaching and engaging in scholarly research – the author identified four factors that make achieving this balance difficult. First, the terms of reference provided by the client (who also happens to be providing funding for the project) place high demands (in terms of delivery times) on academics, leaving them little time to focus on other things. Further, these terms of reference often deviate from disciplinary norms in terms of methodological criteria, and also in staying within current disciplinary debates. As a result, the products from consultancy work cannot be considered for scholarly publication, and thus disadvantages the academic in as far as improving their own research publication

[19] n is the number of individuals interviewed in each discipline.

profile. The lesser emphasis (by clients) on strict methodology also compromises good practice in disciplines such as sociology.

Secondly, there were restrictions imposed by (many, although not all) clients on the use of data collected from funded projects, with researchers often being forbidden to use the data, or only allowed to use it at a much later stage.

Transdisciplinarity *"is a third impediment to translating Mode 2 products into scholarly publications and therefore Mode 1 academic practice*". In many commissioned projects the clients stipulated the disciplines that should form part of the research team, and proposals that demonstrated participation beyond a single discipline were most likely to receive funding. In economics, this presented challenges for "*academic publication and promotion*".

Lastly, similar to other professions, social scientists build their academic profiles by focusing on becoming experts in a particular niche area, which "*can function as a disincentive to the conversion of consultancies into scholarly contributions and therefore Mode 2 to Mode 1 translation*". The consequence of increased pull towards consulting has led to academics becoming 'generalists' rather than specialists in any particular area. The study shows that the most (financially) successful consultants are those that are able to take on any project, without being selective. However, this trend is said to work against "*the accumulation of knowledge in an area*".

Holland (2009) concluded that "*the norms of the academic role, which was institutionalised in Malawi with the considerable support of international agents during the first few decades after independence, sit uneasily with the norms of the flexible and marketable intellectual characteristic of Mode 2 production. And while Mode 1 in Malawi has historically promoted an ethos of service and duty to the nation, Mode 2 tends instead to demand a service-to-the-client orientation and to promote monetary incentives more so than intellectual or service-oriented ones*".

Despite the negative consequences of commercialisation such as those discussed above, universities in other parts of the world are seeking ways of increasing commercialisation. Rasmussen *et al*. (2006) examined the initiatives (towards increasing commercialisation) of four universities in four European countries, i.e. Chalmers University of Technology (Chalmers) in Sweden, Norwegian University of Science and Technology (NTNU) in Norway, University of Oulu (Oulu) in Finland, and Trinity College Dublin (TCD) in Ireland. These universities were chosen because they have similar settings as far as commercialisation is concerned, and the focus of all four is on increasing their efforts.

Chalmers has research units dedicated to increasing university-industry partnerships, most of which are as a result of individual initiatives. Furthermore, the university has produced hundreds of spin-off companies over the years. Similarly, NTNU has produced more than a hundred spin-off companies and the number continues to rise. In 2000 alone, NTNU formed thirteen new companies (Chalmers is reported to produce fifteen new companies annually). The University of Oulu is no different from the previous two, with over 200 spin-off companies (predominantly in the fields of telecommunications and medicines) at an average of between 10 and 20 new companies per year. TCD, however, seems to have made a slower start as far as the formation of spin-off companies is concerned. With three new companies formed each year, TCD is still far behind the production rate of the other three universities.

A total of 65 personal interviews (Chalmers = 18, NTNU = 19, Oulu = 16, and TCD = 12) were conducted with university managers, heads of departments, researchers involved in partnerships with industry and managers of research institutes. Additional relevant data was obtained from sources such as articles, books and websites. The authors indicated that available data was insufficient to do a statistical comparison between the four universities. They also indicated that, "*it is difficult to draw comparisons between different nations and universities as to the extent of spin-offs, because no common definition of a spin-off exists*". Other challenges encountered during data collection were that some of the universities do not keep a record of the number of spin-off companies created as a result of direct involvement by the university, while others have only incomplete figures. The findings presented are therefore based on qualitative data in terms of the four "key research topics", which are: the changing role of the universities, the initiatives and policies, the overall commercialisation system, and the output from commercialisation.

The findings confirmed that the four universities under study have intensified their focus on commercialisation, particularly in recent years. Some respondents/participants raised concerns with regard to the phenomenon of increasing commercialisation. First, researchers should be left to decide on their own if they want to pursue commercialisation of their outputs, thus they should not be obliged to do so. Second, there should not be any restrictions as far as the publication of research outputs is concerned. Lastly, traditional university roles (teaching and research) should not be neglected while pursuing commercialisation. In this regard, the authors indicated that "by increasing commercial activity, the university rather expands than changes its activity". Initiatives to increase commercialisation at all four universities were undertaken by individuals, including students. Such initiatives include the introduction of specific programs dedicated to educating and motivating interested persons into entrepreneurial activities. Common outputs from commercialisation are spin-off companies and licensing, with the former more important than the latter. The study clearly demonstrates that commercialisation has become a part of the four universities, though this is not without its challenges; as the authors indicate, "*the overall challenge is how to find proper arrangements to link teaching, research and commercialization making the latter a positive contribution rather than a load on the others*".

3.6. CONCLUDING REMARKS

The main claim of the Gibbons thesis is that a new mode of knowledge production, Mode 2, is emerging parallel to the traditional mode, called Mode 1. It further claims that Mode 2 "*is different from Mode 1 – in nearly every respect*". Gibbons *et al*. also discuss several trends that they argue have contributed to the shift in mode of knowledge production, such as the marketability and commercialisation of knowledge; the massification of research and higher education; the growth in collaboration; and changes in the institutional landscape, particularly the university.

Previous studies have shown that one of the shifts that can be linked to the change in mode of knowledge production has to do with the funding of research. Gibbons *et al*. also make this point, indicating that increasing demand for higher education is placing pressure on available resources. Traditionally, academics relied primarily on public/government funding for research, but recent decades have witnessed an increase in industry funding in countries such as Canada (Crespo & Dridi, 2007), Korea (Om *et al*., 2007), Germany (Meyer-Krahmer & Schmoch, 1998), USA (Poyago-Theotoky *et al*., 2002) and Norway (Gulbrandsen & Smeby, 2005). Some authors (Mansfield and Lee, 1996; Crespo and Dridi, 2007) argue that changes in knowledge production practices could potentially influence policy makers who are more interested in university research that has direct benefits for industrial innovations, rather than adding to the pool of knowledge.

One of the key pieces of legislation in South Africa, the Education White Paper 3 – A Programme for the Transformation of Higher Education (DoE, 1997c), calls for a research system that embraces the new way of producing knowledge. Education White Paper 3 clearly states that the South African research system must "*keep abreast with the emerging* *global trends, especially, the development of participatory and applications-driven research addressing critical national needs, which requires collaboration between knowledge producers, knowledge interpreters and knowledge managers and implementers*" (DoE, 1997c: 31 – 32). The recently published Green Paper for Post-School Education and Training (DHET, 2012) echoes the message that research produced at universities, science councils, and other research institutes should lead to economic benefits and also improve the lives of ordinary citizens (DHET, 2012: 13; 44).

Johann Mouton (2000) highlighted the implications of the Mode 2 thesis for South African science, some of which are already evident today, while Jonathan Jansen (2002) demonstrated through a case study of the University of Durban Westville, that there is resistance to Mode 2 practices within sections of the academic community. A shift towards Mode 2 will place several demands on academics, one of which is that they have to develop skills in obtaining additional funding from the private sector. The significant increase in the proportion of industry funding for academic research, particularly the influence of this funding on the type of research conducted (thus the mode of knowledge production), is the focus of the current study. This study aims to determine, whether researchers who receive public funding and those receiving industry funding engage in different modes of knowledge production. Furthermore, it seeks to determine whether these differences in modes of knowledge production are field- and discipline-specific.

Current debates on the Mode 2 thesis can be divided into two groups: proponents and critics. These groups provide arguments that either support or reject the Mode 2 claims, and, in some cases, provide evidence for or against the thesis. While a few studies also provide empirical evidence to back up their arguments, the majority are not backed by empirical data. This lack of empirically-based studies around the Mode 2 debate is one area that has received criticisms from some scholars. For example, a recent publication by Bartunek (2011) titled W*hat has happened to Mode 2?* argues that "*there has been much more discussion of Mode 2 than illustrations of it in academic journals*" (Bartunek, 2011).

In general, the proponents of Mode 2 agree on the following claims:

- Knowledge is increasingly being produced within the context of application.
- Criteria for quality control are more diverse, and extend beyond the peer review process (Fujigaki and Leydesdorff, 2000).
- Market demands influence the process of knowledge production, and the commercialisation of research outputs is on the increase (Holland, 2009). Furthermore,

diminishing public funding for research has led to an increase in private funding, which is often directed towards 'mission-oriented' research (Fujigaki and Leydesdorff, 2000).

- Entrepreneurial tendencies among academics are on the rise (Harvey *et al*. 2002).
- Transdisciplinarity is central to Mode 2 research (Manathunga *et al*. 2006; Lenhard *et al*. 2006). In addition, Mode 2 research may involve collaborations between academic researchers and industry partners (Harvey *et al*. 2002; Lundequist and Waxel, 2010; Ferlie and Wood, 2003; Godin and Gingras, 2000; Prpic, 2007).

On the other hand, critics of Mode 2 argue that:

- The 'new' mode is not new. Researchers have been producing knowledge within the context of application for centuries (Weingart, 1997; Etzkowitz and Leydesdorff, 2000; MacLean *et al*. 2002; Pestre, 2003).
- Universities are not losing their position as the primary site for knowledge production (Godin and Gingras, 2000; Fujigaki and Leydesdorff, 2000).
- Mode 2 is not replacing Mode 1. In some cases, Mode 1 research forms the foundation for Mode 2 (Albert, 2003).
- A significant portion of public funds still goes towards basic/fundamental research (Lundequist and Waxel, 2010).
- There is a need for more empirical studies on the Mode 2 debate (Fujigaki and Leydesdorff, 2000; Harloe and Perry, 2004).

There is no doubt that the publication by Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott and Martin Trow has been successful in starting a debate around *the way* knowledge is produced, and *the purpose* for which we produce knowledge. One author also points out that "*Mode 2 is stimulating and obliges us to think again about knowledge production"* (Pestre, 2003). Despite the differences of opinion that exist in the literature on the status of the Gibbons thesis, there is sufficient evidence to support the Mode 2 thesis. In particular, researchers are increasingly forming transdisciplinary teams, with collaborations by individuals in the social sciences and the natural sciences, for example. There is also increased pressure on academics across a range of disciplines to become entrepreneurial, to engage in research that is marketable, and thus embracing the concept of "knowledge produced within the context of application". As a result, universities elsewhere in the world and in South Africa are establishing Technology Transfer Offices (TTOs) to manage products arising from research conducted by university-based researchers (see section 4.3 for further discussion on TTOs). Another development is the introduction of research ethics committees within universities to ensure ethical compliance of the research produced, before the project commences. Some universities have research ethics committees for the various faculties or broad fields, for example: animal sciences, education, health sciences and humanities research ethics committee. Research ethics committees are therefore a way of ensuring "social accountability" among academics. Against this background, this study has set out to determine whether the mode of knowledge production is influenced by sources of funding.

CHAPTER 4: IMPACT OF INDUSTRY FUNDING ON THE PRODUCTION OF KNOWLEDGE

4.1 INTRODUCTION

Good quality research requires good and quality investment of resources. Worldwide, governments are responsible for providing funding for research conducted in public institutions such as universities[20] and government research institutes. Previous studies (Pavitt, 1991; Martin *et al*. 1996; Salter and Martin, 2001; Martin and Tang (2007), have shown that there are several benefits of public funding for (mainly basic) research. For instance, "*one important function of academic research is the provision of trained research personnel, who go on to work in applied activities and take with them not just the knowledge resulting from their research, but also skills, methods, and a web of professional contacts that will help them tackle the technological problems that they later face*" (Pavitt, 1991). Government funding for research is said to contribute six types of benefits to the economic growth of a country: *increasing the stock of information, new instrumentation and methodologies, skilled graduates, professional networks, technological problem solving and creation of new firms* (Martin *et al*., 1996; Martin and Tang, 2007).

Given that many industries depend for new ideas and technological knowledge on government-funded research, which is often "*quite basic, quite recent and published in highly influential journals*" (Narin *et al*., 1997), funding for basic research is an integral part of knowledge production. In many countries, public funding is channelled to universities through the two streams discussed in detail in Chapter 2 above: the first usually a block grant allocation from a government department of education (or higher education) and the second often from a national funding agency which itself receives its funds from a government department of science and technology. Since the early 1970s, however, there has been a rise in a third funding stream, coming from industry or the business sector. The primary aim of this chapter is to discuss this rise in industry funding for university research, both across the globe in relation to the South African science system.

This chapter is organised into three main sections. Section 1 reviews the literature on the rise in industry funding for university research in many parts of the world, and also identifies trends within the South African research system; Section 2 investigates the consequences

[20] For the purpose of this study, the term "university" will be used to refer to all forms of Higher Education Institutions (HEIs).

(both positive and negative) of such increased industry funding on the science system; and Section 3 examines studies of the impact of industry funding on the mode of knowledge production, the level of scientific productivity between industry funded and government funded researchers, and the extent of collaboration among academics.

4.2 RISE OF INDUSTRY FUNDING FOR UNIVERSITY RESEARCH

In recent decades, there has been an increase in sources of funding outside government, particularly from industry. In Germany for example, Meyer-Krahmer and Schmoch (1998) found that "*industrial funds for research activities at German universities increased by a factor of 2.4 between 1985 and 1995 (in real terms); the relative share of industrial money within the total research budget for universities increased from 5% to 9%*". Hottenrott and Thorwarth (2011) also point to an increase in industry contribution to academic research from 6.2% in 1997 to 12.5% in 2007 in Germany. Crespo and Dridi (2007) found that there was an increase in industry spending on university research in Canada over the years, from 4.2% in 1985 to 11.6% in 1997; while Manjarrés-Henríquez *et al*. (2009) found that the share of industry funding for Spanish universities had grown at twice the rate of public funding, from €17 million in 1999 to about €43 million in 2004.

Evidence suggests that in some cases, researchers receive more funding from industry than from government. Connolly (1997) investigated the relationship between external and internal[21] funding of university research in the US. Data was obtained from the National Science Foundation's CASPAR database system, resulting in a sample size of 195 universities funded between 1979 and 1990 (twelve years). Mean internal funding increased from US$4.2 million in 1979 to US$10.3 million in 1990, while external funding increased from US$25.6 million to US$43.1 million over the same period. Furthermore, the amount of external funding received by universities was significantly higher than internal funding. The study found that "*external funding has a positive effect on future levels of internal support*", and show that institutional funding is not "*crowded out by external support*".

Alongside the evident growth in the funding of university research by industry, we are also witnessing a growth in university-industry relationships. Numerous studies across different parts of the globe and across various disciplines have been published on university-industry

[21] External funding is described as funding that "originates from a source outside of the university, such as a government agency, a private firm, or a non-profit foundation, and must be designated for scientific research by the outside organisation – therefore the university cannot use this funding on purposes other than research. Internal funding, on the other hand, comes from funds that can be used in any way the university chooses (regardless of the original sources of those funds), and must be budgeted for research by the university itself" (Connolly, 1997: 392).

partnerships, including in Germany (Meyer-Krahmer & Schmoch, 1998), Norway (Gulbrandsen & Smeby, 2005), United States (Mansfield, 1991; Payogo-Theotoky *et al*., 2002) and South Africa (Kruss, 2005), and in disciplines such as engineering (Mansfield, 1991; 1995), information technology (Balconi & Laboranti, 2006) and life sciences (Blumenthal *et al*. 1986; 1996).

Universities have welcomed industry as an important source of funding for research. Several reasons have been attributed to the rise in third stream funding, the most important being the decline in government funding across many countries. While universities benefits financially from industry contribution, industry on the other hand taps into the wealth of knowledge that university researchers possess. Thus, in recent years, industry has used financial resources to forge formal relationships with university researchers for the benefit of their products and/or processes.

Public science, i.e. research produced within universities, government laboratories or public research institutes, makes important contributions to industry, particularly through the production of patents. A study by Narin *et al*. (1997) analysed 430 226 "*non-patent references (NPR's)*" (including publications such as journal articles, books, technical documents, manuals, meeting reports) cited on 397 660 US patents issued over four years (1987-1888, and 1993-1994). About 175 000 of the NPR's were papers published in SCI journals, and after matching these journals to the SCI-based Science Literature Indicators Database (SLID) and identifying the addresses of the authors and the funding agencies, it was found that "*there has been a remarkable increase in linkage between US patents and US-authored scientific papers; in just six years the number of US-authored papers cited in patents has more than doubled, the number of citations to these papers almost tripled, and the number of research support acknowledgements on the papers more than tripled*". Furthermore, the cited papers (the majority of the papers received funding from government or research agencies, and are of basic nature) were produced by academics in prestigious universities and laboratories, and published in high impact journals.

In an earlier publication, Mansfield and Lee (1996) also found that the majority of university publications that are frequently cited in industry patents come from universities that "*tend to be world leaders in science and technology*", such as the Massachusetts Institute of Technology (MIT), the University of California at Berkeley, Stanford, Harvard, Yale, and Carnegie Mellon University. Similar results were found from a case study of university-industry linkages in the wine industry in Chile and Italy (Giuliani and Arza, 2009).

Morgan and Strickland (2001) examined the contributions of university research to industry in the US, between June 1995 and August 1998. Data was collected via two methods: (1) a mail survey in 1997, which 926 academics (57%) in biology, chemistry, and physics responded; and (2) telephone interviews conducted with 104 academics from science faculties, who had indicated during the mail survey that their previous research made contributions to industry (and an additional 39 industry researchers identified as being knowledgeable about their research contributions) and 99 academics from engineering faculties whose research had made contributions to industry, 49 who had not made any contribution to industry, and 61 industry researchers considered knowledgeable about their research contributions.

The findings from the mail survey showed that academics in engineering described their research as more applied (50%) than basic (33%) or development (18%), compared with those in science whose research was much more basic (82%) than applied (14%) or development research (4%). At the discipline level, those in biology conducted more basic research than academics in chemistry and physics. Between 42% and 65% of the academics contributed to industry through involvement in activities aimed at improving or developing new products or processes for the industry. Another 15% to 35% were involved in improving existing commercial products. Nineteen percent were involved in the design of prototypes, and 11% in the testing of market-ready prototypes. At 81%, the most common contribution made by academics to industry was "*conducting basic research that provided a foundation for industry research*".

Results from the telephonic interviews showed that university researchers whose work had contributed to industry also received funding from the industry. For example, the 104 science academics received an average of 46% of their total funding from industry, while the 99 engineering academics received 55% of their total funding from industry. About 70% of the respondents from the science faculties indicated that their contributions to industry were through new or improved methodologies or processes and products. Only 24% indicated that their contributions were towards the foundation of basic scientific knowledge. For those in the engineering faculty, "*design tools and improvement of manufacturing operations*" were the two most common contributions, and only 5% of the contributions were towards the foundation of basic knowledge. Respondents were also asked why their research was conducted in the university and not in industry, and the most cited reason by researchers in both science and engineering was the availability of technical expertise in the university.

Engineering researchers also reported that the research conducted was too basic to be carried out in industry.

The authors also looked at the types of interaction between university researchers and industry partners. Results showed that the most common type of interaction was through the presentation of research results to industry (96% for both science and engineering). Engineering faculty members demonstrated more interactions with industry than the science faculty, for example, through joint university-industry meetings (93% for engineering versus 72% for science); by submitting periodic progress reports to industry (91% engineering versus 67% science); as well as through co-authoring articles with industry partners (60% versus 46% science).

Seventy-one percent of academics who had strong ties with industry also involved their doctoral students in their industry-oriented projects. Students interactions in industry projects was higher among engineering students than science students: 88% of engineering students participated in university-industry meetings, compared with 55% of science students; and 80% of engineering students had working relations with industry personnel, compared with only 43% for science students.

Participants from both engineering and science backgrounds, indicated that they would like to keep their involvement with industry. In fact, the majority of respondents (79% and 73% of respondents from engineering and science) indicated that they would prefer "*a greater level of industry involvement in their research*".

Similar trends are apparent in South Africa. Although there have not been many studies published on the prevalence of industry funding in the South African science system, anecdotal evidence suggests that the same trends being witnessed elsewhere in the world are manifesting themselves here too, that is, there is an increase in non-government funding of university research, particularly industry funding.

4.2.1. Third stream sources of funding for university research in South Africa

Third stream funding refers to research funding arising from sources other than government department or government-funded agency (such as the NRF in the case of South Africa). Third stream funding therefore includes funding from industry (see for example Clark, 2001: 12).

South Africa conducts an annual survey of spending on research and experimental development, and determines the Gross Domestic Expenditure on R&D (GERD) for the country across various sectors: business; government; higher education; not-for-profit organisations; and science councils. The total GERD during the latest survey year available (2009/10) was R20.9 billion, a decrease of R86 million from the previous survey (2008/09) (DST, 2013). GERD as a percentage of the Gross Domestic Product (GDP) was 0.87%, compared to 0.92% in 2008/09. The country continues to remain below the 1% of GDP mark, which was a target set for the 2008/09 survey year. By comparison with OECD countries (some of which spend more than 3% of their GDP on research and development, including Finland, Sweden, and Japan), South Africa is one of only a few countries with a GERD lower than 1% (OECD, 2012).

Spending on the higher education sector (HERD[22]) during this latest survey year was R5.1 billion, which came from various sources, including general university funds (government block grant), external sources (which include agency and industry funding), other South African sources such as not-for-profit organisations, and foreign sources. Government continues to be the largest contributor to HERD at 50.3% (from 47.3% in 2008/09), followed by 38.5% for external sources, 9.8% from foreign sources, and 2.4% from other South African sources (Table 4.1). Of the 38.5% from external sources, funding agencies contributed 14.6%; domestic business 11.9%; science councils 9.2%; national, provincial and local government 1.8% and government research institutes 0.9%. Forty-eight (48) percent of the R5.1 billion (thus R2.5 billion) was spent on basic research, while 33.9% and 17.9% were spent on applied research and experimental development, respectively (Table 4.2) (DST, 2013).

Universities and individual academics obtain industry funding through various means, either directly from individual companies (such as Sasol and other large companies), or through funding agencies. One of the common avenues through which South African academics obtain industry funds is by applying for THRIP (Technology and Human Resources for Industry Programme) funding from the National Research Foundation (NRF). The THRIP Programme (described in detail in Chapter 2) is based on a partnership between government and industry, and its mission is "*leveraging collaborative partnerships on a cost-sharing basis, for research in science, engineering and technology, in order to provide technology solutions towards a competitive industry and to produce a flow of highly skilled researchers and technology managers for industry*" (THRIP 2011: 6).

[22]HERD = Higher Education Expenditure on R&D.

Over the years, industry contributions to THRIP projects have fluctuated, but generally have been on the increase (Figure 4.1). Since THRIP's inception, the contribution from government and industry has been based on a 1:2 funding ratio, where government contributes R1 and industry R2. In 2007, the industry contribution increased to R3 while government contribution remained the same. As can be expected, the total investment into projects from industry increased as a result of the increase in the funding ratio. However, the number of companies, both large and small, partnering with universities, decreased as they could no longer afford the higher contribution (THRIP 2010: ix).

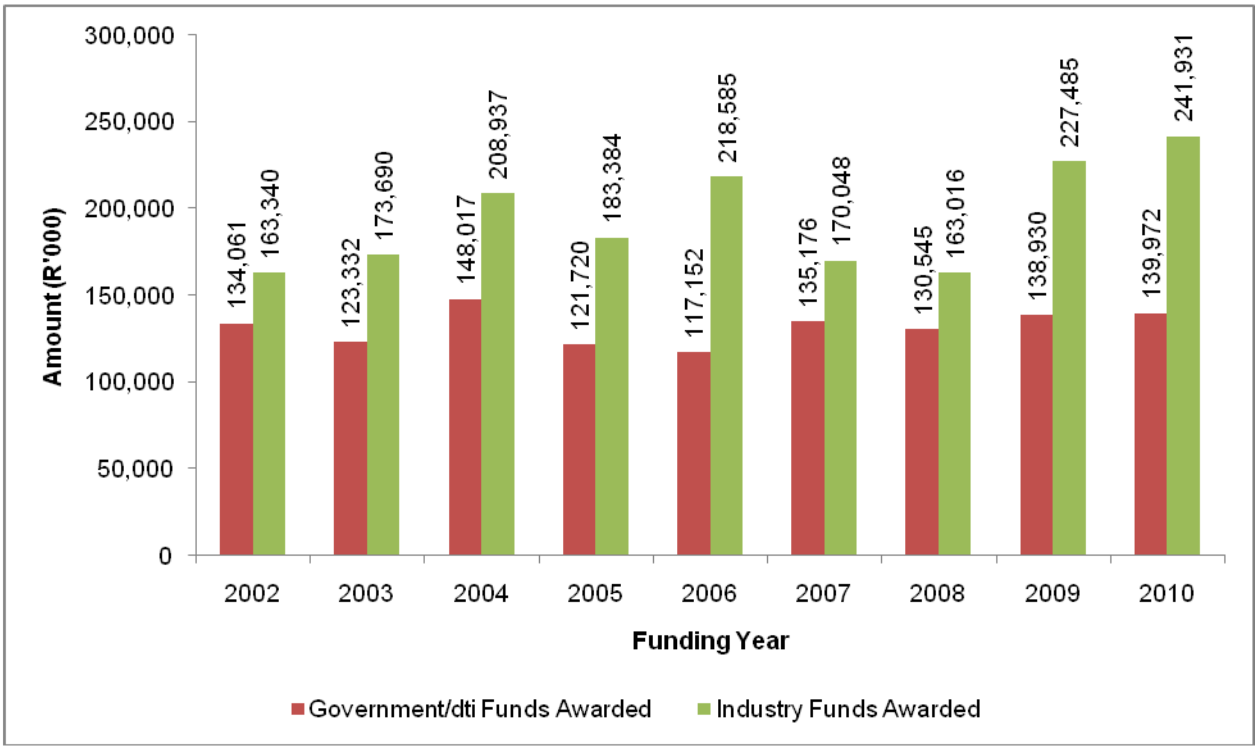


Figure 4.1. A comparison of government/dti contribution and industry funding for THRIP over a nine year period (*Source*: THRIP 2011: 15).

To date, THRIP has conducted a series of programme evaluations (see, for example, the evaluation reports of 1997 and 2002). In January 2010, THRIP produced another report on the findings of a study commissioned to investigate "*the decline in THRIP applications between 2006/7 and 2008/9*" (THRIP 2010). THRIP has not only been witnessing a decline in applications for funding during these years, but also a significant decrease in the number of research outputs arising from THRIP projects, from 1697 in 2006 to 1151 in 2008 (excluding patents, products and artefacts) (THRIP 2010: 32). A survey of academics was conducted to determine the reasons for the decline in applications, and the top five reasons given by academics were (THRIP 2010: 85):

- *The change in THRIP: large company contributions from 1:2 to 1:3 in 2007*.
- *The administrative burden of applying and reapplying for THRIP*.
- *The difficulty in finding appropriate SMMEs with an interest, and firm requirement for R&D to partner with.*
- *The fact that universities find it difficult to liaise with industry*.
- *The current world-wide economic recession*.

Some of the suggestions given by academics as possible solutions towards curbing the decline in THRIP participation were (THRIP 2010: 86).

- *Revisit the funding framework (what is funded) and the application process.*
- *Announce grants before year-end*.
- *Increase flexibility in the application of funds*.
- *Lengthen the grant duration and allow roll-over of funds*.
- *Fix the ratios and fix the problems emanating from the new IP [Intellectual Property] law*.
- *Revisit the strict rule-based approach (which has discouraged many researchers from even trying to apply)*.

At the time of writting, the THRIP programme was still in place, awarding grants to researchers, and its mission has remained unchanged[23].

Table 4.1. HERD by source of funds (2009/10, 2008/09, 2007/08, 2006/07, 2005/06).
Source: DST (2009; 2011; 2013)

Source of funds	2009/10		2008/09		2007/08		2006/07		2005/06	
	R'000	%	R'000	%	R'000	%	R'000	%	R'000	%
General university funds[24]	2 565 633	50.3	1 983 683	47.3	1 734 903	47.9	1 759 499	53.3	1 601 444	58.6
External sources[25]	1 962 237	38.5	1 697 175	40.5	1 546 458	42.7	1 250 128	37.9	1 130 771	41.4
Other South African sources[26]	130 245	2.6	100 470	2.4	20 215	0.6	10 473	0.3	16 657	0.6
Foreign sources	443 109	8.7	410 038	9.8	320 286	8.8	278 708	8.4	305 590	11.2
Total	**5 101 224**	**100**	**4 191 366**	**100**	**3 621 861**	**100**	**3 298 808**	**100**	**2 732 215**	**100**

[23] http://www.thrip.nrf.ac.za. Date accessed: 9 July 2013
[24] General university funds also refer to government funds (i.e. block grants).
[25] External sources includes national, provincial and local government; government research institutes; funding agencies such as the National Research Foundation and the Medical Research Council; and domestic business.
[26] Other South African sources include not-for-profit organisations, and individual donations.

Table 4.2. HERD by type of research (2009/10, 2008/09, 2007/08, 2006/07, 2005/06). *Source*: DST (2009; 2011; 2013)

Type of research	2009/10		2008/09		2007/08		2006/07		2005/06	
	R'000	**%**	**R'000**	**%**	**R'000**	**%**	**R'000**	**%**	**R'000**	**%**
Basic research	2 459 733	48.2	1 965 121	46.9	1 709 334	47.2	1 348 299	40.9	1 134 411	41.5
Applied research	1 729 496	33.9	1 468 624	35.0	1 262 425	34.9	1 282 627	38.9	1 045 483	38.3
Experimental development	9 11 994	17.9	757 621	18.1	650 102	17.9	667 882	20.2	552 321	20.2
Total	**5 101 224**	**100**	**4 191 366**	**100**	**3 621 861**	**100**	**3 298 808**	**100**	**2 732 215**	**100**

4.3 CONSEQUENCES OF INCREASED INDUSTRY FUNDING OF ACADEMIC RESEARCH

Studies have shown that university-industry relationships are in most cases of mutual benefit to both the university and industry, i.e. academia provides the knowledge and know-how, while industry provides the resources in the form of funding and research equipment where necessary. Poyago-Theotoky *et al*. (2002) state that "*building relationships between universities and firms can serve to bridge [the] information gap and so promote the beneficial exploitation of fundamental knowledge*". The authors examined "*the antecedents and consequences of policies to promote university-industry partnerships*" in the United States. In addition, they identified both "benefits and drawbacks" of university-industry partnerships. The US went through a period of slow productivity growth, particularly in the high-technology sector, during the 1970s and into the early 1980s. One mechanism through which the country set out to improve the situation was a reform of university-industry technology transfer. "*Several leading experts on technology had asserted that US firms were not commercializing university-based technologies at a sufficiently rapid rate to maintain the nation's technological leadership*". Following this decision, key pieces of legislations supporting partnerships between universities and industry were enacted. The most important piece of legislation in this regard is the Bayh-Dole Act (No. 96-517 of 1980), which "*allowed universities (rather than the federal government) to own patents arising from federal research grants*". Another piece of legislation was the National Cooperative Research Act (NCRA) of 1984. The NCRA "*provided additional incentives for firms to engage in research joint ventures (RJVs), by significantly reducing antitrust penalties associated with collaborative research*".

The development of legislation encouraging university-industry partnerships was followed by further legislation which would ensure the provision of funding, such as the Omnibus Trade and Competitiveness Act of 1988 which established the US Commerce Department's Advanced Technology Program (ATP). The ATP provides support for projects on generic technologies, which may involve collaboration between university researchers and industry partners. In addition, the country's largest funding agency, i.e. the National Science Foundation, increased its funding for Industry-University Cooperative Research Centres (IUCRCs) during the same period. The IUCRCs are funded primarily by industry, and are "*designed to promote technological diffusion, commercialization, and integration of research and education*".

As a result of the initiatives discussed above, among others, there has been a growth in university-industry partnerships in the US, to an extent that most research universities have established Technology Transfer Offices (TTOs) to manage these partnerships and "*facilitate commercial knowledge transfers*". Some significant outcomes of this are the increase in the number of patents granted to universities (from 300 in 1980 to 3 661 in 1999); a 12-fold increase in licenses since 1991; and a growth in licensing revenue from $160m in 1991 to $862m in 1999. This growth, however, has been accompanied by both benefits and drawbacks, which are summarised in Table 4.3 below.

Table 4.3. Trade-offs associated with an increase in university-industry partnerships (source: Poyago-Theotoky *et al*. 2002)

Benefits	***Drawbacks***
Additional revenue for the university	*Negative impact on culture of open science*
More rapid technological diffusion	*Negative impact on student/adviser relations*
Choices regarding technological emphasis	*Could reduce the quantity and quality of basic research*
Positive effects on curriculum	*Negative effects on curriculum*
Local/regional economic development	*Could affect types of research questions addressed*
Two-way knowledge transfer	*Academics could spend less time on teaching and service*

The establishment of TTOs in South African universities is a recent development, with most TTOs having being established in the last five years or so. These TTOs are managed through the National Intellectual Property Management Office (NIPMO), an entity of the Department of Science and Technology established mid-2011 under the Intellectual Property Rights through the Publicly Financed Research and Development Act 51 of 2008. Most of the 23 public universities currently have a Technology Transfer Office, and the functions of this office is similar across the sector, i.e. to facilitate the process of transferring new scientific discoveries, by staff and students, into commercial products that will benefit the general public. In 2013, NIPMO developed the Offices of Technology Transfer (OTT) Framework: Moving towards a technology transfer oriented nation, a framework within which university TTOs will be regulated. At the time of writing, the draft framework was still undergoing a consultation process within the sector.

4.3.1. Negative consequences of industry funding

Aldo Geuna (2001) warned of the “negative unintended consequences” of the new shift in research funding from the traditional government mechanism to what he called a “contractual-oriented rationale” for funding. Geuna examined changes in university research funding mechanisms and sources in ten European countries[27] over a period of fifteen years (1981 – 1996), focusing in particular on the negative unintended consequences of the emerging “quasi-market” way of funding research, which is worsened by the growth in other private sources of funding.

European universities rely primarily on government for research support, which comes in the form of university funds or direct government funds. Additional funds are obtained from the sale of academic services and from internal funds. The allocation of government funding to individual universities is done through three channels, (1) incremental funding – which is based on past expenditure levels, (2) formula funding – calculated on the expenditure per student enrolled, and is based on the ratio for teaching and research, and (3) contractual funding – which is applied for via project proposals from research councils. The late 1990s, however, saw an increase in the last two mechanisms of funding, i.e. formula and contractual funding.

A comparison of Higher Education Expenditures on Research and Development (HERD) as a percentage of GDP was done for Germany, France, Italy and the UK (based on data provided by the OECD) for the period 1981 to 1996. Analysis showed a slow increase in HERD during the 1980s, followed by a decline from the mid-1990s. Further analyses were done on the sources of HERD funds for seven countries (Denmark, France, Germany, Italy, Ireland, the Netherlands, and the UK), with Belgium, Greece, and Spain excluded due to incomplete data. About 80% of the total research performed in European universities during the period studied came from these seven countries. Results showed a decrease in government funding (for the aggregate of the seven countries) from 94% in 1983 to 85.6% in 1995, while the share of business, foreign, and private organisations funding increased during the same period – from 2.9% to 5.7% for business; 0.6% to 3.2% for foreign funding; and 1.5% to 3.7% for private non-profit organisations. The bulk of non-government funding

[27] The ten countries included in the study were: Belgium, Denmark, France, Germany, Greece, Italy, Ireland, Spain, the Netherlands, and the UK.

was awarded to universities/academics in the form of contracts or collaborative projects with industry. University-industry collaborations "*are all characterised by an exchange of knowledge among participants, with the university usually being the most important supplier of knowledge*".

The shift in the allocation of research funding in Europe occurred after the Second World War, when the proportion of funding allocated to a university was based on academic quality. This model (of linking funding to academic quality) had two assumptions, that (1) *the transfer of knowledge from basic research to commercialisation is seen as a linear process, in which basic research leads to applied research and development and then to commercialisation,* and (2) *knowledge is a public good with important positive externalities and hence there is a need for public funding to reach a socially more appropriate level of investment*. As a result of this model, large investments were made in university research in many European countries and in the United States. After the Second World War, funding in Europe (both government and industry funding) was allocated through a competitive, peer review process based on "*an ex-post evaluation of university research performance*".

Geuna concluded that the "*negative unintended consequences*" of the new funding mechanism, particularly the increase in industry and other private funding opportunities, manifested in the following ways:

(1) *Increased concentration of resources*. The allocation of funds through a competitive process could result in a situation where the bulk of industry and other non-government funding goes towards universities already receiving large grants from public funds. Thus, there is a concentration of funds in a few 'highly productive' universities.

(2) *Disproportionate incentives for a short-term foreseeable research endeavour*. Industry funding is allocated towards short-term projects that will respond to the needs of industry. Therefore, under this funding mechanism, "*application-oriented short-term research will substitute for long-term research in the university research activity portfolio, dismantling what was the core activity and the source of comparative advantage for the university*".

(3) *Changing incentive structures*. Industry funding brings with it restrictions not common in public funding. In particular, industry-funded academics face restrictions with regard to publishing their work, i.e. they have to delay publication to allow for patent application to take place.

(4)*Cumulative and self reinforcement phenomena*. Similar to the situation described under 'increased concentration of resources', here, the "*organisation and resource allocation structure of science tends to reward successful individuals and groups with access to means that increase their probability of being successful in the future*". Thus, academics with a successful publication record will attract better funding opportunities and continue to have access to more private funding than academics with a poor publication history. Furthermore, industry partners are more willing to collaborate with well established, successful universities/academics than those who are still trying to develop their careers. Therefore, "*quasi-market allocation mechanisms based on ex-post accountability not only produce a biased evaluation of real scientific capabilities but also, due to their mechanistic accounting, tend to reinforce a virtuous and vicious circle*".

Several studies show that industry funding of university research may also have a positive impact, such as increased scientific productivity; higher citation counts from industry-funded publications compared to government-funded publications; as well as the production of commercial outputs. The next section reviews studies that examined the relationship between industry funding and scientific productivity, the mode of knowledge production and; the extent of collaboration between academics and industrial partners.

4.4 IMPACT OF INDUSTRY FUNDING ON SCIENTIFIC PRODUCTIVITY, MODE OF KNOWLEDGE PRODUCTION, AND THE EXTENT OF COLLABORATION BETWEEN ACADEMICS AND INDUSTRIAL PARTNERS

One of the earliest publications on university-industry relationships was by Blumenthal *et al.* (1986), who highlighted that "*university-industry research relationships (UIRRs) in biotechnology have grown increasingly important for both industries and universities in the United States*". The aim of the study was partly to determine the effects of UIRRs in the discipline of biotechnology. The authors conducted a survey among 40 research-intensive universities in the United States in 1985. A total of 3180 names of staff members in life sciences faculties was compiled, from which 1594 individuals were randomly selected for the study. The sample included individuals from disciplines such as biochemistry, molecular biology, genetics, microbiology, biology, cellular biology and botany. A second group of 403 staff members in the non-life science disciplines of chemistry and engineering was also included in the study "*in order to assess the relative prevalence of UIRRs in biotechnology and in other fields known to have a long history of involvement with industry*".

The impact of industry funding on research productivity was assessed by determining the following three aspects: the number of journal articles that industry funded researchers had published in the last three years; the number of hours spent per week on student supervision; and information on other commitments both within and outside the university, (such as university administration and journal refereeing). The results showed that industry funded researchers in biotechnology published significantly more articles (14.6 articles) over the three year period than researchers without industry funding (at 11.3); that they spent more hours per week supervising students than non-industry funded academics (22.2 versus 20.3 hours); and they were involved in more activities both inside and outside universities compared to their counterparts (with 1.4 activities for industry funded researchers and 1.1 activities for the non-industry funded). The authors indicate that the reasoning behind this pattern, i.e. the positive relationship between industry funding and high productivity is that "*companies selectively support talented and energetic faculty who were already highly productive before they received industry funding*".

One of the benefits of industry funding for university research that the study highlighted was the possible commercialisation of research. The authors asked respondents to indicate the extent to which industry funding, among other things, might "involve less red tape than federal funding; increase the rate of applications from basic research; provide resources not obtainable elsewhere; and enhance career opportunities for students". Results showed that 76% of the respondents indicated that there was less red tape involved with industry funding, while only 51% of non-industry funded researchers share this sentiment; and 67% of industry funded individuals agreed that it increases the rate of scientific applications from basic research, compared with 52% of those not funded by industry. Furthermore, 63% of industry funded researchers indicated that this source of funding provided more resources than would otherwise be available from elsewhere compared with only 36% of those not receiving industry funding; and 60% also believed that it enhanced the career opportunities of students participating in industry funded projects, while only 43% of non-industry funded researchers viewed this as a benefit.

The study not only investigated the benefits of industry funding but potential risks as well. Eighty-two percent of respondents who were not funded by industry agreed that industry funding creates "*pressures for faculty to spend too much time on commercial activities*", with 68% of industry funded researchers also agreeing. Other highlighted risks of industry funding were that the research focus of academics will shift towards applied research at the expense of basic research, and that the publication of results will be affected through, for example, unreasonable delays.

Landry and colleagues (1996) conducted an "*econometric analysis*" to determine whether university-industry collaborations have an effect on scientific productivity. They collected data through a questionnaire distributed to 9350 professors at universities in Quebec, covering all scientific disciplines. A total of 1566 professors returned their responses, thus a response rate of 17%. The questionnaire was designed to gather information on the relationship of Quebec's university researchers with: (1) each other, their peers throughout Canada and in the rest of the world; (2) with industry; and (3) with institutions (such as government agencies, local governments, and organised interest groups). Among other things, the questionnaire asks respondents about their sources of funding, as well as the reasons for them choosing to collaborate with other researchers.

Results showed that collaborations between academics and researchers from other sectors increase scientific productivity. The relationship is more significant when it is between university and industry. Academics produced more scientific publications when they collaborated with industry than with their fellow academics and researchers from other institutions. However, factors such as the field of research and the geographical distance between the university researcher and the collaborating partner also played a role. For example, academics who are located closer to their industrial partner tended to be more productive than those further apart. Not surprisingly, academics in the humanities were found to engage less in university-industry collaboration, and were thus less productive in these relationships than academics in other fields of study. Similarly, academics who produce mostly patents and products, scientific instruments, software and artistic production also showed fewer scientific publications, i.e. journal articles, than their counterparts. The authors concluded by stating that their results show that "*university researchers have the ability to simultaneously satisfy the needs of industry and other institutions and increase their academic productivity*".

In Germany, Meyer-Krahmer and Schmoch (1998) studied the nature of interaction between university researchers and industry partners. A survey of academics at German Universities was conducted in 1995, and covered the following technology fields: biotechnology, production technology, microelectronics, and software. An additional survey of academics in chemistry was conducted in 1997. A total of 994 questionnaires were distributed, and 433 were returned (resulting in a response rate of 44%). Production technology had the highest percentage share of industrial funds at 25%, while chemistry had the lowest share (11%).

Results showed that collaborative research, followed by informal contacts, was the most common type of interaction between German academics and industrial partners. This pattern (of interaction types), however, holds true only for fields such as microelectronics, software, and biotechnology, and differed for other fields in the study. Contract research, for example, was the most important type of interaction in production technology.

The study also discussed the advantages of partnering with industry for academics, who in turn ranked "additional funds" as the number one advantage, followed by "knowledge exchange". The "observation of scientific development" was cited as the most common reason why companies pursue interaction with universities. The short-term nature of projects involving industrial partners was viewed by academics as the number one problem, while the restriction of publication was only second. A comparison between advantages and disadvantages of the interaction between German university academics and industry revealed that the advantages far outweighed the disadvantages. The authors conclude that "*although the institutional orientation of academic and industrial researchers is different, the exchange of knowledge can be considered a common denominator where both interests meet*".

Grant Harman (1999) conducted a survey of academics in the science and technology disciplines at three universities in 1997, covering a three year period. The aim of the study was "*to explore issues related to the effects on academics and universities of university-industry research links*". Five hundred and thirteen questionnaires were distributed to a randomly selected sample of one in three staff members, and 200 were returned (thus a response rate of 39%). Although the author's intention was to divide the sample group into industry funded and non-industry funded groups, the industry funded group also included individuals (about 40%) who concurrently held a grant from public funding agency such as the Australian Research Council or the National Health and Medical Research Council.

His results showed that industry funded researchers published significantly more articles than non-industry funded researchers. Furthermore, a larger number of academics with industry funding were involved in other roles outside traditional academic roles compared with academics not receiving industry funding. For example, 97.2% of respondents receiving industry funding had served as referees for journal articles compared with only 8.3% of those not receiving funding; and 42.2% of industry funded were members of government committees versus only 17.5% of non-industry funded. Despite the rise in industry funding, academics still held traditional academic values, with 95% of respondents agreeing that "*the results of research should be widely shared in the academic community*", and 65% indicating that "*being active in research is essential if an academic is to be a good teacher*".

When asked about the benefits and pitfalls of industry funding, half of the respondents indicated that one of the possible benefits of industry funding was the provision of extra resources they otherwise would not have. Other possible benefits were the increased career opportunities for students involved in the projects, as well as a higher rate of basic research results being applied to industry problems (both at 37%). Some of the potential risks that respondents identified were that industry funded academics may spend too much time on commercial activities, and that these academics may be drawn towards applied research versus basic research (with almost 80% of respondents indicating these concerns in both cases). Industry funded researchers were found to spend significantly more hours per week in various activities (including undergraduate teaching, postgraduate supervision, research and writing) than non-industry funded academics. Harman (1999) concluded that "*overall, academics funded by industry stand out as being a well qualified and highly motivated group who attract research funds from a variety of sources and have excellent records in terms of publications and service to their department/centre, the academic profession and scholarly associations*".

Hicks and Hamilton (1999) set out to answer this question: "*does university-industry collaboration adversely affect university research?*" The authors conducted a bibliometric analysis of over 2 million SCI-indexed journal articles published by researchers in the United States between 1981 and 1994. Of these, 43 000 articles were joint publications between university researchers and industry partners.

Results showed that the number of papers from university-industry collaborations doubled between 1981 and 1994. The study also looked at the quality of the papers arising from the partnership by using citation counts as proxy. It was found that university-industry papers received more citations on average than papers authored by researchers from a single university. Studies that show similar results, i.e. that industry-funded articles receive higher citation counts than government-funded ones, include Lewinson (1998), Bourke and Butler (1999) and, Tijssen and Van Leeuwen (2006). Furthermore, when Hicks and Hamilton focused on the list of 1 000 most cited papers in a year, an average of 3.3 university-industry papers made it onto the list, compared to an average of 1.7 for single university researchers. Finally, the authors also determined the nature of research published from this university-industry collaboration, i.e. whether basic or applied, and found that "*industry's agenda dominates and the work produced is less basic than the universities would produce otherwise*".

In Canada, Benoȋt Godin and Yves Gingras (2000) assessed "*the extent to which collaborative research influences the nature of scientific production and the level of international scientific collaboration*". Data for their study was compiled from the Canadian bibliometric database, which contains publications produced by Canadian researchers and are indexed in the Science Citation Index (SCI). The database contains publications produced between 1980 and 1997; however, only publications for the years 1980, 1985, 1990 and 1995 were included in the analysis. The sample was divided into two groups: those publications that were produced as a result of domestic collaboration, versus international collaboration. Publications were codified into eight disciplines, depending on the discipline of the journal in which it appeared. These disciplines were: biomedical research, clinical medicine, biology, chemistry, earth and space sciences, engineering, physics, and mathematics. Furthermore, the articles were grouped into one of five sectors based on the authors' address: universities, business firms, government laboratories, hospitals, and colleges.

Results showed that the number of publications grew in absolute terms across all five sectors between 1980 and 1996, for example from 11 838 to 21 336 for the university sector; 1 896 to 3 320 for hospitals; 2 841 to 4 093 for government laboratories; 595 to 1 229 for business firms; and 105 to 300 for the college sector. Overall, publications for Canadian researchers during the period under review increased from 17 724 to 31 179.

The extent of joint publications between university researchers and researchers from other sectors grew from 14.6% in 1980 to 21% in 1995. Similarly, the amount of publications involving intersectoral collaborations grew by 155.2%, from 1 732 to 4 420. Researchers in clinical medicine were the most involved in intersectoral collaboration, producing 33.2% of their articles jointly between university and hospital researchers. The authors attributed this level of collaboration to "*the strong links between universities and affiliated hospitals*". Finally, collaborations with international partners increased from 16% in 1980 to 30.4% in 1995.

To determine the impact of collaborations on the level of researchers' productivity, two groups were considered. First, the authors considered a group of thirty-seven researchers who are involved the most in intersectoral collaborations. The share of publications between the 37 researchers and non-academic partners increased from 25.7% in 1980 to 43% in 1995. On average, this group published 3.7 journal articles in 1980, and this increased to an average of 7.1 articles in 1995. Similarly, they increased their level of collaborations with international partners to 30% in 1995, whereas it was 13.6% in 1980. The second group considered for this part of the analysis comprised 100 of the most productive researchers. Forty-nine percent of the researchers in this group had collaborations with industrial partners. Furthermore, the share of publications from academic researchers which were co-authored with industry partners increased from 1% in 1980 to 4.7% in 1995. Most significantly, results showed that researchers that published with industry partners published more articles than their counterparts that did not collaborate with industry. In 1995, a total of 682 articles were as a result of university-industry partnerships, compared to 593 for those that involved university researchers only. However, researchers involved with industry demonstrated a slightly lower level of collaboration with international partners compared to their counterparts.

Finally, the authors set out to test the hypothesis that university-industry relationships "*would push toward more applied research and that it would have less scientific impact*". To achieve this, they used "*the classification scheme for determining the degree of application of science journals constructed by CHI Inc, where journals are classified by experts according to the degree to which they contain applied or basic research on a scale from 1 (very applied) to 4 (very fundamental)*". The analysis in this regard revealed that research produced from university-industry partnerships, across all eight disciplines, is more applied than that which involves university researchers only.

Bart Van Looy and colleagues (2004) examined the impact of entrepreneurship or industry involvement on academic research productivity at the Catholic University of Leuven (KU Leuven) in Belgium. KU Leuven was founded in 1425, making it one of the oldest universities in Europe. It is involved in teaching and research across a wide variety of fields, including engineering, medicine, social sciences, arts and the humanities. The university has been involved with industry from as early as the 1970s, as evidenced in the establishment of the KU Leuven Research and Development (LRD), which is "*primarily oriented towards stimulating and supporting the knowledge and technology transfer between the academic and the industrial spheres*". The LRD has three main functions: implementation of the patenting and licensing policy; creation of spin off companies; and the administration of contract research, which provides about a quarter of the university's total R&D budget. Most of the university's contract work, i.e. research involving academic researchers and industry partners, is undertaken within semi-autonomous university structures called "research divisions", which consists of a group of researchers. This empirically-based study aimed to answer three questions:

(1) *Do faculty members, who are systematically involved in contract research with industry, publish more or less than their colleagues in comparable research areas and faculties who are not engaged in such systematic endeavours*?
(2) *Do faculty members, who are systematically involved in contract research with industry, have different publication profiles (applied versus basic) than their faculty colleagues*?
(3) *Is there a shift over time in the differential publication profiles observed*?

Data was collected by analysing the publication history (or scientific performance) and profiles of academics involved in contract work (thus research division members) and those who were not involved in such contract work (non-research division members). The sample comprised of 14 research divisions, with eight from the Faculty of Applied Sciences. Other faculties included in the study were the Faculties of Sciences, Medicine, Agricultural Sciences, and Pharmaceutical Sciences. The Arts and Humanities as well as Social Sciences were excluded from the study, "*as the majority of them have been established only very recently*". Only publications that are covered in the Web of Science's Science Citation Index for the period 1998 to 2000 were included in the analysis.

The study found that research division members involved in contract work published significantly more articles than non-division members who were not involved in contract work. Furthermore, scientific field was shown to play a role in the number of publications produced, as results showed that academics in the pharmaceutical sciences (both division and non-division members) published more articles on average (7.43), than their colleagues in other disciplines: agriculture (6.64); medicine (5.99); and physics and mathematics (5.34). Second, results showed that there was no significant difference in the nature of publication produced by academics with contracts. Thus, academics involved with industry produced articles of both applied and basic nature, with a yearly average publication per academic at 1.14 and 1.06 for applied and basic research, respectively. Non-division members published an average of 0.53 articles of an applied nature (per researcher per year) and 1.1 articles of a basic nature. Overall, academics with contract funding published more articles on average in both applied and basic research (an average of 1.10) than non-contract funded academics (an average of 0.81). Lastly, the study showed that the average number of publications produced by contract funded academics accumulated over time. On the basis on these findings, the authors concluded that "*it is indeed feasible to organize both scientific and entrepreneurial activities, without one jeopardising the other*".

Gulbrandsen and Smeby (2005) indicate that in Norway, the share of research funding by industry has increased to more than double what it was in the 1980s. In their study, the authors found *"significant differences between university professors with industrial funding and professors with other types of funding or no external research funding at all with respect to their research activities, and that there is a negative relationship between entrepreneurial activities and academic publishing on an individual level*". Five hypotheses were tested:

- Hypothesis 1: *professors with industrial funding depict their own activities as applied research or development work, more often than professors without industrial funding do*;
- Hypothesis 2: *professors with external funding generally collaborate more than their colleagues with no external funding do, but professors with industrial funding have a somewhat diverging collaboration profile and co-operate more frequently with groups outside of the higher education sector*;
- Hypothesis 3: *professors with external funding publish more than colleagues with no external funding, but there are differences in publishing profile between professors with industrial and other types of funding*;
- Hypothesis 4: *professors with industrial funding can point to more patents, spin-off companies and other commercial results than other professors*; and
- Hypothesis 5: *there is a negative relationship between scientific publishing and commercial outputs*.

Data was collected via questionnaires distributed among assistant professors, associate professors and full professors at four Norwegian universities, and covered various fields of study such as the natural sciences, social sciences, medicine, humanities and technology. The total number of responses received was 1967 questionnaires, with the highest responses received from natural sciences (66%), followed by medicine (64%), social sciences (58%) and the humanities and technology (54%). For the purpose of data analyses, the sample was divided into three groups of academics/professors: those without external funding; those with industry funding; and those with other types of external funding.

The study showed a decrease in public funding between 1981 and 2001 in Norway, accompanied by an increase in industry and other external funding during the same period. There were significant differences in the funding patterns between fields of study for the period 1995 to 2000, with over 80% of academics in the natural sciences and medicine as well as technology fields receiving funding from industry and other external sources. The social sciences and humanities received 74% and 54 % from these sources, respectively. There was even a much greater variation as far as industry funding is concerned, with the technology field receiving 66% of its funding from industry while the humanities received the least support from industry at 3%.

Almost fifty percent of the academics who received industry funding described their work as applied research, compared to only twenty-five percent of those without industry funding. A higher percentage of professors with industry funding reported a high level of collaborations with academics at their home universities (78% of respondents) and foreign institutions (81% of respondents), while only 43% and 35% of professors without any external funding reported collaboration with academics in their home universities and in foreign institutions, respectively. Industry funded professors published an average of 7.2 journal articles and 4 book chapters over a five year period, while professors with other forms of external funding published 5.6 journals articles and 2.5 book chapters during the same period. Professors without any form of external funding only published 2.3 journal articles and 1.4 book chapters over five years. There was a much larger difference between groups as far as commercial outputs, particularly patents, were concerned, with a higher percentage of industry funded professors reporting patent production (24%), than professors without external funding (1%) as well as those with other forms of external funding (4%). Lastly, the study found a positive relationship between the number of scientific publications and commercial outputs such as patents and the establishment of firms.

Balconi and Laboranti (2006) studied the impact of university-industry partnerships among Italian researchers in the field of microelectronics. The study aimed to test four hypotheses: (1) *the best academic centres of research are those more closely connected to industry*, (2) *the interactions are founded on research teams, comprising both industrial and academic researchers, engaged in face-to-face knowledge exchanges, and give rise to a well connected network*, (3) *links with strongly connected, qualified universities are particularly useful to firms for effective recruiting (i.e. they allow firms to hire productive individuals as researchers or designers)*, and (4) *border-crossing connections linking individual* *researchers of the two spheres tend to be driven by cognitive proximity and personal relationships*.

Data was obtained primarily from patent data, with a focus on teams that included both academics and industrial partners. Additional information was obtained from bibliometric data such as the scientific productivity of all Italian academic centres in the field of electronics; by conducting interviews with professors who co-authored a patent with an industrial partner; and data on students who graduated in electronics from the University of Pavia, which is considered to be a university most closely connected with industry.

To test hypothesis 1, the authors measured the extent of collaboration between academics in electronics and industry, and the scientific performance of academics. The extent of collaboration between the two parties was determined from the number of patents (those filed with the European Patent Office – EPO, and US Patent and Trademark Office – USPTO) assigned to the industrial partner, but which were co-invented by an academic. Scientific performance was determined by the number of citations (obtained from ISI – Web of Science database) that academics received from their publications. Results showed that the extent of university-industry collaboration in Italy is concentrated within two universities, namely the University of Bologna and the University of Pavia. Fifty-six percent of the USPTO patents and sixty-one percent of the EPO ones were co-produced by academics from these two universities. The study also reported that academics that produced patents had the most number of citations compared to those who were not producing patents[28]. In particular, the most productive academics (those with the highest citations) were found to be the 28 professors who were collaborating the most with industry, and who were co-inventors in both EPO and USPTO patents.

The testing of hypothesis 2 was based on information received via telephone interviews with the 28 ‘most patenting’ academics mentioned above. The academics were requested to provide the working position/level of their co-authors, and information for 142 of the 151 collaborators was obtained. Academics were collaborating with individuals in various positions, such as fellow academics/professors; final year students; doctoral students; post-doctoral fellows; university technicians; employees of the assignee company (thus the company contracting out the research); and employees at other companies). Results showed that the 28 academics co-authored the most patents with employees of the assignee company (with 86 co-authors) than with any other group (the second highest was with 23

[28] The article, however, does not show the number of citations received by non-patenting academics.

other university personnel). This finding confirms, as the authors state, "*the importance of face-to-face knowledge exchanges between researchers of the two spheres, the academic and the industrial one*".

Hypothesis 3 related to the critical role of connections between universities and private companies for recruiting. Here, the authors considered links between companies and the University of Pavia. In particular, they aimed to determine if individuals who graduated from the University of Pavia, and are now working as industrial researchers, produced more patents that individuals who graduated from other Italian universities (with less connections to industry compared to Pavia). There was a significant difference in productivity between individuals who graduated from the University of Pavia and those who graduated from other Italian universities, with a *mean number of signatures on patents* of 11.7 and 8.4, respectively. Thus, graduates of the University of Pavia who are recruited by companies are more productive than other graduates.

The final hypothesis dealt with individual network connectedness and had two aims: "*to analyse the extent to which the characteristics of the ties (such as variety, persistence, direction) vary according to the identity of the connected nodes (academic versus industrial inventors); and to evaluate the importance of cognitive proximity and personal relationships, taking into consideration the universities of origin of the industrial inventors collaborating with professors*". The 28 academics who had authored EPO and USPTO patents were used as the starting set of participants, followed by the identification of their direct and indirect links. This is known as a "snowballing technique" – where participants are asked to nominate other participants in their network, and these participants are also asked to nominate their participants, and so on. The network therefore grows just like a snowball. The analyses revealed that academics/professors at the University of Pavia maintain links with their graduate students, and that these graduates constitute an important link between the academics and the non-academic world. Furthermore, most of these links, i.e. professor-student link, last for a long time. The study concluded by stating that "*the networks of academic and industrial researchers are a fundamental instrument of collaboration between the two worlds and seem quite effective in enhancing productivity in terms of both discoveries and inventions*".

Bozeman and Gaughan (2007) provide empirical evidence of the impact of the source of funding on academic research. The authors determined the impact of government funding (through grants) and industry funding on US academic researchers. Academics in the US have relied on government support for many years and continue to do so despite the growing support by industry. To date, there have been very few studies done on industry funding of academic research, particularly studies that focus on the individual faculty and not institutions. The authors argued that "*industry funding may encourage academic researchers to interact with industry in some ways and not others*".

The study addressed the following questions: "*does industry research support contribute more to university-industry collaborative activities than do other types of grants? do federal grants enhance or inhibit academic researchers' interactions with industry?* and, *whether industry research support is best viewed as a determinant of academic faculty interaction with industry or, rather, just another variety of interaction, one inseparable from other sorts of faculty-industry interactions*". The central question of the study, however, was: "*what is the relationship, if any, of grants and contracts to academic researchers' propensity to work with industry*?" Two hypotheses were tested: (1) *university researchers who have active grants and contracts will be more likely to work with industry*; and (2) *among those university researchers who have active grants and contracts, those with industry grants will be more likely to work with industry than will researchers who only have government grants and contracts*.

Data was collected via a questionnaire, mailed to 4916 academics belonging to 13 disciplines at various universities. The disciplines surveyed were biology, computer science, mathematics, physics, earth and atmospheric science, chemistry, agriculture, sociology, chemical engineering, civil engineering, electrical engineering, mechanical engineering, and materials engineering. Respondents were requested to provide information on funding, collaboration, institutional affiliations, career timing and transitions, and distribution of work effort. In addition, demographic information of the respondents, their research-specific motivations and values, and the perceived benefits derived from their work, was requested. A total of 1795 questionnaires were returned, thus a response rate of 37%.

Results confirmed both hypotheses: that academics with government grants and industry contracts have more working relationships with industry compared with those without grants and contracts; and those with industry funding have greater interaction with industry than those who only receive government funding. The study also found that the extent of interaction with industry varies between disciplines, with academics in agriculture, engineering and computer science interacting more with industry than disciplines such as physics, chemistry, and mathematics.

Brent Goldfarb (2008) investigated the influence of industry funding (through NASA - National Aeronautics and Space Administration) on publication patterns of academic researchers in the United States. The study also looked at "*limitations of the grant funding mechanism*". The author highlighted that most of the US' government grants are obtained from "*programmatic, mission-oriented agencies*" whose main focus is meeting practical goals. Goldfarb cautioned that such agencies may "*insist on the production of immediately useful knowledge at the expense of traditional academic scholarship*". The sample included 221 academic researchers who had received funding from the NASA aerospace engineering program between 1981 and 1988.

Data was obtained from NASA's publication called the University Program Management Information System, also known as "Greenbooks". The publication contains information of all individuals receiving grants from NASA, and whose projects are not yet completed, i.e. considered as active grants. The information in the Greenbooks is captured by grant and not by individual. That is, if an individual is receiving two grants, he/she will appear twice in the publication. Only individuals receiving grants under the discipline of aerospace engineering were considered, and the database contained 302 academic researchers receiving this grant. Some academics were removed from the sample for various reasons, for example, 27 researchers were removed because they were awarded training grants, which were not considered for the purpose of this study. For this and other reasons, the sample was reduced from 302 to a final total of 221. Additional information collected for each academic include their PhD history (institution and year awarded) and publication record (obtained from the Institute for Scientific Information's Science Citation Index).

First, the findings of the study showed that academic merit was of less importance as far as obtaining funding from NASA is concerned, and that other criteria were used in awarding grants. For example, academics with common research interest to those of NASA were most likely to receive the grant. Results revealed that researchers who received funding through the aerospace engineering program published significantly more journal articles between 1988 and 1994 than those who did not receive this type of funding, i.e. 6.13 and 3.54 articles, respectively. Eighty percent of articles published by funded researchers were classified as being in the aerospace engineering discipline whereas only 25% of those published by researchers outside the programme were in this discipline. However, further results showed that for those researchers publishing only in aerospace engineering, with an average of four articles and an average citation count of 6 between 1981 and 1987, research productivity dropped by 10%. Thus, a continued relationship with industry (NASA in this case) showed a negative effect on research outputs, particularly for researchers in aerospace engineering. The author's interpretation of this finding was that "*individuals who do not focus on the area of the applied program are able to leverage the funds with little concern of a long-term relationship with the program*. *Furthermore, individuals whose focus is more squarely in the program's domain are more responsive to the needs of the program, and hence are less able to pursue academic goals in an unfettered way*".

A recent study by Hottenrott and Thorwarth (2011), which also investigated the effect of industry funding on the scientific productivity of German academics, revealed an opposite trend to that of the studies reviewed in this section. The study found that "*a higher budget share from industry reduces publication output of professors both in terms of quantity and quality in subsequent years*". The authors conducted a questionnaire-based survey among academics in the fields of science and engineering, spread across three institutional types, i.e. universities, technical universities, and universities of applied sciences. The questionnaire was sent to heads of departments who were also full professors. Among other things, participants were requested to indicate the amount and composition of funding they had received from a third stream source during 1999 in addition to the core funding. Further, they had to indicate the proportion of third stream funding as a share of the overall budget. Of the 678 professors, 61% received industry funding during 1999. In addition to the survey, the authors obtained publication data (from the ISI Web of Science database) and patent data (from the German Patent and Trademark Office) of the participants, produced during the period 1994 to 1999. For the purpose of the analysis, the authors also included publications produced during a period of eight years after the survey, i.e. 2000-2007, because *"potential effects are unlikely to show up immediately*". The citation counts of both the patent and article publications were taken into account as an indication of the impact of the output.

On institutional differentiation, the findings showed that university professors published more articles than their counterparts, producing 16 articles compared to 6 and 2 articles produced by professors at technical universities and universities of applied sciences, respectively. Similarly, publications from universities received higher citation counts (344), compared to 128 for technical universities and 23 for universities of applied Sciences. However, the difference in patent applications was not very large between institutional types, with 1.54 for universities, 1.27 for technical universities and 1.20 for universities of applied sciences.

Patents produced by professors at technical universities received higher citation counts than their two counterparts.

As already indicated, a significant finding of this study was that whilst industry funding may lead to an increase in publications, particularly in the early stages of the relationship with academia, industry funding has a negative effect on publications later on. The study indicated that "*a higher share of industry funding (in 1999) leads to a lower publication output in subsequent years (2000 – 2007) both in terms of quantity and quality*". That is, any increase in the share of industry funding (by a percentage point) led to a 0.8% reduction in publication output. The quality of publications (taken as the number of citations received) was also negatively affected, with a 1.3% decrease in citations per publication. There was no effect on the number of patents produced as a result of the increase in industry funding. However, results showed a positive effect on the citation count with an increase of 2.6% in the number of citations per patent for each percentage increase in industry funding. The study concluded by stating that "*an increasing reliance on industry funding compared to stagnating core funding may indeed affect the development of science in the long run if publication output is reduced*".

Table 4.4. Summary of studies on the impact of industry funding on the science system

Authors	Date of publication	Aim/Hypotheses	Main findings
Blumenthal, D., Gluck, M., Louis, K.S., Stoto, M.A. & Wise, D.	1986	To determine the effects of university-industry research relationships in the biotechnology discipline among academics in the United States.	Academics who received industry funding published significantly more journal articles than those without industry funding; they spend more time supervising students; and are involved in more activities outside the university compared to their counterparts. Industry funded individuals also spend more time on commercial activities.
Landry, R., Traore, N. & Godin, B.	1996	To determine the effect of university-industry collaborations on scientific productivity.	Collaboration with industry increases scientific productivity.
Meyer-Krahmer, F & Schmoch, U.	1998	To study the nature of interaction between academics and industry partner.	Academics commonly engage in collaborative research with industry, particularly those in fields such as microelectronics, software, and biotechnology. A disadvantage for engaging in projects with industry is the short-tem nature of the projects, followed by

Authors	Date of publication	Aim/Hypotheses	Main findings
			restrictions to publish the results.
Harman, G.	1999	To determine the effects of university-industry links on academics and the university.	Industry funded academics published significantly more journal articles than non-industry funded academics. Those who receive industry funding are involved in other roles outside the university, such as participation in government committees. Industry-funded academics tend to engage in applied rather than basic research.
Hicks, D & Hamilton, K.	1999	To determine the effect of university-industry collaboration on university research.	Collaboration with industry increases the number of journal articles published, and papers co-published with industry receive higher citations on average than those authored by academics alone (also see Lewinson, 1998; Bourke & Butler, 1999; and Tijssen & Van Leeuwen, 2006).
Godin, B & Gingras, Y.	2000	To determine the extent to which collaboration with industry influences the nature of scientific production.	The number of average journal articles published by academics collaborating with industry increased from 3.7 articles in 1980 to 7.1 in 1995. Those academics co-publishing with an industry partner published more journal articles than their counterpart that are not involved with industry. University-industry partnerships lead to applied research.
Van Looy, B., Ranga, M., Callaert, J., Debackere, K. & Zimmermann, E.	2004	To determine the impact of industry involvement on academic research productivity.	Academics involved in contract work with industry published significantly more journal articles than those not involved in contract work. Those involved with industry engaged in both basic and applied research.
Gulbrandsen, M. & Smeby , J.C.	2005	To test whether professors with industrial funding depict their activities as applied research or development work, more than professors without industrial funding; they generally collaborate more than their colleagues without external funding; they publish more than colleagues without external funding; and they can point to more	Professors with industry funding described their work as applied research; they show higher collaborations with both local and international universities than their counterparts; they publish more journal articles on average, than those without external funding; and

Authors	Date of publication	Aim/Hypotheses	Main findings
		patents, spin-off companies and other commercial results.	they produced significantly more patents than those without industry funding.
Balconi, M. & Laboranti, A.	2006	To test whether the best academic research centres are those closely connected to industry; interactions comprise both industrial and academic researchers; links with universities are useful to firms for recruitment; and connections between individuals are driven by cognitive proximity and personal relationships.	Professors who collaborate with industry are more productive and have higher citations than those who do not collaborate with industry; there was high patent co-authorship between academics and industry partner; university professors maintain links with their graduate students employed in industry.
Bozeman, B & Gaughan, M.	2007	To determine the impact of the source of funding on academic research. The following hypothesis was tested: university researchers with industry grants will be more likely to work with industry than those who only have government grants and contracts.	Academics with industry funding have greater interaction with industry than those who only receive government funding. Academics in agriculture, engineering, and computer science interact more with industry than those in physics, chemistry and mathematics (for example).
Goldfarb, B.	2008	To determine the impact of industry funding on publication patterns of academic researchers.	Researchers who received funding from industry (i.e. NASA's aerospace programme) published more journal articles than those without this type of funding. However, a continued relationship with industry had a negative impact on research outputs in later years.
Hottenrott, H. & Thorwarth, S.	2011	To determine the effect of industry funding on scientific productivity.	While industry funding may lead to increased publications in earlier years, a higher share of industry funding leads to a lower publication output in subsequent years.

4.5. CONCLUDING REMARKS

It is clear from the studies reviewed here that, to date, there are a limited number of studies that have explicitly investigated the link between the source of funding and the mode of knowledge production, and provide empirical evidence to this effect. Studies that attempt to make this link include Blumenthal *et al*. (1996), Benner and Sandström (2000), and Gulbrandsen and Smeby (2005).

The current scholarship on the sources of funding for academic research and the implications of the various sources, particularly industry funding, on academic research demonstrates that: (1) governments across the globe remain the primary source of funding for university research, and that the awarding of government funds in most countries is based on performance (Geuna & Martin, 2003). Furthermore, government funding is also used as a mechanism to steer research in areas where it could help solve national problems. (2) There is increasing demand for public funding of university research and, as a result, academics are increasingly relying on other sources of funding, particularly industry funding (Meyer-Krahmer & Schmoch, 1998; Harman, 1999; Gulbrandsen & Smeby, 2005). (3) There is an increase in the number of university-industry partnerships in many countries around the world, and these partnerships are of mutual benefit, i.e. academics get much needed funding while industry gains access to new knowledge that will improve their products and/or processes (Mansfield, 1991; Narin *et al*., 1997). (4) Most industry funding goes towards applied research (Blumenthal *et al*., 1996; Gulbrandsen & Smeby, 2005; Crespo & Dridi, 2007), while government funding is spent mostly on basic research (Benner & Sandström, 2000). (5) Industry-funded academics publish significantly more journal articles than non-industry funded academics (Blumenthal *et al*., 1986; Van Looy *et al*. 2004; Goldfarb, 2008). Thus, university involvement with industry on the whole is not detrimental to academic research (Godin & Gingras, 2000), but rather enhances it. However, authors such as Hottenrott and Thorwarth (2011) question whether "*industry funding is causal or a reflection of the fact that industry selects the most productive researchers".*

Despite the benefits of industry funding, most commonly commercial benefits (Blumenthal *et al*., 1986; Blumenthal *et al*., 1996), some authors have also identified the negative consequences that this funding has on university research, such as the restriction on the publishing of research results imposed by industry partners (Blumenthal *et al*., 1996), and the negative impact on undergraduate teaching, i.e. academics could spend less time on teaching duties (Poyago-Theotoky *et al*. 2002).

The relationship between university researchers and industry should be encouraged as it clearly results in mutual benefits. One of the most important goals of academic research is to increase productivity, which is measured in part in terms of the number of publications produced. Studies reviewed here show that academics with industry support are more productive, thus they publish more, than their counterparts without such support. It was also demonstrated that partnering with industry does not negatively affect academics' involvement in basic and fundamental research (e.g. Crepo & Dridi, 2007). It is therefore critical that national research funding policies reflect support for university-industry partnerships and industry's involvement in funding research performed in universities. This will ensure adequate support for research during a time when governments are unable to meet the demand for funding, and will boost the national science system.

CHAPTER 5: DATA SOURCES AND METHODOLOGY

5.1 INTRODUCTION

This study used a mixed-methods research design, defined by Johnson *et al*. (2007: 113) as "a synthesis that includes ideas from qualitative and quantitative research". Creswell (2003: 4) mentioned that "*mixed methods research has come of age. To include only quantitative and qualitative methods falls short of the major approaches being used today in the social and human science*s". It is evident from previous studies that there is a growing use of mixed-methods research designs across many areas of study, including sociology, education, evaluation and health sciences (see for example Hanson *et al*., 2005; Molina-Azorin, 2012). Johnson and Onwuegbuzie (2004: 14-15) add that "*the goal of mixed methods research is not to replace either of these approaches [qualitative and quantitative research] but rather to draw from the strengths and minimize the weaknesses of both in single research studies and across studies*". Furthermore, Hanson and colleagues (2005: 224) also highlighted the advantages of mixed-methods design, and stated that "*using both forms of data [qualitative and quantitative], for example, allows researchers to simultaneously generalize results from a sample to a population and to gain a deeper understanding of the phenomenon of interest*". Molina-Azorin (2012), for example, found that studies that employed a mixed-method design have a higher impact, thus higher citations, than those that only utilised one method, i.e. mono-method studies. Leech and Onwuegbuzie (2009) however caution that this method is still in the 'adolescence' stage, and that it may not yet be fully understood by some novice researchers and students.

The current study consisted of three main sources of data: (1) a comprehensive bibliometrics analysis of the NRF funding data to determine trends in research funding over the years; (2) a content analysis of the curricula vitae of South African academics focussing on their sources of funding, level of scientific productivity, and modes of knowledge production; and, lastly, (3) telephonic interviews with a select group of academics to establish the link between their sources of funding and mode of knowledge production. In addition, archival materials from the National archives of South Africa (NASA) were consulted to gain deeper understanding of the history of research funding in South Africa.

A review of the history of research funding in the country, reviewed in detail in Chapter 2, shows that research support in South Africa started in the early 20th century through the Royal Society of South Africa (1911); followed by the Research Grant Board (1918) and the National Bureau of Educational Research (1929). With each transition from one agency to the next, the research budget increased with the growing demand for funding. In 1945/46, the country witnessed a significant shift when the Council for Scientific and Industrial Research (CSIR) was established, focusing on conducting research in-house and funding research at universities. Another structure was introduced parallel to the CSIR, namely, the National Council for Social Research (NCSR), with the CSIR providing funding for the natural sciences and the NCSR supporting the social sciences. Nineteen forty-five was therefore the start of a differentiated funding system, along broad scientific fields.

Both the CSIR and NCSR (which became the Human Sciences Research Council in 1969) went through some transformation over the years, including the introduction of dedicated funding structures, namely the Foundation for Research Development (FRD) and the Centre for Science Development (CSD), respectively. The FRD and CSD were merged in 1999 to form the National Research Foundation (NRF) – currently one of the country's largest funding agencies. Other large agencies in the country include the Medical Research Council, which provides research funding to researchers in the health sciences; and the Agricultural Research Council (ARC), which supports those in the agricultural sciences. The NRF, however, is non-discipline specific – it provides funding to researchers across all disciplines.

5.2 TRENDS IN ACADEMIC RESEARCH FUNDING IN SOUTH AFRICA: 1994 – 2008

Over the years, the NRF has introduced several programmes through which it distributes funding, each with slightly different funding criteria to the next. One of the oldest funding programmes of the NRF (inherited from one of its predecessor, the FRD), is the Technology and Human Resources for Industry Programme (THRIP) established in the 1990s to provide funding for the engineering sciences in partnership with industry. Another programme is the Focus Areas programme introduced in 2001. For the purpose of this study, THRIP funding is considered as proxy for industry funding given that a significant portion of the THRIP grant comes from industry contributions; while the Focus Areas programme is taken as proxy for government funding (in that it is fully funded by the NRF/government).

This section compares funding allocation trends through the Focus Areas and THRIP programmes between 1994 (the year the first THRIP grants were awarded) and 2008 (the year the Focus Areas were phased out). The aim of this comparison is to establish whether researchers/academics who receive funding from industry, i.e. THRIP, receive more or less funding than those that receive public funding, i.e. Focus Areas funding.

Funding data was requested for the period 1994 – 2008 from the National Research Foundation (NRF) (**Annexure 4**). In particular, funding data for each funding year was requested for the Focus Areas and THRIP Programmes. Data requested include:

- Biographical details of grantholders, including race, gender, and date of birth;
- Title of the project;
- Area of study (scientific field and/or discipline);
- Amount of grant awarded;
- Details of publications produced; and
- Number of students supervised.

Additional (and relevant) information provided include the grantholder's rating category as well as the university/institution to which they were affiliated at the time the grant was awarded. Some academics were awarded more than one grant (that is, they would have more than one funded project) within the same funding year, either from the Focus Areas or the THRIP programme, or even from both programmes. In this case, all the projects attached to the respective academic were listed separately in the database, that is, if an academic received three grants in 1994, they would be listed three times, and so on. Grantholders were divided into three groups:

- Researchers who received funding from the Focus Areas only,
- Researchers who received funding from THRIP only, and
- Researchers who received both Focus Areas and THRIP funding, concurrently (during the same funding year)

The process of data cleaning involved, among other things, the correcting of grantholders' names to ensure that the individual is treated as one person and not two (in some cases there were errors with the spelling of surnames). Other grantholder details such as the date of birth, institution of affiliation, etc. were used to verify the grantholders' identity. Grants awarded for activities such as conference attendance, and the hosting of a visiting scholar, were removed from the data before analysis, i.e. only grants awarded for research projects were included in the analysis. There were also gaps in the data provided by the NRF. These included the absence of broad scientific field for some researchers. In this case, the person's area of specialisation and/or the project title was used to determine the scientific field. The researcher's institution of affiliation/university was also omitted in some areas, in which case an internet search was conducted using the researcher's name. There were also gaps in the researchers' biographical details such as gender, race, or date of birth. In this case, the individuals were grouped under the "not specified" category during analysis.

The Focus Areas and THRIP programmes were discussed in detail in Chapter 2 of this thesis together with other major funding programmes of the NRF. Nonetheless, these two programmes (Focus Areas and THRIP) will be described briefly below in order to provide more specific context.

As mentioned earlier, THRIP is the NRF's oldest funding programme, having been established in the early 1990s to foster working relationships between academia and industry. The mission statement of THRIP is: "*to improve the competitiveness of South African industry, by supporting research and technology development activities and enhancing the quality and quantity of appropriately skilled people*" (THRIP, 1998). For the purpose of this study, THRIP funding is used as proxy for industry support.

The THRIP programme has three objectives:

- To contribute to the increase in the number and quality of people with appropriate skills in the development and management of technology for industry,
- To promote increased interaction among researchers and technology managers in industry, higher education and SETIs[29], with the aim of developing skills for the commercial exploitation of science and technology. This should involve, in particular, promoting the mobility of trained people among these sectors, and
- To stimulate industry and government to increase their investment in research, technology development, technology diffusion, and the promotion of innovation.

Academics wanting to participate in the THRIP programme therefore must have an industrial partner with whom they will collaborate with in their research. Another critical factor for THRIP has been the involvement of postgraduate students in the project. Project funding is provided by both government (through the Department of Trade and Industry – the dti) and industry. During the early years of THRIP, the funding ratio was R1:R2 – thus for every R1 from government, the industry partner must contribute R2. However, the funding ratio changed in 2007, when industry partners were required to contribute R3 for every R1 from the dti. As a result of the increase in funding contribution, companies (large companies in particular) have found it difficult to partner with academic researchers due to the large cost (THRIP, 2010). The increased ratio has also resulted in a drop in the number of applications for funding.

[29] SETIs = Science, Engineering and Technology Institutions.

The Focus Areas programme was introduced in 2001 and ended in 2008. The thinking behind the Focus Areas programme was that it would cater for experienced/developed researchers, while novice researchers would continue to receive funding from "developmental" programmes such as the Thuthuka programme, among others. Both the Focus Areas and THRIP programmes have awarded grants not only to university researchers, but also to those in science councils such as the Council for Scientific and Industrial Research (CSIR), the Agricultural Research Council (ARC) and the Medical Research Council, and to other institutions that perform research such as national museums and research institutes. The Focus Areas programme had nine focus areas, which were inclusive of all scientific disciplines. Each of the Focus Areas had specific aims as well as research themes highlighting the scope of the particular Focus Area (Table 5.1).

Table 5.1. The nine Focus Area Programmes – their aims, and research themes (*source*: NRF, 2004).

Focus Area	Aims	Research themes
Challenge of Globalisation: Perspectives from the Global South	• To expand our understanding of globalisation through interdisciplinary social scientific enquiry; • To critically engage the idea of globalisation by drawing on experiences from the global periphery; in other words, to 'de-centre' the perspective from which the concept is generally understood and articulated; • To locate and understand South Africa, Southern Africa and the Global South within both the reality of globalisation and discourses that have driven the idea of globalisation; • To assess the impact of globalisation, particularly on South Africa, identifying and analysing the possibilities for change that it creates.	• Theorising the Global • Identities, Movements and Social Change • State, Society and Conflict Resolution • Political Economy and Technology

Conservation and Management of Ecosystems and Biodiversity	• Develop a more comprehensive and scaled understanding of the way that ecosystems are structured and function in South Africa
	• Describe, understand and conserve the biodiversity resources in South Africa at landscape, ecosystem, habitat, community, population, species and gene levels, by:
	    • a) Developing appropriate practices, strategies, tools and policies for the sustainable use and conservation of South Africa's biological diversity
	    • b) Assessing and adding value to South Africa's biological diversity
	• Monitor, interpret and predict environmental change
	• Analyse the environmental potentials for and constraints on human development
	• Expand and increase the representivity of South Africa's human capacity to conserve biological diversity through environmental awareness and education, as well as develop skills, expertise and research infrastructure
	• Contribute, through fundamental research, to the objectives set out in various international conventions to which South Africa is a signatory (for example, the Convention on Biological Diversity)
	• Develop appropriate adaptive management protocols whenever
		• Management of species, populations and ecosystems and decision support
		• Society, the natural environment and ecosystem services
		• Long-term monitoring and research

Focus Area	Aims	Research themes
	research products are management related.	
Distinct South African Research Opportunities	• To generate world-class researchers in fields/areas uniquely defined by South Africa's context and position. • To enable the country, through research, to play an effective role within the regional context. • To improve international understanding and collaboration by promoting unique South African research opportunities.	• Palaeontology and archaeology • Southern skies • Geological heritage • Societies in transformation • Cultural heritage and identity formation • Health • Creative Arts and Cultural Expression
Economic Growth and International Competitiveness	• Establish and grow the research skills with potential to impact on economic growth and competitiveness and help apply these skills to the benefit of South African industry and business for ongoing and sustainable development • Support pre-competitive research relevant to industry in areas of national importance, such as wealth creation, job creation, enhancement of foreign direct investment, and ultimately economic growth • Develop relevant research programmes with key sectors of industry and business • Develop innovative technologies and technology-based solutions to strengthen the competitiveness of sectors and enterprises • Strongly promote entrepreneurship, business creation, commercialisation of research, business development and protection of intellectual property • Pro-actively involve business schools in this focus area • Encourage researchers in science and technology to link up with the human and social sciences in joint research endeavours.	• Technologies for Competitiveness • Management for Competitiveness. Subthemes: o Environment for economic growth; o Management of the enterprise; o Human resources
Education and the challenges for change	• Determine the critical factors of educational change and how they serve as useful indicators for planning and decision making. • Provide reliable databases and benchmarks on various issues for planning and decision making. • Undertake case, systemic, unicultural vs cross-cultural, trend, longitudinal, cross sectional and comparative studies with respect to the diverse aspects of the teaching-learning process (including the classroom environment). • Critically analyse the regulatory framework (past and present) that	• Restructuring in Higher Education / Further Education and Training (FET) • Policy Implementation Studies • Science, Technology and Mathematics Education (STME) • Human Resource Development – Teacher Education and Development • Curriculum, Pedagogy and Assessment • Language issues and Literacy

Focus Area	Aims	Research themes
	shapes the contemporary education system in order to generate corrective action. • Investigate new directions in curriculum research and curriculum theory. • Contribute to multi-disciplinary and transdisciplinary knowledge production and human resources development in education. • Critically explore the impact of HIV/AIDS on the structure and functioning of the education system.	• HIV/AIDS in Education
Indigenous Knowledge Systems	• Develop theoretical and methodological paradigms within which to understand the specific characteristics of IKS • Shed light on the role of IK in nation-building • Develop research capacity in the field of IK in South Africa.	• Production, transmission and utilisation of indigenous knowledge and technology (sub-theme: The nature of IK, IKS and indigenous technology) • Role of IK in nation building (sub-themes: Traditional medicine and health; Indigenous food systems; Socio-cultural systems; Arts, crafts and materials) • IK at the interface with other systems of knowledge.
Information and Communication Technology (ICT) and the Information Society in South Africa	• Ensure that a critical base of ICT specialists is trained and maintained to effectively contribute to the information needs of industry and society. • Grow a strong training and research base in academia to make South Africa an attractive international training ground for ICT • Generate, design, and apply new information and communication technologies in an innovative way. • Develop entrepreneurial skills to take knowledge and skills generated through research into business creation • Enable South Africans, through research, to remain dynamic and accommodate the fast-moving changes and developments of this field. • Form appropriate partnerships to strengthen ICT capability through research capacity building, as well as redress in all sectors • Raise the status and understanding of ICT and the use and management of information in all sectors • Encourage the private sector, through partnerships and co-funding to invest in scholarships and chairs • Make special provisions to attract post-doctoral students in ICT to uplift	• Software Development and Integration • Telecommunications and networking • Human-Information Interactions • ICT Driven Development

Focus Area	Aims	Research themes
	the capacity for research at HEIs • Promote collaboration between science and engineering and social sciences in ICT.	
Sustainable Livelihoods and the Eradication of Poverty	• Contribute to reducing vulnerability to as well as the eradication of poverty, • Better understand sustainable urban and rural development • Investigate micro- and macro-policies for sustainable urban and rural development • Investigate and promote the utilisation of appropriate technologies for sustainable urban and rural development • Investigate the interfaces between urban and rural lives and livelihoods. • Develop ways to measure the impact of micro and macro economic and social policies on people's livelihood strategies.	• Environment and natural resources utilisation, • Integrated food security, nutrition and health, • Local development, • The informal sector and the formal economy • Social institutions and networks, and • Service provision and management
Unlocking the Future: Advancing and Strengthening Strategic Knowledge	• To push the frontiers of knowledge within or between disciplines, advancing or developing paradigms and theories, and leading to new discovery and/or methodological innovation. • To create, maintain and position a knowledge base that empowers our people to resolve current problems, anticipate future ones, and/or intellectually generate new challenges and opportunities. • To contribute to the development of a sound fundamental basis to science in South Africa, whether in the humanities, the natural or the social sciences. • To ensure recognition, both nationally and internationally, of the high quality of the research.	[This Focus Area did not have specific research themes due to its "openness". Self-initiated research, which addresses the aims of the Focus Area, was encouraged].

5.3. DATA ANALYSIS

Broadly, this study was aimed at describing and comparing shifts in funding trends between the Focus Areas and THRIP for the periods 1994 to 2008 (THRIP) and 2001 to 2008 (Focus Areas), given the significant amount of funding that has been invested through both programme over the years. As previously mentioned, the comparison was done for three groups of researchers: those who received a Focus Area grant only; those who received a THRIP grant only; and those who received both Focus Area and THRIP grants, concurrently. The Focus Areas Programmes awarded just over 8100 grants during the eight year period (2001 – 2008), while THRIP awarded just over 3700 during the same period (2001 – 2008). Therefore, the total number of grants included in this study were around 11 900, awarded to about 2349 researchers.

From the funding data provided by the NRF, a selection was made of those researchers who had received significant amounts of funding between 1994 and 2008, either through the Focus Areas or THRIP Programme. In this regard, only researchers who had received an amount of R700 000[30] or more were included. A total of 636 researchers received funding of R700 000 or more from the NRF and were therefore selected for the study. The selected researchers were representative of the broad fields of study supported by the NRF, such as the Agricultural Sciences, Biological Sciences, Engineering Sciences, Social Sciences, and Arts and Humanities. They are also representative of the various institutions (including universities and research councils) as well as demographically (gender, race, and age).

A letter requesting curriculum vitae was e-mailed to selected researchers during the month of July 2012 (**Annexure 5**). The e-mail addresses of 63 researchers could not be found after numerous attempts of searching. Thus, 573 e-mails were sent out. A further 71 e-mails were returned undelivered for various reasons, mostly due to errors in the e-mail addresses used (with a few that could not be delivered because the recipient's mailbox was full). A second e-mail was sent three weeks after the first one, reminding researchers who had not yet responded to do so. Of the 222 researchers that responded to the e-mail request, 45 did not provide their CVs. Respondents gave various reasons for not providing their CV, including:

- "*While I am happy to participate in this survey, my CV does not detail the money I get, merely my publications, student trained, portfolios held etc. I do not include this information as my CV is already a hefty document. I do not have the time to add the information in. And it will take time for me to go back into archives to show the funding trend over the 20 years I have been a*

[30] R700 000 was the highest amount awarded to an individual researcher that included researchers from various fields of study.

researcher. At present I am running the equivalent of 3 jobs, as I am standing in as acting HoD - and have post award related commitments that are keeping me at work till 10 pm every night. My diary is full for every day in august - end September so this cannot be done during that time. However I can do it afterwards, if you write a reminder. But prefer to do it telephonically if required".

- "*I'm afraid the type of information you are looking for is not contained in my CV*".
- "*My current research sits between NRF and Private funding and so will confound your data. I am also a little research fatigued, having been the subject in at least three other PhD studies recently, and all similarly focused (on questions about research output in South Africa). So I am sorry, I have not included my CV nor am I available for an interview. I wish you every success with your study*".
- "*I have been involved in research management since the early '90s and do not have an academic CV with the type of information you are looking for*".
- "*I now live and work in the USA. Have retired from UKZN 13 yrs ago*".
- "*As a part of the Engineering profession, where a PhD is a 3 years extremely hard work, I fail to see the academic value of a doctoral thesis based on your description. I therefore wish to have no part in this attempt*".
- "*My CV is private until when I want to use it for my benefit. I would never send my CV to a student. This communication is over. There will be no further responses from me*".
- "*I am not sure that my CV will support your research question. This is a private matter and can only be shared in confidential purposes*".
- "*I am afraid I am not in a position to send you my CV. I wish you good luck with your research*".

An attempt was also made to search for CVs on the internet. However, this process did not yield much result and proved to be more time consuming than anticipated. Table 2 shows the breakdown of requests (based on the 502 e-mails delivered) by broad field of study, while Table 3 shows the breakdown by institutions (at the time the grant was awarded).

Table 5.2. Distribution of requests by broad scientific field

Broad field of study	**Researchers per broad field**	
	Count (N)	**Percentage (%)**
Biological Sciences	143	28.5%
Engineering and Applied Sciences	102	20.3%
Chemical and Physical Sciences	88	17.5%
Agricultural Sciences	61	12.2%
Social Sciences, Arts and Humanities	45	9%
Health Sciences	24	4.8%
Earth and Marine Sciences	19	3.8%
Information and Communication Technologies	19	3.8%
Economic Sciences	1	0.2%
Total	**502**	**100%**

Table 5.3. Distribution of requests by institution

Institution	Researchers per institution	
	Count (N)	**Percentage (%)**
University of Cape Town (UCT)	91	18.1%
University of Stellenbosch (US)	82	16.3%
University of Pretoria (UP)	67	13.3%
University of the Witwatersrand (WITS)	48	9.6%
University of KwaZulu-Natal (UKZN)	42	8.4%
North-West University (NWU)	30	6.0%
Rhodes University (RHODES)	19	3.8%
Nelson Mandela Metropolitan University (NMMU)	17	3.4%
University of Johannesburg (UJ)	16	3.2%
University of the Free State (UFS)	15	3.0%
University of the Western Cape (UWC)	13	2.6%
Agricultural Research Council (ARC)	7	1.4%
Tshwane University of Technology (TUT)	5	1.0%
Cape Town University of Technology (CPUT)	3	0.6%
Durban University of Technology (DUT)	3	0.6%
University of Zululand (UZ)	3	0.6%
University of Fort Hare (UFH)	2	0.4%
University of Limpopo (UL)	2	0.4%
Vaal University of Technology (VUT)	2	0.4%
*Other research institutions**	*9*	*1.8%*
*Unknown**	*26*	*5.2%*
Total	**502**	**100.0%**

*= Other research institutions include: Council for Scientific and Industrial Research (CSIR); DISTELL; iThemba labs; Iziko Museum; Medical Research Council (MRC); MINTEK; National Health Laboratory Services (NHLS); and World Wide Fund (WWF). The universities/institution to which some 25 researchers were affiliated, were unknown.

5.3.1. The use of curriculum vitae as an important data source

To my knowledge, curriculum vitae have not been widely used as a source of research information/data. A literature search in this domain revealed a team of researchers that have explored this method, based at the Research Value Mapping (RVM) Program within the School of Public Policy at Georgia Institute of Technology. Relevant studies produced by the RVM Program on using CVs as data source include Dietz *et al*. (2000), Corley *et al*. (2002), and Gaughan and Bozeman (2002).

In what seems to be one of the first studies of the use of CVs as a data source, Dietz and colleagues (2000) examined the career paths of scientists and engineers. The authors point out that the CV is a valuable tool in research as it "*contains useful, concrete information on the timing, sequence, and duration of jobs, work products (e.g. articles, patents, papers), collaborative patterns, and scholarly lineage*". Despite the clear potential of the CV as a research tool, there are also some limitations to this approach. First, the authors indicate that some of the information contained in the CV may be "*fabricated*" or exaggerated, although they point out that this may also be the case in "*self-reported questionnaire or interview data*". Second, CVs do not follow a standard format, which could result in the omission of important information, or the inclusion of non-relevant information. Lastly, the process of coding the CVs for data analysis can be time-consuming. In this regard, the authors point out that the process "*is tedious and runs the risk of introducing error due to coder fatigue*". Corley *et al*. (2002) agree that relying on CVs for data can be a labour intensive process, and add that, as a result, "*the use of CVs almost necessarily requires strict limits on the data to be captured*". In 2009, the journal Research Evaluation published a "special issue" on the use of curriculum vitae. Carolina Cañibano and Barry Bozeman (2009) contributed an article to the special issue, in which they indicate that the use of CVs in research evaluation is "*a small but burgeoning research approach*". Other contributions to this 2009 special issue of Research Evaluation were by D'Onofrio (2009), Gaughan (2009), Sandström (2009), and Woolley and Turpin (2009).

The objective of this part of the study was to determine, by using curriculum vitae, whether researchers who receive funding from industry are more or less productive than those who receive public funding only. In this regard, the average number of various types of publications, i.e. journal articles, books, chapters in books, conference proceedings, and technical reports, will be compared between these groups. Researchers' level of involvement in capacity building, through the training of masters and doctoral students, will also be compared.

5.3.2. Analysis of data from curricula vitae

As already indicated, the primary source of data for this study is the curriculum vitae of researchers. It was assumed that the CVs would contain relevant information needed for the analysis, such as the source of funding (e.g. NRF, THRIP, industry – including names of sponsor); the amount of funding awarded; a complete list of outputs by type of publication, i.e. journal articles, books, chapters in books, conference proceedings, and technical reports, complete list of students supervised, particularly at masters and doctoral levels; and an indication of whether or not the researcher engages in commissioned work. The type of publication would be used as proxy for the mode of research. For example, patent production would be viewed as a sign that the researcher engages in applied research.

A total of 122 CVs were received after the first request, followed by a further 59 after the reminder e-mail. A total of 181 CVs were provided, resulting in a response rate of 36% (based on the 502 e-mails assumed to be delivered). An additional two CVs were obtained via the internet search. In general, the majority of researchers sent their CV within days of e-mailing the request, with the rate of responses decreasing after a week or so. Seven of the 183 CVs were deemed "unusable" – they did not contain important information such as publication details and records of students supervised (this includes one of the two downloaded from the internet). As a result, the analysis was based on a total of 176 CVs (thus 35%). Of the "disqualified" CVs, two were in the field of Agricultural Sciences; two in Social Sciences, Arts and Humanities; one in Engineering Sciences; and two in Chemical and Physical Sciences. In terms of the institutions, three of the disqualified CVs were from academics at UCT; one at UKZN; one at NWU; one at US; and one at UZ.

In general, the CVs provided contained the required information (as listed above), although in different formats. The challenges experienced with the CVs include:

- The lack of a standardised format for compiling a CV. However, there are some universities, e.g. the Universities of Pretoria and Stellenbosch, that seem to have a CV template, although not all academics within these universities use the template.
- Some CVs did not contain information on the source of funding, and most did not have the amount of funding received.
- While the majority of CVs contained details of research outputs produced, some only listed "selected publications" rather than all outputs. In addition, the different types of outputs (journal articles versus books/chapters, for example) were not separated in some CVs. This resulted in a tedious process of separating these different output types during data capturing.
- There was a lack of numbering of publications in some CVs, requiring that all publications, e.g. journal articles, be counted manually, increasing the risk of error in counting.
- Some researchers indicated whether a conference contribution was included in "peer-reviewed conference proceedings", while others simply list "conference contributions". Only peer-reviewed conference proceedings were included in this study.
- The length of the CVs varied greatly, with most of the CVs being in the region of 50 or more pages. One CV for example, was 159 pages long.

5.3.3. Response rate

Table 5.4. Distribution of responses by institution

Institution	Researchers per institution	
	Count (N)	**Percentage (%)**
University of Stellenbosch	33*	18%
University of Cape Town	31	16.9%
University of Pretoria	27	14.8%
University of Witwatersrand	16	8.7%
University of KwaZulu-Natal	14	7.7%
North-West University	14	7.7%
Rhodes University	9	4.9%
University of the Free State	7	3.8%
University of Johannesburg	7	3.8%
Agricultural Research Council	5	2.7%
Nelson Mandela Metropolitan University	5	2.7%
Tshwane University of Technology	4	2.2%
University of the Western Cape	3	1.6%
University of Zululand	2	1.1%
Council for Scientific and Industrial Research	1	0.5%
Distell	1	0.5%
iThemba Labs	1	0.5%
Iziko Museum	1	0.5%
Medical Research Council	1	0.5%
National Health Laboratory Services	1	0.5%
Total	**183**	**100.0%**

* = Includes one researcher whose CV was downloaded from the internet.

Table 5.5. Distribution of responses by broad scientific field

Broad field of study	Researchers per broad field	
	Count (N)	**Percentage (%)**
Biological Sciences	53	29%
Chemical and Physical Sciences	31*	16.9%
Engineering and Applied Sciences	28	15.3%
Agricultural Sciences	25	13.7%
Social Sciences, Arts and Humanities	18	9.8%
Health Sciences	14	7.7%
Earth and Marine Sciences	9	4.9%
Information and Communication Technologies	4	2.2%
Economic Sciences	1	0.5%
Total	**183**	**100%**

* = Includes one researcher whose CV was downloaded from the internet.

Table 5.6. Distribution of responses by race

Race	Count	Percentage
Black	6	3%
Coloured	2	1%
Indian	6	3%
White	169	92%
Total	**183**	**100%**

Table 5.7. Distribution of responses by gender

Gender	Count	Percentage
Female	38	21%
Male	145	79%
Total	**183**	**100%**

Table 5.8. Distribution of responses by age

Age	Count	Percentage
35 and younger	1	1%
36 to 40	4	2%
41 to 45	14	8%
46 to 50	28	15%
51 to 55	44	24%
56 to 60	30	16%
61 and older	62	34%
Total	**183**	**100%**

5.4. TELEPHONE INTERVIEWS

5.4.1. Selection of interviewees, and procedure

During the request for CVs, academics were also requested to indicate if they would be willing to be contacted for a short follow-up interview over the telephone. Fifty seven academics (31% of those who responded) indicated that they may be contacted for an interview; 14 (8%) said that they were not available for the interview, mainly due to time constraints (as one academic indicated: "*time is a problem, so I should rather not make a promise of being available for a telephone conversation*"). The majority of respondents (110, or 61% of academics) did not indicate whether they may or may not be contacted for an interview. E-mail requests for a short 15-20 minute telephone interview were sent to academics who had indicated their willingness to be interviewed. In cases where the academic was available for the interview, they were requested to provide a convenient time for the interview, together with a contact telephone number (preferably a landline). A total of 23 academics comprising 16 men and 7 women accepted the request and were interviewed between January and March 2013. The interviewees represented various study disciplines and were of various age groups (Table 5.9).

Table 5.9. Field and gender breakdown of academics who were interviewed

Code	Area of study/discipline	Gender
Ac1	Applied Mathematics	Male
Ac2	Biochemistry	Female
Ac3	Biomedical Engineering	Male
Ac4	Botany	Male
Ac5	Chemical Engineering	Female
Ac6	Chemistry	Male
Ac7	Chemistry	Male
Ac8	Chemistry Education	Female
Ac9	Computer Science	Male
Ac10	Entomology	Female
Ac11	Entomology	Male
Ac12	Genetics	Male
Ac13	Geography	Female
Ac14	Heath Sciences/Virology	Female
Ac15	Human Genetics	Female
Ac16	Mechanical Engineering	Male
Ac17	Mechanical Engineering	Male
Ac18	Metallurgical Engineering	Male
Ac19	Sociology	Male
Ac20	Sports Science	Male
Ac21	Palaeontology	Male
Ac22	Zoology	Male
Ac23	Zoology	Male

5.4.2. Interview questions

The purpose of the interview was to establish if the source of funding, i.e. industry or NRF/public funding, influences researchers' choice of research activity – the mode of knowledge production; choice of topic; dissemination format; and student training. That is, do researchers engage in different research activities with industry funding compared to NRF funding? Although specific questions were prepared for the interviews, these merely served as a guide during the interview, which took the form of a discussion between the interviewer and the interviewee. Preparations for the interviews involved closely studying the CV of the academic to be interviewed, and tailoring the questions in line with the information provided in the CV. For example, if the academic did not receive industry funding per se, but received funding for commissioned research through a non-government organisation, the term used during the interview was "non-NRF funding" or private funding, as opposed to industry funding. Furthermore, only questions that had relevance to the particular researcher were asked, and allowance was also made for follow-up questions.

The pre-planned interview questions were the following:

- Would you say that the research/projects you have undertaken with industry funding (including THRIP funding) is/are different from the kind of research/projects you have conducted with other sources of public funding (such as NRF Focus Areas funding)?
    - Follow-up: Do you think you can distinguish – in your own work – between more basic/fundamental and more applied/problem-solving research?
    - Follow-up: IF YES, how would you describe the differences between basic and applied research in your field/your own research?

- How would you describe the type of research/projects you conduct with industry funding? Who are the intended beneficiaries of industry funded project? Are they different from those of publicly funded projects?

- Who determines the scope or focus of your research, yourself or the donor/company funding the research? In other words, to what extent does industry funding impact on your research autonomy/choice of research?

- Do you disseminate/communicate the results/findings of your industry funded research differently from other forms of research that you do? E.g. in journals, books, through patenting and licensing?

- Does industry funding come with any restrictions on your freedom to publish in the public domain, e.g. in journals and books?

- Does working on industry funded projects impact in any way on your training of post-graduate students? Does this kind of funding allow you to train more or fewer masters and doctoral students? Does it allow for more funding for post-graduate student involvement?

- Is there anything you would like to say about the state of public funding in the country, in particular NRF funding?

5.4.3. Analysis of telephone interviews

The interviews were recorded and transcribed (verbatim) in MS Word. Each interview transcript was analyzed with the aim of identifying common themes among all transcripts. Responses to the interview questions were grouped into three broad themes: source of research funding (i.e. academics were asked for their opinion on the state of public funding in South Africa through the NRF); nature of research (i.e. the type of research academics conduct with industry and NRF funding); and research outputs (i.e. the impact of funding on publications and postgraduate student training). The segments from each transcript were then grouped under relevant themes and a narrative was written to connect the themes, and to offer some discussion/observation.

5.5. CONCLUDING REMARKS

The next chapter (Chapter 6) presents quantitative results of the trends in funding allocation by the NRF over the years through the Focus Areas and THRIP programmes. A comparison in funding patterns within the two programmes is made by institutions, scientific fields, demographics, and rating category. Thereafter, Chapter 7, which consists of two sections, first, it provides findings from the analysis of the curricula vitae of academics, where the scientific productivity (publications and postgraduate student training) of academics receiving funding from industry and the NRF is compared; and second, presents the outcome of the telephone interviews which shed light on the possible link between the source of funding and mode of knowledge production, as well as the implications of the findings. Possible areas for future research are provided in the concluding chapter (Chapter 8).

CHAPTER 6: TRENDS IN ACADEMIC RESEARCH FUNDING IN SOUTH AFRICA: 1994 – 2008

6.1. INTRODUCTION

The majority of South African academics rely primarily on public funds to support their research activities. As indicated in a previous chapter, public funding is channelled to institutions and individuals through a funding agency called the National Research Foundation (NRF). The NRF has several funding programmes through which it allocates funding. The analysis in this chapter is focuses on the funding distributed through two of NRF's programmes between 1994 and 2008, namely: the Technology and Human Resources for Industry Programme (THRIP) and the Focus Areas Programme. Both these programmes have been described in detail in previous chapters. For the purpose of this analysis, THRIP funding is used as a proxy for industry funding (due to the large industry contribution), while the Focus Areas funding is considered government funding (as it is fully funded by government). Funding patterns of both THRIP and Focus Areas will be compared to answer several research questions.

Research question

The central questions of this chapter are:

- Do researchers/academics who receive funding from industry, i.e. THRIP, receive more or less funding than those who receive NRF funding, i.e. Focus Areas funding?
- What have been the trends in the allocation of funding from both the THRIP and the Focus Areas programmes over the years? In particular, the chapter will investigate shifts (if any) in funding allocation from both programmes by:
    - University – what is the proportion of funding received by different universities, from each programme, during the period under study?
    - Scientific field – what is the proportion of funding per scientific field from both the Focus Areas and THRIP programmes? Differences in field distribution by demographics, i.e. gender, race, and age, are also investigated.
    - Demographics – are there differences in funding received from both the Focus Areas and THRIP programmes in terms of gender, race, and age?

6.2. FUNDING

6.2.1. Total funding

Between 1994 and 2008 the NRF funded over 11 900 projects through the Focus Areas and THRIP programmes. As one would expect, more projects have been funded through the Focus Areas than THRIP, with 8154 and 3747 projects respectively. The number of individual researchers who have received funding from either the Focus Areas, THRIP, or both programmes between 1994 and 2008 is 2349, with 828 having received THRIP funding during this period. There are also researchers who, at some point, received both grants in the same year.

The total amount of funding awarded between 1994 and 2008 is more than R2 billion: Focus Areas R883 million and THRIP R1.1 billion (Table 6.1). THRIP awarded a higher proportion of the total funds than the Focus Areas, with 56% and 44% respectively (Figure 6.1). This funding was awarded to researchers at universities, science councils and other research institutions such as museums. The total amount of funding awarded by THRIP between 2001 and 2008, the same timeframe as the Focus Areas programme, was R897 million. The Focus Areas awarded more grants than THRIP, in total, between 2004 and 2008 (with the exception of 2007 – Table 6.1).

Table 6.1. Total funding distributed by the THRIP and Focus Areas Programmes, by year

Year	No. Grants: THRIP	Amount (Rm): THRIP	No. Grants: Focus Areas	Amount (Rm): Focus Areas
1994	43	R 1 846 371.50	n/a	n/a
1995	68	R 3 622 011.47	n/a	n/a
1996	71	R 4 529 370.00	n/a	n/a
1997	226	R 19 478 171.00	n/a	n/a
1998	403	R 42 844 691.97	n/a	n/a
1999	534	R 83 559 143.58	n/a	n/a
2000	444	R 83 581 884.31	n/a	n/a
2001	94	R 5 155 835.19	676	R 57 563 826.20
2002	241	R 123 556 556.09	968	R 84 598 445.97
2003	250	R 147 167 993.53	900	R 85 664 994.50
2004	258	R 103 745 089.74	993	R 116 968 941.53
2005	300	R 116 965 423.86	1175	R 123 115 621.87
2006	312	R 134 005 808.90	1147	R 137 114 721.60
2007	264	R 128 358 173.71	1125	R 126 095 989.77
2008	239	R 138 678 264.36	1170	R 152 279 992.90
Total	**3747**	**R 1 137 094 789.21**	**8154**	**R 883 402 534.34**

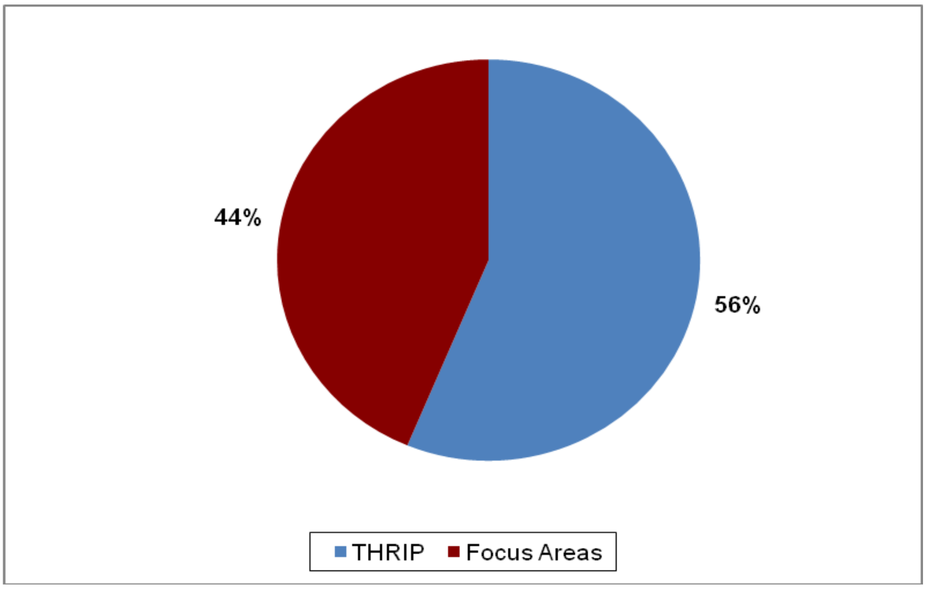


Figure 6.1. Percentage of total funding distributed by the Focus Areas (2001 – 2008) and THRIP Programmes (1994 – 2008)

On average, those who received funding from both programmes received larger amounts per year compared to the Focus Areas and THRIP Programmes (Figure 6.2). The average funding researchers received from both programmes concurrently, is over R800 000, compared to just under R300 000 obtained from THRIP only, and a little over R121 000 from the Focus Areas only.

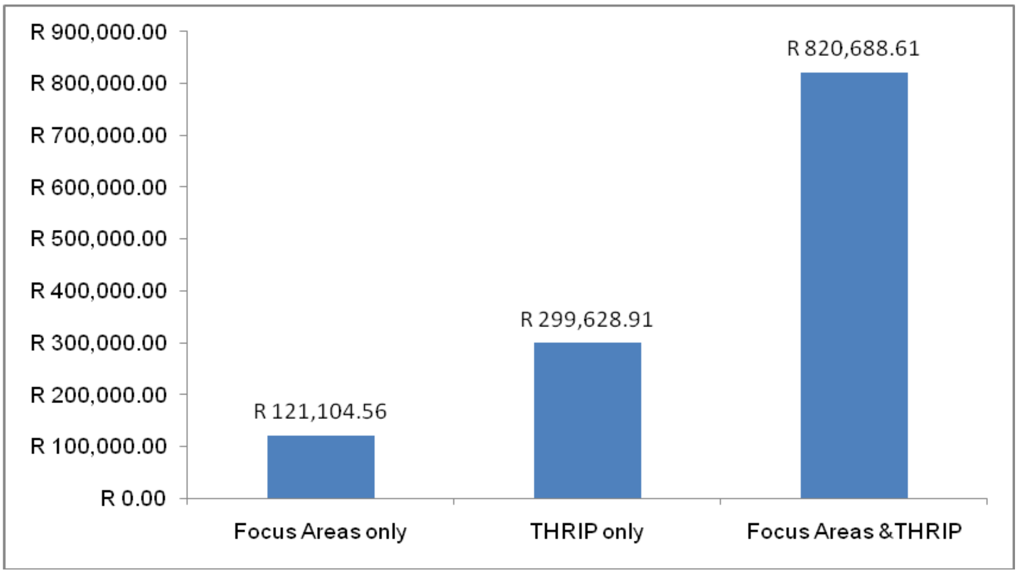


Figure 6.2. Average amount of grant awarded per project under the Focus Areas and THRIP Programmes during 1994 – 2008 (THRIP) and 2001 – 2008 (Focus Areas).

In 2001, THRIP experienced a significant drop in the number of grants awarded, and ultimately the amount of funds allocated to researchers (Table 6.1). Reasons for this drop could not be determined on the basis of data analysed in this study. According to Mr Mmboneni Muofhe, who was part of the THRIP programme management at the time, THRIP introduced a set of new funding rules and criteria around this time (2000/2001). One of the criteria was that THRIP would begin to prioritise partnerships between academia and companies classified as "Small, Medium, and Micro Enterprises (SMMEs)" (Muofhe, personal communication, 21 July 2012). Therefore many projects not conforming to this criterion were not funded. Another significant change to the THRIP funding rules was that the funding of projects that were not contributing to manufacturing would be discontinued (Muofhe, personal communication, 21 July 2012). It was also in 2001 that the NRF commissioned the second review/evaluation of the THRIP programme (the first one was conducted in 1997). The evaluation report highlighted "*constraints to participation*" in the THRIP programme as a major concern (THRIP 2002: 22). The main constraint has been considered as the THRIP administration process, as well as IT-related problems. In this regard, the report states that "*the processing of grants has been subject to very lengthy delays, especially during the last year, and there is still significant uncertainty concerning some 2001 applications. The panel considers these delays to be extremely serious and to be materially affecting the effectiveness of THRIP*" (THRIP 2002: 29). The evaluation panel recommended that, among other things, "*the THRIP office should improve its administrative performance*" (THRIP 2002: 21).

Of the nine Focus Areas, *Conservation and Management of Ecosystems and Biodiversity* awarded the largest grants on average (R129 695.68), compared to the other Focus Areas (Table 6.2). *Economic Growth and International Competitiveness* awarded the second largest grants on average (R 126 642.06), and the largest total amount throughout the study period (just over R255 million). On average, *Education and Challenges for Change* awarded the lowest grant amounts to researchers (R62 728.84). The aims of each Focus Area as well as the research themes under each are described in detail in Table 5.1 (Chapter 5: Data Sources and Methodology).

Table 6.2. Average and total funding per Focus Area Programme, 2001 - 2008

Focus Area Programme	No. Grants	Average funding	Total funding (Rm)
Conservation and Management of Ecosystems and Biodiversity	1222	R 129 695.68	R 158 488 116.57
Economic Growth and International Competitiveness	2014	R 126 642.06	R 255 057 117.23
Indigenous Knowledge Systems	511	R 124 298.11	R 63 516 332.13
Sustainable Livelihoods: the Eradication of Poverty	548	R 107 663.29	R 58 999 484.45
Unlocking the Future	1557	R 104 416.50	R 162 576 482.91
Information and Communication Technology	338	R 93 230.88	R 31 512 036.30
Challenge of Globalisation: Perspectives From the Global South	143	R 90 799.82	R 12 984 373.61
Distinct South African Research Opportunities	980	R 86 145.94	R 84 423 016.82
Education and Challenges for Change	494	R 62 728.84	R 30 988 047.23

6.2.2. Funding by sector

The institutions to which grant recipients from both the Focus Areas and THRIP programmes were affiliated at the time of receiving the grant, can be divided into three sectors: universities, science councils, and other research institutes including museums (Table 6.3).

Universities received the largest share of the total funding awarded over the 15 year period (90.8%, thus R1.8 billion), followed by science councils at 6.6% (around R132 million), and the “other” institutions of research receiving 2.6% of the total funding (just over R52 million) (Figure 6.3). As a result of the funding distribution pattern between these three sectors (and also the fact that the largest proportion of researchers in the country are based in universities), the rest of the analysis in this chapter will be based on universities only.

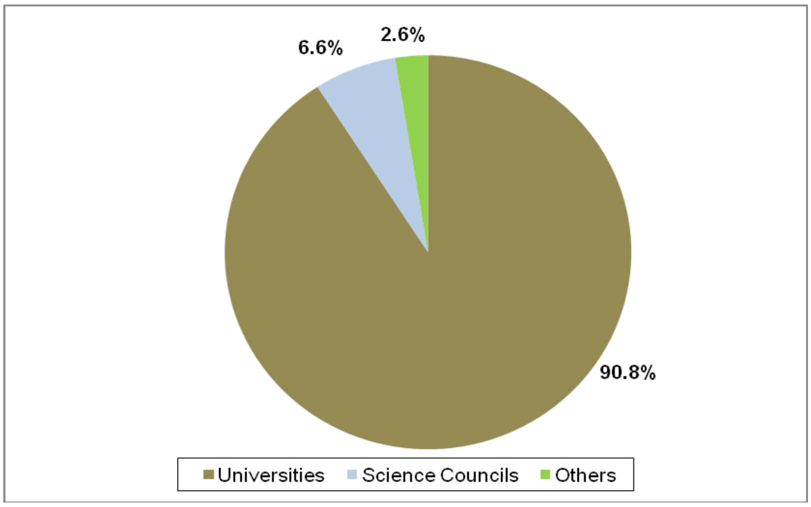


Figure 6.3. Percentage of total funding by sector

Table 6.3. Specific institutions in each sector

	Universities	**Science Councils**	**Other Research Institutions**
1	Cape Town University of Technology (CPUT)	Agricultural Research Council (ARC)	African Equations
2	Central University of Technology (CUT)	Council for Industrial and Scientific Research (CSIR)	African Renaissance Development Institute
3	Durban University of Technology (DUT)	Ithemba Labs	Albany Museum
4	Mangosuthu University of Technology (MUT)	Medical Research Council (MRC)	Coaltech 2020
5	Nelson Mandela Metropolitan University (NMMU)	MINTEK	Eastern Platinum LTD
6	North-West University (NWU)	South African Astronomical Observatory (SAAO)	Ethekwini Municipality
7	Rhodes University (RHODES)	South African Institute for Aquatic Biodiversity (SAIAB)	Ezemvelo KZN Wildlife
8	Tshwane University of Technology (TUT)	South African National Biodiversity Institute (SANBI)	Gwala Khumalo Vilakazi AIDS Cancer Research Institute
9	University of Cape Town (UCT)		Icamagu Institute
10	University of Fort Hare (UFH)		Inala Identification & Control (PTY) LTD
11	University of Johannesburg (UJ)		Inyathelo Training & Development
12	University of Kwa-Zulu Natal (UKZN)		Iziko Museum
13	University of Limpopo (UL)		McGregor Museum
14	University of Pretoria (UP)		Natal Museum
15	University of South Africa (UNISA)		Natal Sharks Board
16	University of Stellenbosch (US)		National Health Laboratory Services (NHLS)
17	University of the Free State (UFS)		National Museum
18	University of the Western Cape (UWC)		Northern Flagship Institute
19	University of the Witwatersrand (WITS)		Port Elizabeth Museum
20	University of Venda (UNIVEN)		Poynting Innovations (PTY) LTD
21	University of Zululand (UZ)		Sappi Management Services (PTY) LTD
22	Vaal University of Technology (VUT)		Southern Cape Herbarium
23	Walter Sisulu University (WSU)		Telkom SA LTD

6.2.2.1. Funding by university

In 2004, there was a restructuring of higher education institutions in South Africa, which involved the merging of some universities. Therefore, for this part of the analysis, data was combined under the “new” university name. For example, data for Eastern Cape Technikon has been added to that of Walter Sisulu University (WSU); Peninsula Technikon data was added to Cape Town University of Technology (CPUT); Pretoria Technikon was added to Tshwane University of Technology (TUT), and University of the North was added to University of Limpopo (UL). There was also one THRIP grant (to the value of R110 000) awarded to a researcher at VISTA University in 2003. This grant record has been removed from the analysis as VISTA University was incorporated into several universities, such as the Nelson Mandela Metropolitan University (NMMU), University of the Free State (UFS), University of Pretoria (UP), and University of South Africa (UNISA), making it difficult to place it under any existing university. Generally, the number of university researchers participating in the THRIP programme grew annually until it dropped significantly in 2001 as already discussed (Table 6.4; Figure 6.4). Since 2001, the Focus Areas consistently had more grantholders than the THRIP.

Table 6.4. Total number of university grantholders per programme per year

Year	THRIP only	Focus Areas only	THRIP & Focus Areas, concurrently	Total grantholders
1994	33	n/a	n/a	**33**
1995	59	n/a	n/a	**59**
1996	59	n/a	n/a	**59**
1997	164	n/a	n/a	**164**
1998	288	n/a	n/a	**288**
1999	371	n/a	n/a	**371**
2000	288	n/a	n/a	**288**
2001	60	539	15	**614**
2002	102	755	72	**929**
2003	112	720	71	**903**
2004	111	786	74	**971**
2005	144	850	83	**1077**
2006	149	865	81	**1095**
2007	131	848	66	**1045**
2008	109	847	62	**1018**

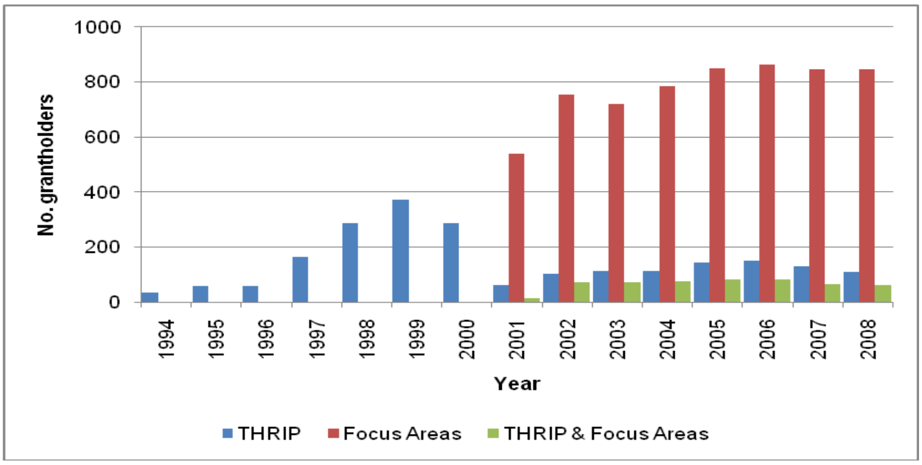


Figure 6.4. Number of university grantholders per programme, per year

The University of Cape Town (UCT), followed by the University of Stellenbosch (US), received the largest share of funding from the Focus Areas Programme at 20% (R174 million of the R858 million allocated during the period under study (Figure 6.5; Table 6.5). The University of Stellenbosch received the highest amount of THRIP funding over the fifteen year period (R180 million of R977 million, thus 18%), followed by University of Pretoria (UP), and UCT in third place (Figure 6.6). Forty-seven percent and 50% of the total funding from the Focus Areas and THRIP Programmes, respectively, was awarded to only three universities: UCT, US and UP. All but one university, namely Vaal University of Technology, received Focus Areas grants at some point during the eight year period.

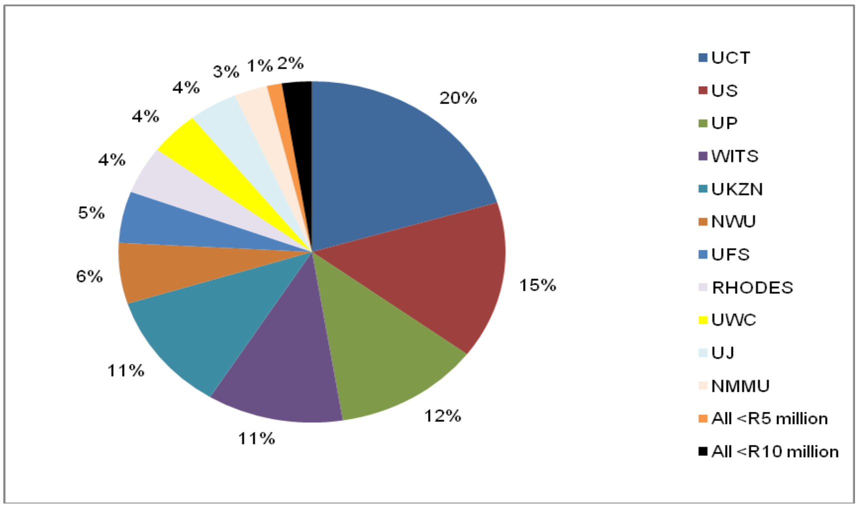


Figure 6.5. Distribution of Focus Areas grants to universities, 2001 – 2008[31]

[31]Universities that received total funding of less than R5 million during 2001-2008 include: CPUT, CUT, DUT, MUT, UFH, UNIVEN, and WSU. Those that received total funding of less than R10 million include: TUT, UL, UNISA, and UZ.

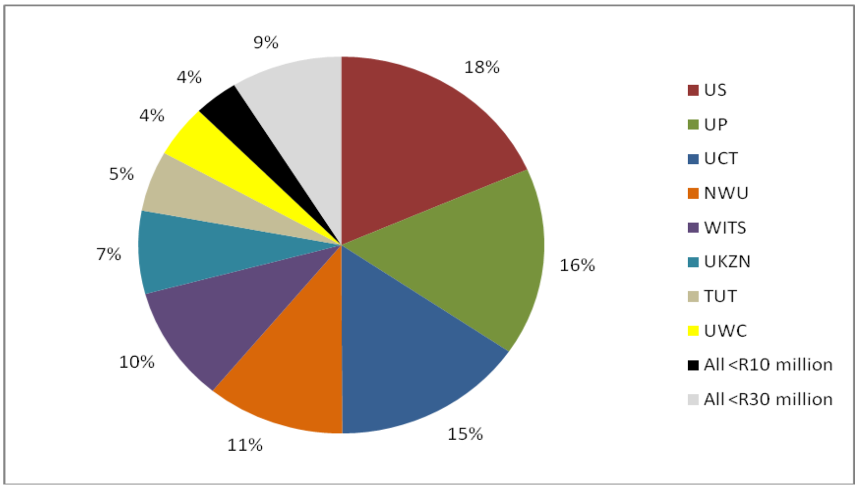


Figure 6.6. Distribution of THRIP grants to universities, 1994 – 2008[32]

Table 6.5. Total Focus Areas and THRIP programmes funding by university, 1994 – 2008

University	Focus Areas	THRIP	Total funding (Rm)
University of Cape Town	R 174 361 819.91	R 150 216 087.73	**R 324 577 907.64**
University of Stellenbosch	R 128 244 079.60	R 180 063 569.15	**R 308 307 648.75**
University of Pretoria	R 104 870 685.89	R 157 538 121.98	**R 262 408 807.87**
University of Witwatersrand	R 97 491 867.82	R 96 686 588.92	**R 194 178 456.74**
University of KwaZulu-Natal	R 96 774 056.88	R 69 582 463.94	**R 166 356 520.82**
North-West University	R 49 547 528.60	R 107 424 987.55	**R 156 972 516.15**
University of the Western Cape	R 35 715 453.49	R 43 820 819.47	**R 79 536 272.96**
University of the Free State	R 41 938 300.67	R 15 572 133.29	**R 57 510 433.96**
Tshwane University of Technology	R 5 915 700.02	R 50 650 937.36	**R 56 566 637.38**
Rhodes University	R 38 618 999.43	R 13 710 484.33	**R 52 329 483.76**
University of Johannesburg	R 34 929 267.53	R 17 059 838.60	**R 51 989 106.13**
Nelson Mandela Metropolitan University	R 23 887 196.87	R 24 894 621.06	**R 48 781 817.93**
Central University of Technology	R 36 958.00	R 15 180 437.23	**R 15 217 395.23**
University of Zululand	R 5 193 254.20	R 6 085 250.00	**R 11 278 504.20**
Durban University of Technology	R 2 323 878.75	R 8 477 549.00	**R 10 801 427.75**
University of Fort Hare	R 4 718 679.81	R 5 647 274.00	**R 10 365 953.81**
University of Limpopo	R 5 015 334.02	R 3 313 173.97	**R 8 328 507.99**
Cape Peninsula University of Technology	R 1 001 753.03	R 7 200 353.00	**R 8 202 106.03**
University of South Africa	R 5 336 447.73	R 161 325.00	**R 5 497 772.73**
Vaal University of Technology	R 0.00	R 2 706 776.00	**R 2 706 776.00**
University of Venda	R 2 339 001.00	R 133 250.00	**R 2 472 251.00**
Walter Sisulu University	R 270 069.00	R 623 000.00	**R 893 069.00**
Mangosuthu University of Technology	R 14 675.00	R 233 469.86	**R 248 144.86**
Total (Rm)	**R 858 545 007.25**	**R 976 982 511.44**	**R 1 835 527 518.69**

[32]Universities that received total funding of less than R10 million during 1994-2008 include:CPUT, DUT , MUT, UFH, UL, UZ, UNISA, UNIVEN, VUT, and WSU. Those that received total funding of less than R30 million include: CUT, UFS, UJ, NMMU, and Rhodes.

6.2.3. Funding by broad scientific field

Data was grouped into six broad scientific fields: Agricultural Sciences; Biological Sciences; Chemical and Physical Sciences; Engineering and Applied Sciences; Health Sciences; and Social Sciences, Arts and Humanities. Results showed that over the years, the bulk of projects funded under the Focus Areas programme were in the field of Biological Sciences, followed by the Social Sciences, Arts and Humanities (Table 6.6). Projects in the Biological Sciences also received larger grant amounts, on average (R155 028.64), compared to other fields (Table 6.6). The Health Sciences were second, with average grant amount of R125 212.19. The Social Sciences, Arts and Humanities received the lowest grant amounts from the Focus Areas programme, at an average of R83 217.65 per project (Table 6.6).

Not surprisingly, most of the THRIP funding was allocated to projects in the Engineering and Applied Sciences field, particularly in the years following the inception of the programme, i.e. 1994 to 1996 (Table 6.7). Since 1997, THRIP has awarded grants to researchers in an increasing number of fields, mostly in the Biological Sciences as well as the Chemical and Physical Sciences. There have also been a few grants awarded to projects in the Social Sciences, Arts and Humanities fields (48 grants). The Social Sciences, Arts and Humanities also received lower average funding from THRIP compared to other scientific fields, although the average grant amount received from THRIP is higher than that received from the Focus Area programme (R188 950.22, compared to R83 217.65 from the Focus Areas) (Table 6.6 and Table 6.7).

Researchers who received funding from both programmes concurrently were predominantly in the Chemical and Physical Sciences, followed by those in the Engineering and Applied Sciences (Table 6.8). Those who received funding from both programmes, across all broad scientific fields, recieved significantly larger grants than their counterparts who received funding from only one source (Figure 6.7).

Table 6.6. Average and total Focus Areas funding by broad scientific field, 2001 – 2008

Broad scientific field	No. grants awarded	Average funding	Total funding
Biological Sciences	1983	R 155,028.64	R 307,421,789.72
Health Sciences	430	R 125,212.19	R 53,841,243.51
Eng & Applied Sciences	633	R 118,295.70	R 74,881,176.59
Agricultural Sciences	485	R 116,004.08	R 56,261,980.62
Chem & Physical Sciences	1308	R 111,285.73	R 145,561,734.45
SSA&H	1371	R 83,217.65	R 114,091,404.38

Table 6.7. Average and total THRIP funding by broad scientific field, 1994 – 2008

Broad scientific field	No. grants awarded	Average funding	Total funding
Eng & Applied Sciences	1121	R 333,438.47	R 373,784,527.56
Agricultural Sciences	242	R 319,617.61	R 77,347,462.51
Chem & Physical Sciences	307	R 286,956.55	R 88,095,659.93
Biological Sciences	384	R 227,696.50	R 87,435,457.86
Health Sciences	77	R 225,172.78	R 17,338,303.97
SSA&H	48	R 188,950.22	R 9,069,610.39

Table 6.8. Average and total funding by broad scientific field, for researchers receiving both Focus Areas and THRIP, concurrently (1994 – 2008)

Broad scientific field	No. grants awarded	Average funding	Total funding
Chem & Physical Sciences	116	R 917,802.91	R 106,465,137.22
Agricultural Sciences	95	R 896,066.09	R 85,126,278.63
Health Sciences	19	R 781,828.90	R 14,854,749.18
Eng & Applied Sciences	176	R 780,019.23	R 137,283,384.15
Biological Sciences	108	R 744,893.43	R 80,448,490.34
SSA&H	10	R 586,279.13	R 5,862,791.31

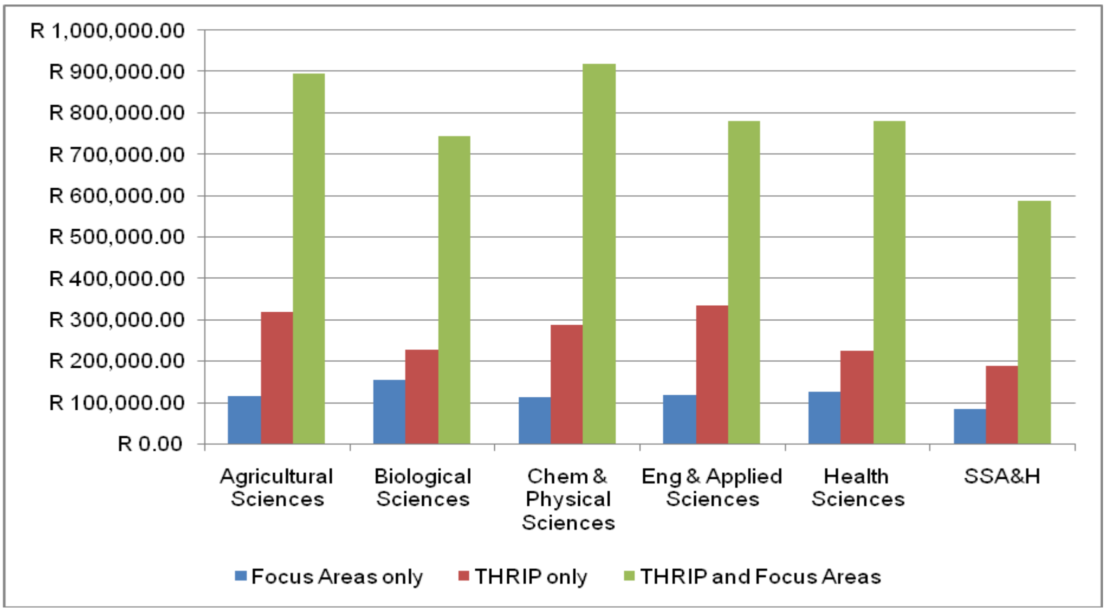
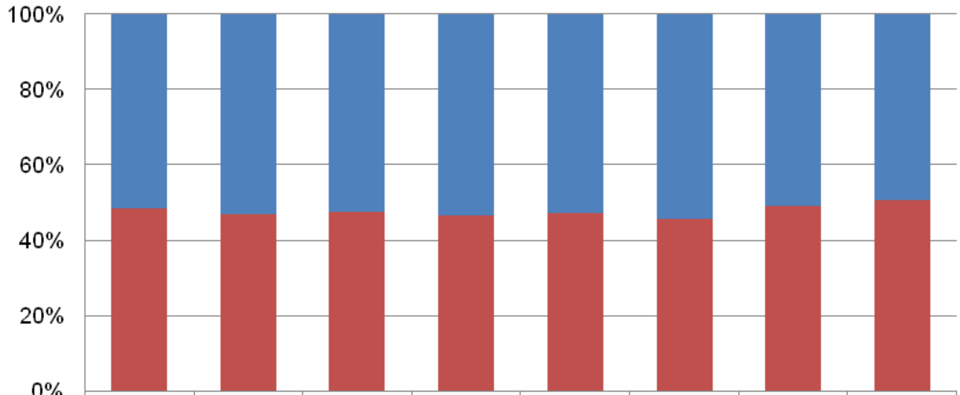


Figure 6.7. Average funding by broad scientific field by source of funding (1994 – 2008)

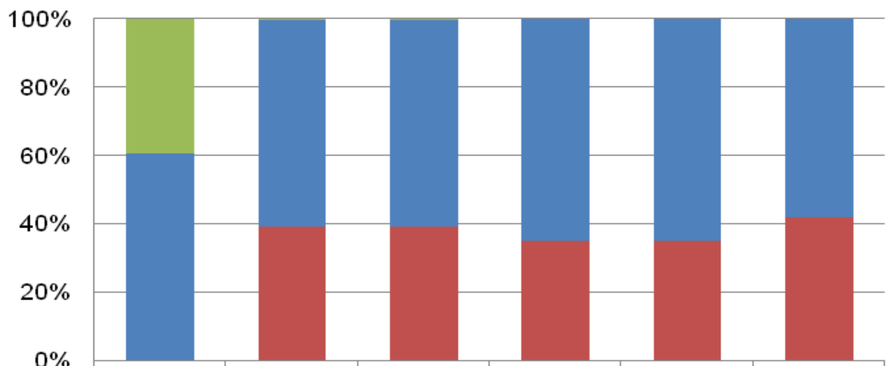
6.2.4. Funding disaggregated by demographics

We compared the average grant awarded to males and females receiving funding from the three groups (Focus Areas only, THRIP only; and both Focus Areas and THRIP, concurrently), we found that there was very little difference in the average grant amount awarded to male and female researchers through the Focus Areas only (Figure 6.8). Of those who received funding from THRIP only received, males received on average larger grants than their female counterparts (Figure 6.9). On the other hand, female researchers who received funding from both programmes in the same year received much higher average grants than male researchers (Figure 6.10).



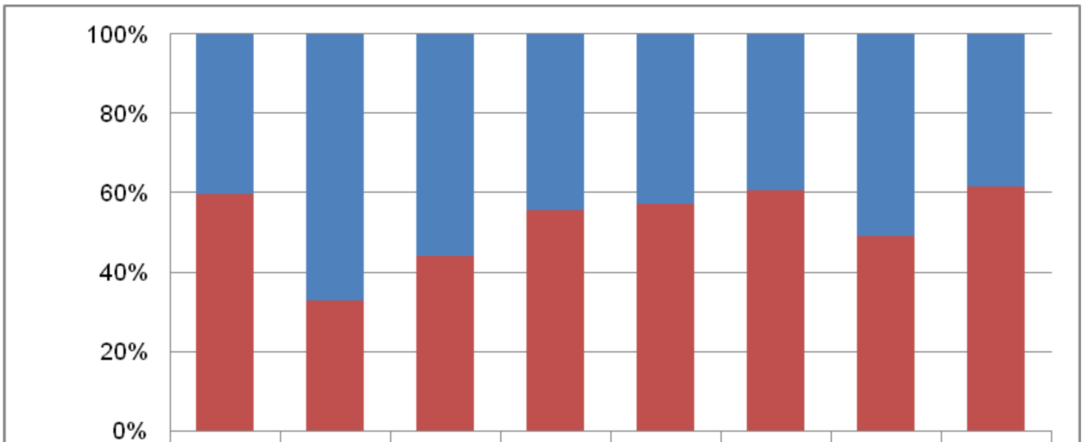
	2001	2002	2003	2004	2005	2006	2007	2008
Males	95,510	95,267	101,450	130,398	125,564	139,584	130,400	153,652
Females	90,827	84,820	92,060	114,190	112,286	117,938	126,749	158,533

Figure 6.8. Average funding (R'000) by gender (Focus Areas) by year



	1994	1997	2000	2003	2006	2008
Not specified	34,981	609	930	0	0	0
Males	54,214	129,304	264,380	521,826	487,329	740,482
Females	0	83,579	172,300	283,180	263,018	535,127

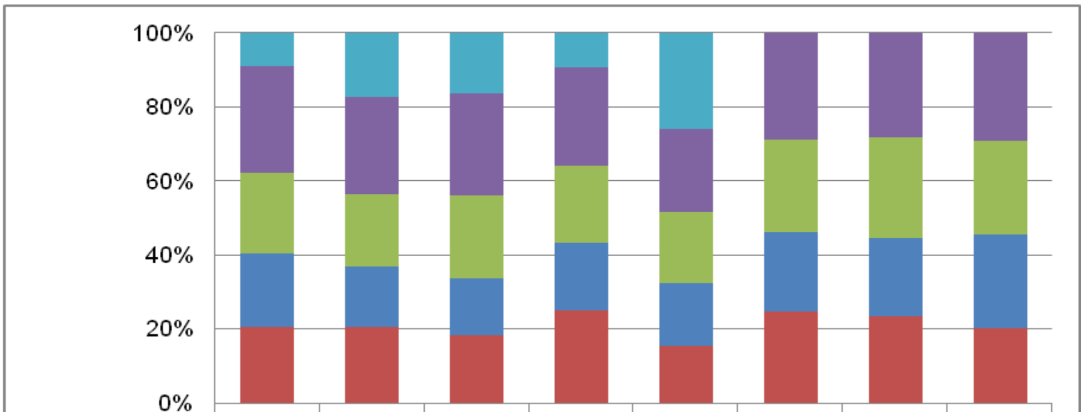
Figure 6.9. Average funding (R'000) by gender (THRIP) by year



	2001	2002	2003	2004	2005	2006	2007	2008
Males	191,051	920,846	1,053,4	635,001	701,148	694,110	860,904	974,163
Females	283,804	452,822	830,575	800,881	947,045	1,069,9	837,944	1,565,6

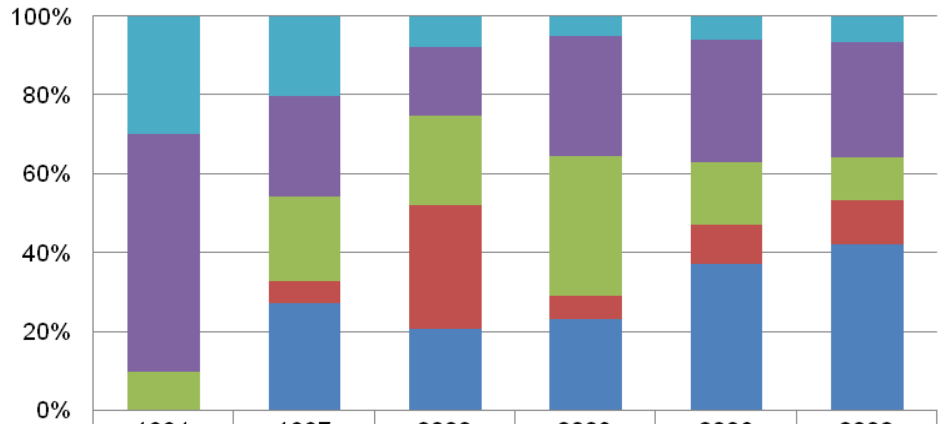
Figure 6.10. Average funding (R'000) by gender for academics who received both Focus Areas and THRIP grants concurrently, by year

Results regarding the distribution of funding by race show that, throughout the years, white researchers received larger average grant from the Focus Areas than other race groups (Figure 6.11). White researchers also received larger grants from the THRIP programme, particularly in the years before 2000 (Figure 6.12). Between 2006 and 2008, blacks received large average grants from THRIP than all other races, including whites (Figure 6.12). Similarly, whites received larger average grants from both the Focus Areas and THRIP concurrently, than the rest of the race groups, except in 2008 when blacks received significantly larger grants than others (Figure 6.13).



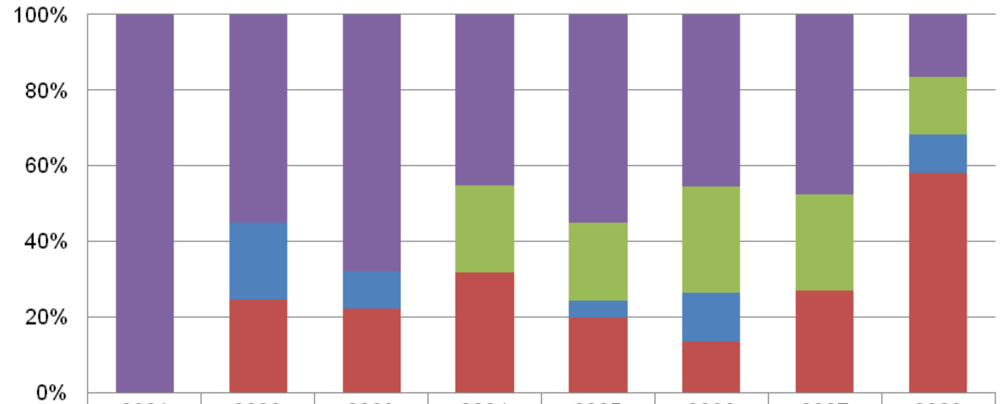
	2001	2002	2003	2004	2005	2006	2007	2008
Not specified	30,000	62,923	61,756	45,966	145,871	0	0	0
White	98,009	96,408	103,532	129,521	127,101	137,057	132,509	161,090
Indian	74,566	71,383	84,477	101,965	106,743	117,375	128,652	137,996
Coloured	67,430	60,124	57,889	88,913	96,761	101,710	100,160	139,994
Black	69,822	75,345	68,427	121,486	86,316	117,268	110,597	111,289

Figure 6.11. Average (R'000) funding by race (Focus Areas) by year



	1994	1997	2000	2003	2006	2008
Not specified	30,598.13	100,544.25	116,540.19	86,170.00	90,000.00	160,000.00
White	61,512.35	126,180.66	254,182.73	535,278.30	459,155.36	711,448.72
Indian	10,290.00	106,250.00	333,260.50	622,932.73	238,566.67	268,702.04
Coloured	0.00	28,142.00	463,105.08	100,000.00	146,769.50	267,187.50
Black	0.00	135,916.67	308,273.40	409,735.65	555,887.00	1,035,521.0

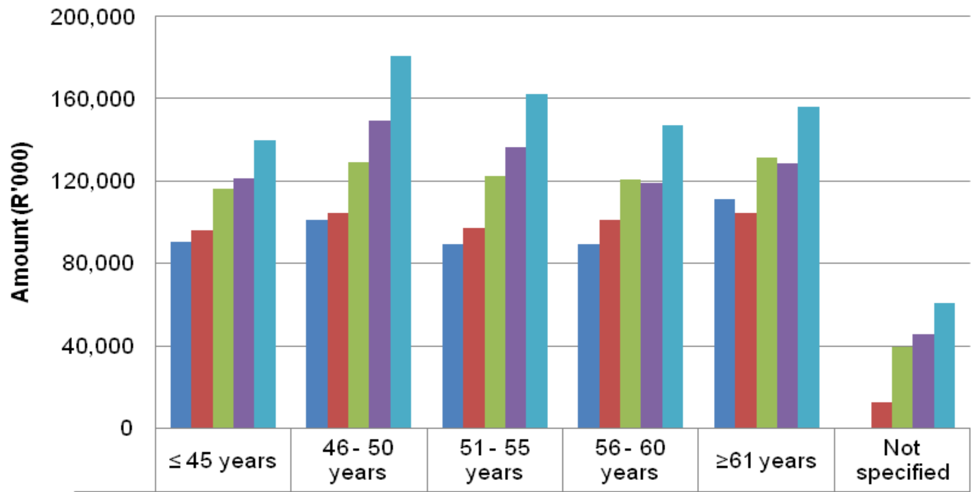
Figure 6.12. Average funding (R'000) by race (THRIP) by year



	2001	2002	2003	2004	2005	2006	2007	2008
White	203,417.9	858,020.9	1,041,264	664,475.1	762,533.8	801,234.0	886,224.2	980,492.9
Indian	0.00	0.00	0.00	335,643.0	283,532.0	498,476.0	475,709.0	917,248.0
Coloured	0.00	312,828.1	150,395.5	0.00	62,921.50	227,225.0	0.00	610,536.8
Black	0.00	387,467.0	346,643.0	471,027.0	275,888.0	242,289.2	511,012.0	3,504,388

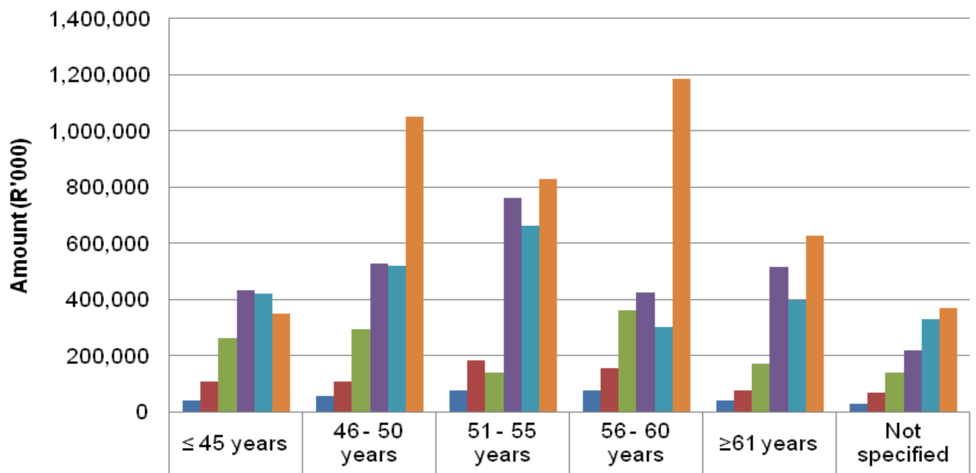
Figure 6.13. Average funding (R'000) by race for academics who received both Focus Areas and THRIP grants concurrently, by year

The distribution of funding by both the Focus Areas and THRIP programmes shows very little shift within age groups over the years (Figures 6.14 and 6.15). There were small differences in the average grant amount awarded to researchers across age groups through the Focus Areas (Figure 6.14). The group comprising researchers between the ages of 51 and 55 received larger average grant from the THRIP programme only, compared to other age groups. Of those researchers who received Focus Areas and THRIP grants concurrently, researchers above the age of 56 received larger average grants than other groups (Figure 6.16).



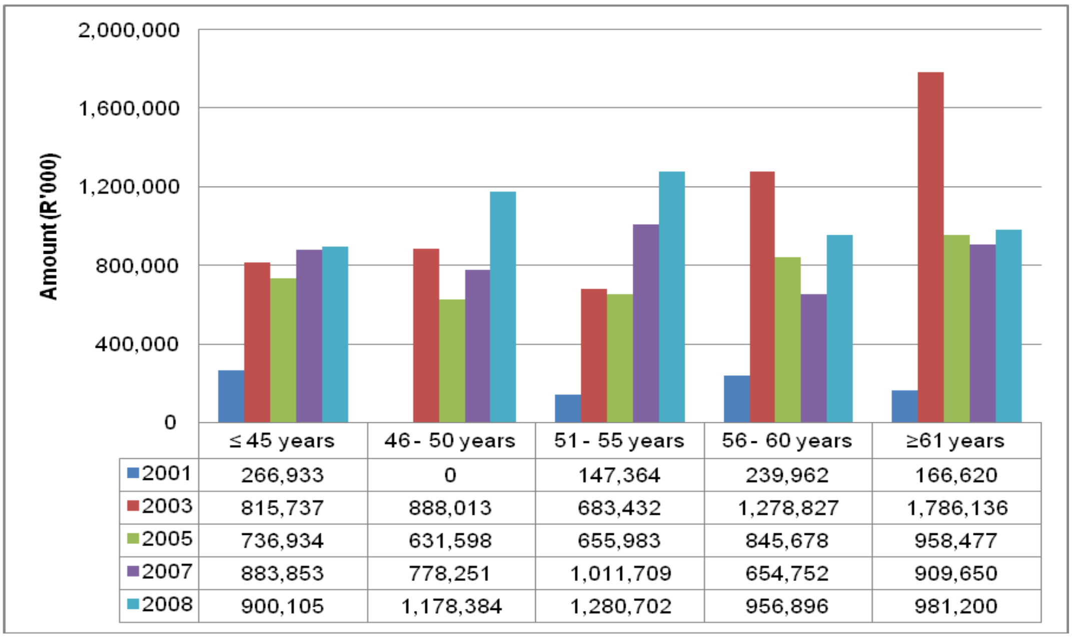
	≤ 45 years	46 - 50 years	51 - 55 years	56 - 60 years	≥61 years	Not specified
2001	90,689	101,298	89,600	89,572	110,995	0
2003	96,237	104,463	97,459	101,155	104,260	12,090
2005	116,356	128,943	122,431	120,638	131,248	39,595
2007	121,235	149,710	136,764	119,164	128,493	45,617
2008	139,951	180,879	162,109	146,915	156,334	60,855

Figure 6.14. Average funding (R'000) by age (Focus Areas) by year



	≤ 45 years	46 - 50 years	51 - 55 years	56 - 60 years	≥61 years	Not specified
1994	44,798	57,499	79,668	79,685	44,019	31,847
1997	111,439	108,945	184,063	159,538	81,006	69,873
2000	266,701	295,602	141,523	362,310	175,432	141,842
2003	433,113	529,471	761,658	427,301	518,796	222,557
2006	422,420	521,896	663,713	303,963	401,247	332,906
2008	352,126	1,053,545	831,844	1,186,778	628,813	369,976

Figure 6.15. Total funding (R'000) by age (THRIP) by year



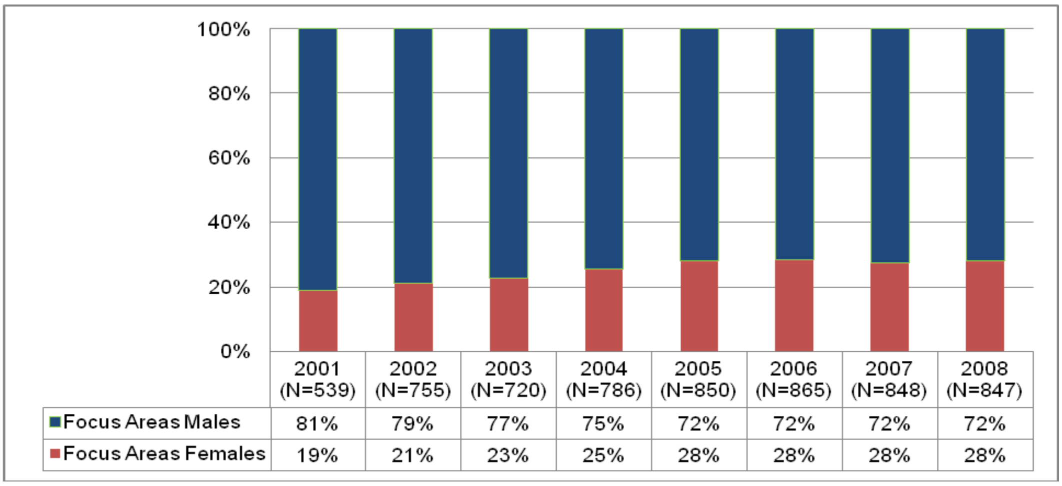
	≤45 years	46 - 50 years	51 - 55 years	56 - 60 years	≥61 years
2001	266,933	0	147,364	239,962	166,620
2003	815,737	888,013	683,432	1,278,827	1,786,136
2005	736,934	631,598	655,983	845,678	958,477
2007	883,853	778,251	1,011,709	654,752	909,650
2008	900,105	1,178,384	1,280,702	956,896	981,200

Figure 6.16. Average funding (R'000) by age for academics who received both Focus Areas and THRIP grants concurrently, by year

6.3. GRANTHOLDER DEMOGRAPHICS

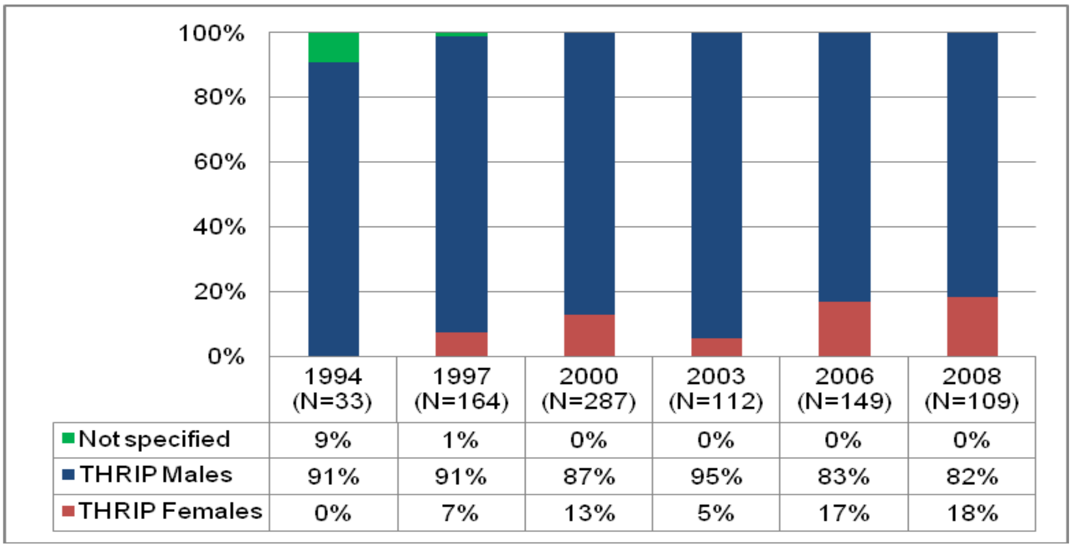
6.3.1. Gender

Since the inception of both the Focus Areas and THRIP programmes, the majority of participants have been males (Figures 6.17 and 6.18). However, since 2005, the proportion of female grantholders started increasing slightly, while the proportion of male grantholders showed a slight decrease in both programmes. Not surprisingly, more than 85% of those academics who held grants from both programmes concurrently have been men (Figure 6.19). Data contained a small proportion of THRIP grantholders whose gender was not specified, and these are shown as such in Figure 6.18.



	2001 (N=539)	2002 (N=755)	2003 (N=720)	2004 (N=786)	2005 (N=850)	2006 (N=865)	2007 (N=848)	2008 (N=847)
Focus Areas Males	81%	79%	77%	75%	72%	72%	72%	72%
Focus Areas Females	19%	21%	23%	25%	28%	28%	28%	28%

Figure 6.17. Gender distribution of Focus Areas grantholders, by year



	1994 (N=33)	1997 (N=164)	2000 (N=287)	2003 (N=112)	2006 (N=149)	2008 (N=109)
Not specified	9%	1%	0%	0%	0%	0%
THRIP Males	91%	91%	87%	95%	83%	82%
THRIP Females	0%	7%	13%	5%	17%	18%

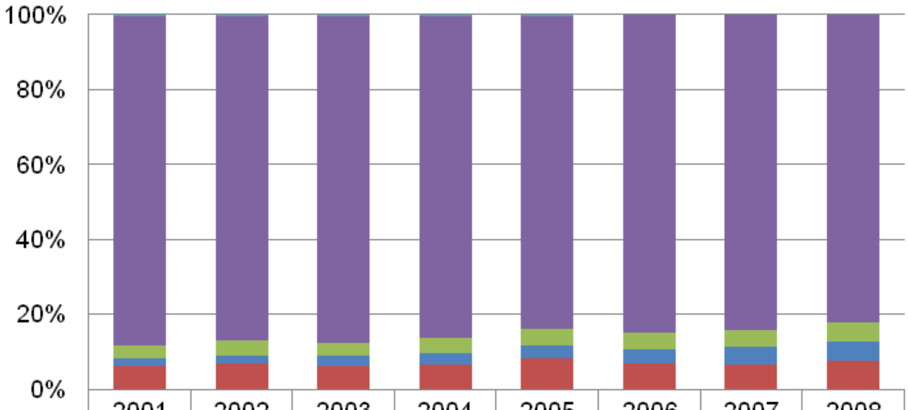
Figure 6.18. Gender distribution of THRIP grantholders, by year

	2001 (N=15)	2002 (N=72)	2003 (N=71)	2004 (N=74)	2005 (N=83)	2006 (N=81)	2007 (N=66)	2008 (N=62)
Focus Areas & THRIP Males	87%	82%	79%	86%	86%	83%	82%	81%
Focus Areas & THRIP Females	13%	18%	21%	14%	14%	17%	18%	19%

Figure 6.19. Gender distribution of grantholders who received both Focus Areas and THRIP grants concurrently, by year

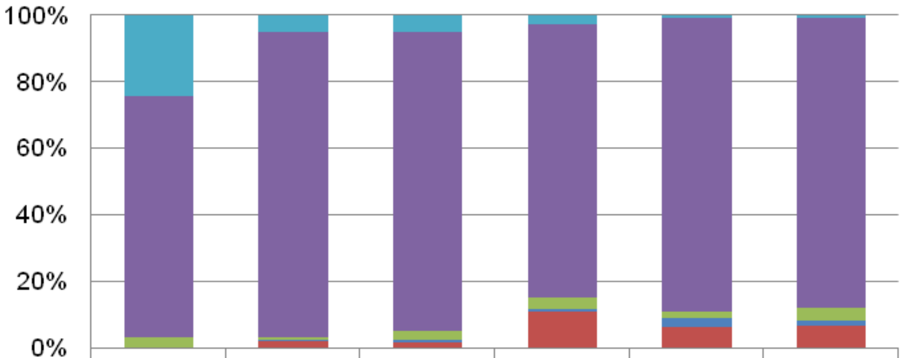
6.3.2. Race

Whites comprise more than 85% of academics who received grants from the Focus Areas programme over the years, with Blacks, Coloureds, and Indians receiving the remaining 15% (Figure 6.20). With an average of 6% participation per year, Blacks comprised the largest group of all the three "non-white" groups of academics receiving funding from the Focus Areas. A similar trend is evident within the THRIP-funded group. There was an average participation rate of 86% per year by white academics in the group receiving THRIP funding only, compared to the other races (Figure 6.21). The difference in participation rate is even bigger within the group receiving both Focus Areas and THRIP grants concurrently, with an average of 95% participation by white academics (Figure 6.22).



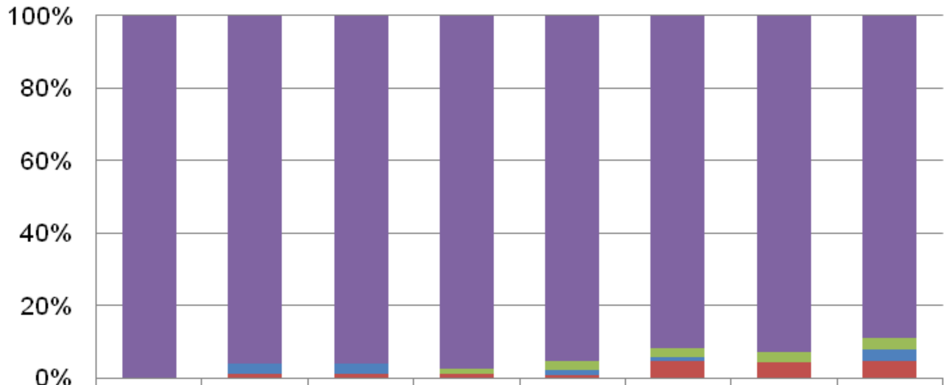
	2001 (N=539)	2002 (N=755)	2003 (N=720)	2004 (N=786)	2005 (N=850)	2006 (N=865)	2007 (N=848)	2008 (N=847)
Not specified	0.4%	0.3%	0.4%	0.4%	0.1%	0.0%	0.0%	0.0%
White	88.1%	86.6%	87.4%	85.8%	83.9%	84.9%	84.1%	82.1%
Indian	3.3%	4.2%	3.3%	4.2%	4.4%	4.5%	4.7%	5.3%
Coloured	2.0%	2.1%	2.6%	3.1%	3.3%	3.9%	4.6%	5.1%
Black	6.1%	6.8%	6.3%	6.6%	8.4%	6.7%	6.6%	7.6%

Figure 6.20. Race distribution of Focus Areas grantholders, by year



	1994 (N=33)	1997 (N=164)	2000 (N=60)	2003 (N=112))	2006 (N=149)	2008 (N=109)
Not specified	24.2%	4.9%	5.2%	2.7%	0.7%	0.9%
White	72.7%	92.1%	89.6%	82.1%	88.6%	87.2%
Indian	3.0%	0.6%	2.8%	3.6%	2.0%	3.7%
Coloured	0.0%	0.6%	0.7%	0.9%	2.7%	1.8%
Black	0.0%	1.8%	1.7%	10.7%	6.0%	6.4%

Figure 6.21. Race distribution of THRIP grantholders, by year

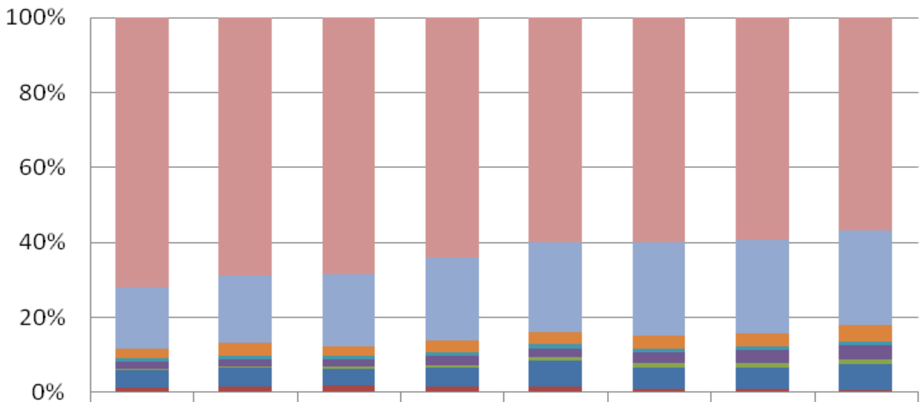


	2001 (N=15)	2002 (N=72)	2003 (N=71)	2004 (N=74)	2005 (N=83)	2006 (N=81)	2007 (N=66)	2008 (N=62)
White	100.0%	95.8%	95.8%	97.3%	95.2%	91.4%	92.4%	88.7%
Indian	0.0%	0.0%	0.0%	1.4%	2.4%	2.5%	3.0%	3.2%
Coloured	0.0%	2.8%	2.8%	0.0%	1.2%	1.2%	0.0%	3.2%
Black	0.0%	1.4%	1.4%	1.4%	1.2%	4.9%	4.5%	4.8%

Figure 6.22. Race distribution of grantholders who received both Focus Areas and THRIP grants concurrently, by year

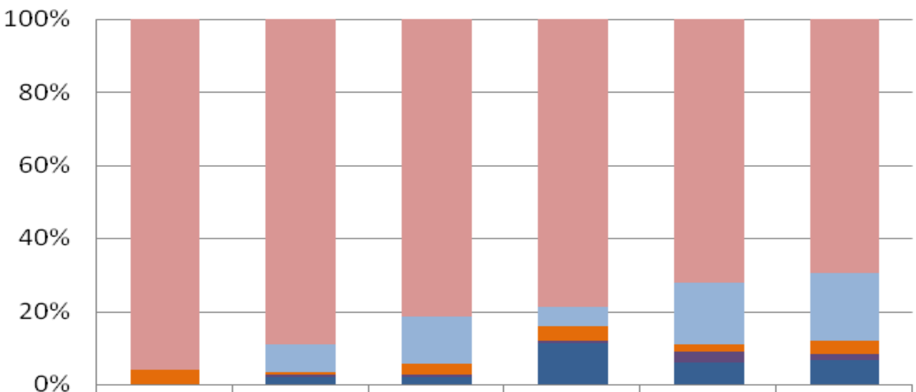
6.3.3. Race by Gender

As can be inferred from Figures 6.17 to 6.22, white males, followed by white females comprised the majority of grantholders across all three groups: those receiving grants from Focus Areas only, THRIP only, and those receiving both concurrently (Figures 6.23 to 6.25. There were no Black females and Coloured females awarded the THRIP grant between 1994 and 2007, with only one Black Female receiving the THRIP grant (together with the Focus Areas grant) in 2008 (Figure 6.25).



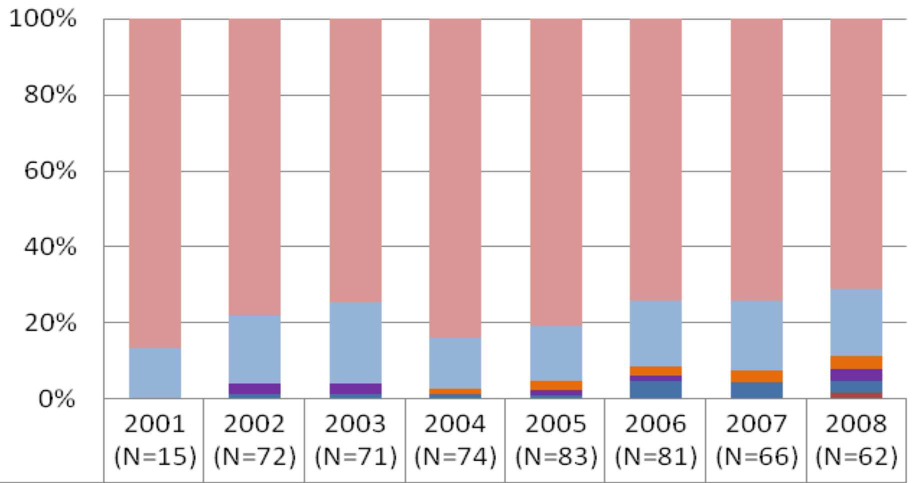
	2001 (N=537)	2002 (N=752)	2003 (N=715)	2004 (N=783)	2005 (N=849)	2006 (N=865)	2007 (N=848)	2008 (N=847)
White Males	72%	69%	69%	64%	60%	60%	59%	57%
White Females	16%	18%	19%	22%	24%	25%	25%	25%
Indian Males	2%	3%	3%	3%	3%	3%	4%	4%
Indian Females	1%	1%	1%	1%	1%	1%	1%	1%
Coloured Males	2%	2%	2%	2%	2%	3%	3%	4%
Coloured Females	0%	0%	1%	1%	1%	1%	1%	1%
Black Males	5%	5%	4%	5%	7%	6%	6%	7%
Black Females	1%	2%	2%	2%	2%	1%	1%	1%

Figure 6.23. Race-gender distribution of Focus Areas grantholders, by year



	1994 (N=25)	1997 (N=154)	2000 (N=271)	2003 (N=108)	2006 (N=148)	2008 (N=108)
White Males	96%	89%	82%	79%	72%	69%
White Females	0%	8%	13%	6%	17%	19%
Indian Males	4%	1%	3%	4%	2%	4%
Indian Females	0%	0%	0%	0%	0%	0%
Coloured Males	0%	1%	1%	1%	3%	2%
Black Males	0%	2%	2%	11%	6%	6%

Figure 6.24. Race-gender distribution of THRIP grantholders, by year

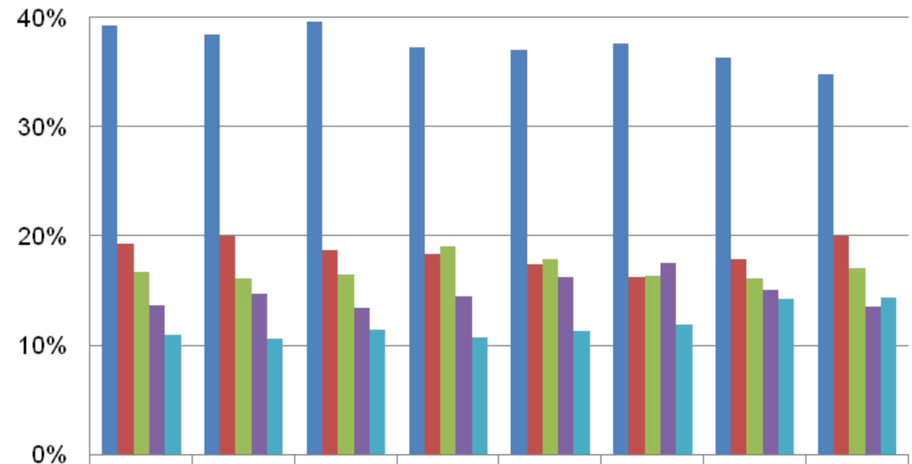


	2001 (N=15)	2002 (N=72)	2003 (N=71)	2004 (N=74)	2005 (N=83)	2006 (N=81)	2007 (N=66)	2008 (N=62)
White Males	87%	78%	75%	84%	81%	74%	74%	71%
White Females	13%	18%	21%	14%	14%	17%	18%	18%
Indian Males	0%	0%	0%	1%	2%	2%	3%	3%
Coloured Males	0%	3%	3%	0%	1%	1%	0%	3%
Black Males	0%	1%	1%	1%	1%	5%	5%	3%
Black Females	0%	0%	0%	0%	0%	0%	0%	2%

Figure 6.25. Race-gender distribution of grantholders who received both Focus Areas and THRIP grants concurrently, by year

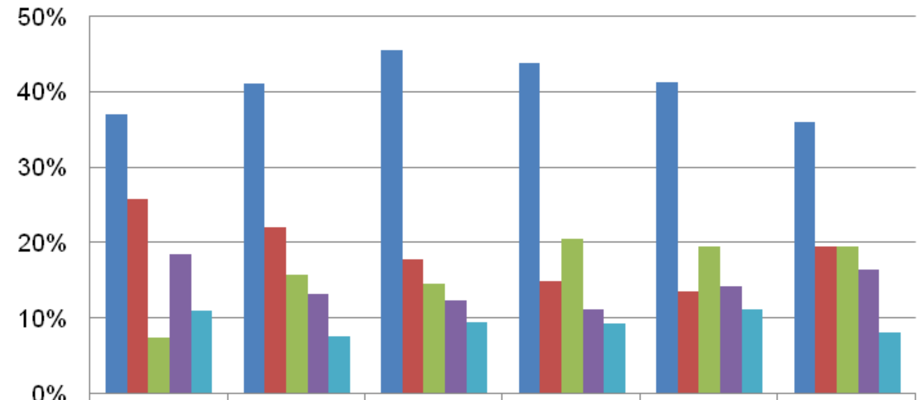
6.3.4. Age

Focus Areas grantholders who are 45 years or younger comprised the largest group throughout the study period (above 35% each year), followed by those who are between 46 and 50 years of age (Figure 6.26). The proportion of Focus Areas grantholders above 60 years increased slightly, from 11% in 2001 to 14% in 2008 (Figure 6.26). Similarly, the majority of THRIP grantholders are in the age group “45 and younger” (Figure 6.27), also making up more than 35% of all grants awarded throughout the years. THRIP witnessed a steady increase in the proportion of grantholders between the ages of 51 and 55, from 7% in 1994 to 20% in 2008 (Figure 6.27). During the same time, the proportion of THRIP grantholders over the age of 61 showed a slight decrease, from an 11% participation rate by this group in 1994, to 8% in 2008, at an average rate of 9%. The proportion of younger researchers, i.e. those under the age of 45, who held both Focus Areas and THRIP grants concurrently, decreased from the highest participation rate of 54% in 2002 to 21% in 2008 (Figure 6.28). While researchers in the age group “45 and younger” were the majority of grantholders receiving funding from both programmes for the greater part of the study period, from 2001 to 2006, there was a shift in 2007 and 2008, with the age group “46 to 50” showing the highest participation rates in these last two years.



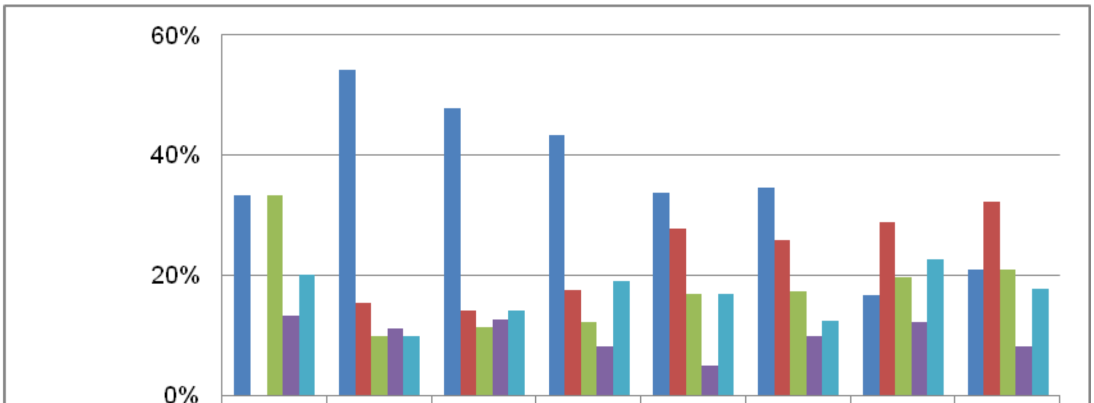
	2001 (N=539)	2002 (N=754)	2003 (N=718)	2004 (N=784)	2005 (N=848)	2006 (N=863)	2007 (N=846)	2008 (N=845)
≤ 45 years	39%	38%	40%	37%	37%	38%	36%	35%
46 - 50 years	19%	20%	19%	18%	17%	16%	18%	20%
51 - 55 years	17%	16%	17%	19%	18%	16%	16%	17%
56 - 60 years	14%	15%	14%	15%	16%	18%	15%	14%
≥61 years	11%	11%	11%	11%	11%	12%	14%	14%

Figure 6.26. Age distribution of Focus Areas grantholders, by year



	1994 (N=27)	1997 (N=158)	2000 (N=274)	2003 (N=107)	2006 (N=133)	2008 (N=97)
≤ 45 years	37%	41%	46%	44%	41%	36%
46 - 50 years	26%	22%	18%	15%	14%	20%
51 - 55 years	7%	16%	15%	21%	20%	20%
56 - 60 years	19%	13%	12%	11%	14%	16%
≥61 years	11%	8%	9%	9%	11%	8%

Figure 6.27. Age distribution of THRIP grantholders, by year



	2001 (N=15)	2002 (N=72)	2003 (N=71)	2004 (N=74)	2005 (N=83)	2006 (N=81)	2007 (N=66)	2008 (N=62)
≤ 45 years	33%	54%	48%	43%	34%	35%	17%	21%
46 - 50 years	0%	15%	14%	18%	28%	26%	29%	32%
51 - 55 years	33%	10%	11%	12%	17%	17%	20%	21%
56 - 60 years	13%	11%	13%	8%	5%	10%	12%	8%
≥61 years	20%	10%	14%	19%	17%	12%	23%	18%

Figure 6.28. Age distribution of grantholders who received both Focus Areas and THRIP grants concurrently, by year

6.3.5. Demographics aggregated by broad scientific field

While there have been a general dominance of male grantholders across all fields of study in both the Focus Areas and THRIP programmes, there has also been shifts in some fields over the years. Since 2001, female participation under the Focus Areas programme has significantly increased in fields such as the Health Sciences (from 17% in 2001 to 44% in 2008) and Agricultural Sciences (from 22% to 34%) (Table 6.8). Participation by women in the Social Sciences, Arts and humanities was 38% in 2008 (from 37% in 2001). Women remained less represented in the Engineering and Applied Sciences, despite the minor growth from 7% in 2001 to 14% in 2008 (Table 6.8).

Gender representation remains a challenge in the THRIP programme across fields, with the exception of Agricultural Sciences at 43% in 2008 (Table 6.9). In 2001, 43% of THRIP grantholders in the Health Sciences were female, however by 2008 all grantholders in this field were male (Table 6.9). Of those receiving both the Focus Areas and THRIP grants concurrently, women were better represented in the Agricultural and Biological Sciences (both at 30% in 2008) (Table 6.10). There were only two grantholders who received both the Focus Areas and THRIP grants in the Health Sciences field in 2008, and both of them were women (Table 6.10).

White researchers dominate across all scientific fields in both funding programmes: Focus Areas and THRIP (Table 6.11 to 6.13). By 2008, researchers younger than 45 were generally well represented across the various study fields in both the Focus Areas and the THRIP programmes (Table 6.14 and 6.15). Of those who received funding from both programmes, researchers between 46 and 50 in the Agricultural Sciences, comprised the majority of grant recipients (Table 6.16).

Table 6.9. Summary of grantholder gender demographics by broad scientific field (Focus Areas): 2001, 2004, and 2008

Broad scientific field	2001					2004					2008				
	Fem	Males	Total	%Fem	%Males	Fem	Males	Total	%Fem	%Males	Fem	Males	Total	%Fem	%Males
Agricultural sciences	11	39	50	22%	78%	16	47	63	25%	75%	21	41	62	34%	66%
Biological sciences	2	97	99	2%	98%	57	187	244	23%	77%	84	206	290	29%	71%
Chem & Physical Sciences	16	144	160	10%	90%	21	142	163	13%	87%	29	141	170	17%	83%
Eng & Applied Sciences	6	80	86	7%	93%	7	68	75	9%	91%	13	81	94	14%	86%
Health Sciences	4	20	24	17%	83%	19	30	49	39%	61%	32	41	73	44%	56%
SSA&H	33	57	90	37%	63%	80	112	192	42%	58%	60	98	158	38%	62%

Fem = Females

Table 6.10. Summary of grantholder gender demographics by broad scientific field (THRIP): 2001, 2004, and 2008

Broad scientific field	2001					2004					2008				
	Fem	Males	Total	%Fem	%Males	Fem	Males	Total	%Fem	%Males	Fem	Males	Total	%Fem	%Males
Agricultural sciences	1	8	9	11%	89%	2	9	11	18%	82%	6	8	14	43%	57%
Biological sciences	3	7	10	30%	70%	1	12	13	8%	92%	5	10	15	33%	67%
Chem & Physical Sciences	0	4	4	0%	100%	0	15	15	0%	100%	4	14	18	22%	78%
Eng & Applied Sciences	2	25	27	7%	93%	2	67	69	3%	97%	5	52	57	9%	91%
Health Sciences	3	4	7	43%	57%	0	1	1	0%	100%	0	4	4	0%	100%
SSA&H	0	2	2	0%	100%	1	1	2	50%	50%	0	1	1	0%	100%

Fem = Females. The gender of one grantholder was not specified for 2001 data in the Biological Sciences. This entry was removed from the analysis.

Table 6.11. Summary of grantholder gender demographics by broad scientific field (Focus Areas & THRIP, concurrently): 2001, 2004, and 2008

Broad scientific field	2001					2004					2008				
	Fem	Males	Total	%Fem	%Males	Fem	Males	Total	%Fem	%Males	Fem	Males	Total	%Fem	%Males
Agricultural sciences	1	1	2	50%	50%	5	8	13	38%	62%	3	7	10	30%	70%
Biological sciences	0	4	4	0%	100%	1	12	13	8%	92%	3	7	10	30%	70%
Chem & Physical Sciences	0	0	0	0%	0%	1	16	17	6%	94%	2	12	14	14%	86%
Eng & Applied Sciences	0	6	6	0%	100%	2	25	27	7%	93%	2	22	24	8%	92%
Health Sciences	1	2	3	33%	67%	1	1	2	50%	50%	2	0	2	100%	0%
SSA&H	0	0	0	0%	0%	0	2	2	0%	100%	0	2	2	0%	100%

Fem = Females

Table 6.12. Summary of grantholder race demographics by broad scientific field (Focus Areas): 2001 and 2008

Broad scientific field	2001									2008								
	Bl	Col	Ind	Wht	Total	%Bl	%Col	%Ind	%Wht	Bl	Col	Ind	Wht	Total	%Bl	%Col	%Ind	%Wht
Agricultural sciences	4	0	0	46	50	8%	0%	0%	92%	9	4	0	49	62	15%	6%	0%	79%
Biological sciences	3	0	4	122	129	2%	0%	3%	95%	8	16	15	251	290	3%	6%	5%	87%
Chem & Physical Sciences	9	5	5	139	160	6%	3%	3%	87%	16	11	10	133	170	9%	6%	6%	78%
Eng & Applied Sciences	2	2	2	80	86	2%	2%	2%	93%	13	3	6	72	94	14%	3%	6%	77%
Health Sciences	3	1	3	17	24	13%	4%	13%	71%	5	4	8	56	73	7%	5%	11%	77%
SSA&H	12	3	4	71	90	13%	3%	4%	79%	13	5	6	134	158	8%	3%	4%	85%

Bl = Black; Col = Coloured; Ind = Indian; Wht = White. The race of two grantholders was not specified for 2001 data in the Chemical and Physical Science. These entries were removed from the analysis.

Table 6.13. Summary of grantholder race demographics by broad scientific field (THRIP): 2001 and 2008

Broad scientific field	2001									2008								
	Bl	Col	Ind	Wht	Total	%Bl	%Col	%Ind	%Wht	Bl	Col	Ind	Wht	Total	%Bl	%Col	%Ind	%Wht
Agricultural sciences	0	0	0	7	9	0%	0%	0%	78%	0	0	0	14	14	0%	0%	0%	100%
Biological sciences	0	0	1	9	10	0%	0%	10%	90%	0	0	0	15	15	0%	0%	0%	100%
Chem & Physical Sciences	0	0	0	4	4	0%	0%	0%	100%	1	1	1	15	18	6%	6%	6%	83%
Eng & Applied Sciences	0	0	1	26	27	0%	0%	4%	96%	6	1	3	46	56	11%	2%	5%	82%
Health Sciences	1	0	0	6	7	14%	0%	0%	86%	0	0	0	4	4	0%	0%	0%	100%
SSA&H	0	0	0	2	2	0%	0%	0%	100%	0	0	0	1	1	0%	0%	0%	100%

Bl = Black; Col = Coloured; Ind = Indian; Wht = White. Grantholders whose race was not specified were removed from the analysis.

Table 6.14. Summary of grantholder race demographics by broad scientific field (Focus Areas & THRIP, concurrently): 2001 and 2008

Broad scientific field	2001			2008								
	Wht	Total	%Wht	Bl	Col	Ind	Wht	Total	%Bl	%Col	%Ind	%Wht
Agricultural sciences	2	2	100%	0	0	0	10	10	0%	0%	0%	100%
Biological sciences	4	4	100%	1	0	0	9	10	10%	0%	0%	90%
Chem & Physical Sciences	0	0	0%	0	1	1	12	14	0%	7%	7%	86%
Eng & Applied Sciences	6	6	100%	2	1	1	20	24	8%	4%	4%	83%
Health Sciences	3	3	100%	0	0	0	2	2	0%	0%	0%	100%
SSA&H	0	0	0%	0	0	0	2	2	0%	0%	0%	100%

Bl = Blacks; Col = Coloureds; Ind = Indians; Wht = Whites.

Table 6.15. Summary of grantholder age demographics by broad scientific field (Focus Areas): 2008

Broad Scientific Field							Percentages (%)				
	≤45	46-50	51-55	56-60	≥61	Total	% ≤45	% 46-50	% 51-55	% 56-60	% ≥61
Agricultural sciences	24	14	8	8	7	61	39%	23%	13%	13%	11%
Biological sciences	114	60	48	38	30	290	39%	21%	17%	13%	10%
Chem & Physical Sciences	56	32	23	19	40	170	33%	19%	14%	11%	24%
Eng & Applied Sciences	38	20	15	12	8	93	41%	22%	16%	13%	9%
Health Sciences	32	20	10	4	14	80	40%	25%	13%	5%	18%
SSA&H	37	23	41	34	23	158	23%	15%	26%	22%	15%

Table 6.16. Summary of grantholder age demographics by broad scientific field (THRIP): 2008

Broad Scientific Field							Percentages (%)				
	≤45	46-50	51-55	56-60	≥61	Total	% ≤45	% 46-50	% 51-55	% 56-60	% ≥61
Agricultural sciences	7	1	2	1	0	11	64%	9%	18%	9%	0%
Biological sciences	7	4	1	1	0	13	54%	31%	8%	8%	0%
Chem & Physical Sciences	5	5	4	2	3	19	26%	26%	21%	11%	16%
Eng & Applied Sciences	17	9	9	10	5	50	34%	18%	18%	20%	10%
Health Sciences	0	0	3	1	0	4	0%	0%	75%	25%	0%
SSA&H	0	0	0	1	0	1	0%	0%	0%	100%	0%

Table 6.17. Summary of grantholder age demographics by broad scientific field (Focus Areas & THRIP, concurrently): 2008

Broad Scientific Field							Percentages (%)				
	≤45	46-50	51-55	56-60	≥61	Total	% ≤45	% 46-50	% 51-55	% 56-60	% ≥61
Agricultural sciences	0	7	3	0	0	10	0%	70%	30%	0%	0%
Biological sciences	4	4	1	1	0	10	40%	40%	10%	10%	0%
Chem & Physical Sciences	4	1	4	1	4	14	29%	7%	29%	7%	29%
Eng & Applied Sciences	5	8	3	3	5	24	21%	33%	13%	13%	21%
Health Sciences	0	0	1	0	1	2	0%	0%	50%	0%	50%
SSA&H	0	0	1	0	1	2	0%	0%	50%	0%	50%

6.4. DISCUSSION AND CONCLUDING REMARKS

The main aim of this chapter was to determine if there are significant differences in the distribution of funding between the Focus Areas and THRIP programmes, in terms of the amount of grants; across various scientific fields; and across demographics.

The central questions of this chapter are:

- Do researchers/academics who receive funding from industry, i.e. THRIP, receive more or less funding than those that receive NRF funding, i.e. Focus Areas funding?
- What have been the trends in the allocation of funding from the both THRIP and the Focus Areas programme over the years? In particular, the chapter investigated shifts (if any) in funding allocation from both programmes by:
    - University – what is the proportion of funding received by different universities, from each programme, during the period under study?
    - Scientific field – what is the proportion of funding per scientific field from both the Focus Areas and THRIP programmes? Differences in field distribution by demographics, i.e. gender, race, and age, were also investigated.
    - Demographics – are there differences in funding received from both the Focus Areas and THRIP programmes in terms of gender, race, and age?

6.4.1. Differences in amounts of funding

The findings show that, overall, more funds have been allocated through the THRIP programme than the Focus Areas programme. The average THRIP grant was more than 2.5 times larger than the Focus Area grant. Of course, those who received grants from both programmes within the same year accumulated much larger grants than those who only received funding from either one of the two programmes (6.7 times more than the Focus Areas only grantholders, and 2.7 times more than the THRIP only grantholders). The difference between THRIP and Focus Areas grant may be attributed to the fact that THRIP is co-funded by industry (the industry contribution is twice that of the government contribution), while the Focus Areas are fully funded by government/NRF.

6.4.2. Distribution of funding by university

The distribution of funds between universities appears to be line with the history of the university sector in South Africa. Universities that are described as "Historically Disadvantaged Institutions (HDIs) or Historically Black Universities (HBU)[33]" – those that were established for non-white individuals, received significantly lower funds from both the Focus Areas and THRIP during the period examined, compared to the "Historically White Institutions (HWIs)" – those that were meant for white individuals. An exception is the

[33]HDIs include University of Fort Hare (UFH); University of Limpopo (UL); University of Venda (UNIVEN); University of the Western Cape (UWC); Walter Sisulu University (WSU); University of Zululand (UZ); Mangosuthu University of Technology (MUT); Durban University of Technology (DUT). Cape Peninsula University of Technology (CPUT) involves a merger of an HDI, namely Peninsula Technikon, and a HWI, namely Cape Town Technikon.

University of the Western Cape (UWC), an HDI that received more funding, overall, than institutions such as the University of the Free State (UFS) and Rhodes University. The culture of research at HDIs and HWIs is also different. For many years, HDIs focused mainly on teaching, with minimal research taking place, while HWIs have always engaged in research. The THRIP evaluation report of 2002 also speaks to this challenge, and states that "*HBUs...face additional constraints [to participation in the THRIP programme], since research is a recent addition to their missions and teaching loads are heavy*" (THRIP 2002: 29). It was only in the past decade or so that all public universities in the country were required to engage actively in research.

A critical hurdle in research is to secure funding by way of submitting a proposal to a potential donor/agency. Writing a funding proposal requires experience and skill, which academics at HDIs did not have for many years. Obtaining funding from THRIP seems to be a particular challenge for academics at HDIs since they need to have an industry partner willing to invest in their work. Unlike public agencies such as the NRF, private companies expect (monetary) returns from their investment in research, and are therefore most likely to partner with researchers who are already established (and are more often based at a Historically White University). A researcher's reputation therefore plays an important role in attracting industry funding.

6.4.3. Distribution of funding by demographics

The distribution of NRF funds during the study period is skewed towards older white-male academics. Those who are above 50 years also received larger grants, on average, than academics who are 45 or younger. This finding is consistent with what Mouton (2003) found, that "*the knowledgebase of the country is still mainly confined to a minority of white, male scientists and academics*". Over the past decade, the NRF has intensified efforts to encourage younger academics, through the launch of funding programmes such as Thuthuka which, introduced in 2001, has four specific objectives[34]:

- *Support researchers from designated groups in their pursuit to attain formal post graduate qualifications or a NRF rating;*
- *Improve the research capacity of individual researchers from designated groups;*
- *Foster a culture of research excellence and aid in the development and expansion of the national knowledge-based economy by boosting research outputs and human capital development; and*

[34]Obtained from http://hicd.nrf.ac.za/

- *Effect a transformation in the demographic composition of the established researcher community with respect to gender, race and persons with disabilities.*

The idea behind Thuthuka was that after a few years of researchers receiving support from this “developmental” programme, they should be able to apply for funding from programmes such as the Focus Areas. Thus they should be able to compete for funding with other established researchers. It would therefore be interesting to investigate the proportion of Focus Areas and/or THRIP grantholders who came through the Thuthuka programme to determine if this programme achieved its objectives.

There is an expectation that each funded project will result in an output, ideally in the form of a scientific publication. The NRF tries to gather information on publications that come out of the projects it has funded. However, so far there is no reliable data that links specific publications to NRF-funded projects. The next chapter aims to determine whether there is a link or correlation between funding and scientific productivity. In other words, do academics who receive more money produce more outputs than those who receive less funding? Also, what kind of outputs are they producing?

CHAPTER 7: THE IMPACT OF FUNDING ON SCIENTIFIC PRODUCTIVITY AND MODE OF KNOWLEDGE PRODUCTION

7.1. INTRODUCTION

The South African government has invested billions of Rands into research conducted in public universities through the National Research Foundation since its inception in 1999. Figure 7.1 shows the total funds awarded to NRF by the Department of Science and Technology (DST) for distribution as grants to university between 2000 and 2010 (which amounts to just under R3.5 billion). Additional funds have also been invested in research by industry. It was shown in Chapter 4 that there has been an increase in industry funding for university research all over the world. The literature further shows that the source of funding has an influence on scientific productivity, indicating that industry funded researchers produce more outputs than researchers who rely solely on public funding. There is also a body of literature which shows that the source of funding influences the kind of research that academics engage in. For example, academics with industry funding tend to engage in more applied research while those with public funding engage in more basic research.

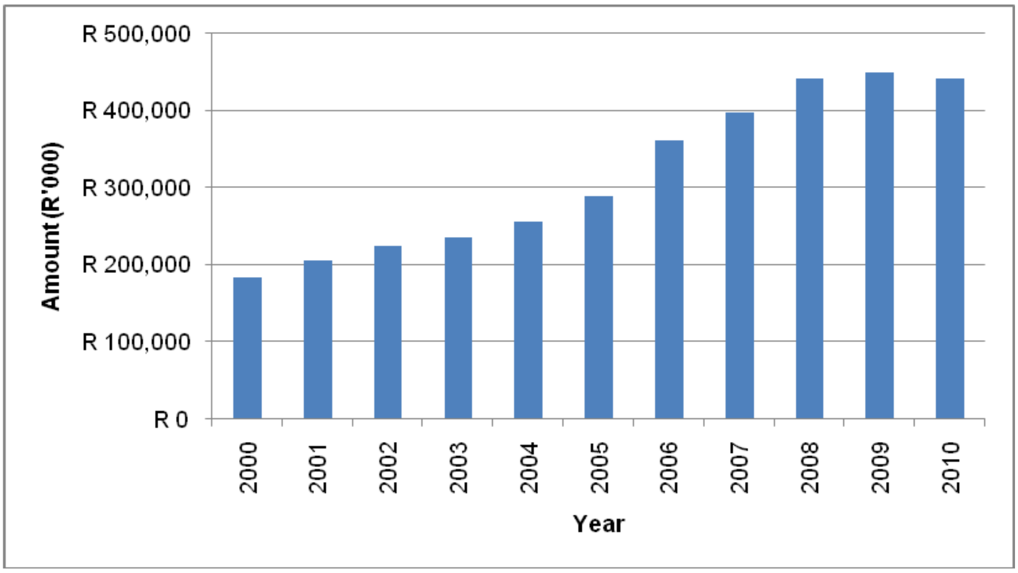


Figure 7.1. Annual allocation to NRF (RISA[35]unit) from DST

In this chapter the question is addressed as to whether researchers who receive funding from industry, including THRIP, are more or less productive than those who receive NRF funding (i.e. Focus Areas). Another central question of this chapter is whether there are significant differences in the modes of knowledge production utilised by researchers who

[35]RISA (Research and Innovation Support and Advancement) is one of NRF's three main business units, and grants to university researchers are distributed from this unit.

receive funding from different sources, i.e. from industry as compared to the NRF. That is, do researchers engage in different research activities and research dissemination modes with industry funding compared to NRF/public funding?

7.2. USING RESEARCHERS' CURRICULA VITAE TO DETERMINE THE IMPACT OF FUNDING ON SCIENTIFIC PRODUCTIVITY

As indicated in Chapter 5, all curricula vitae were scrutinised for the researcher's sources of funding. In addition, the total number of the various types of publications produced by the respondent in their career was calculated (journal articles, books and book chapters, technical reports, and conference proceedings), as well as the total number of masters and doctoral students supervised to date. Data for both publications and students supervised was normalised by each respondent's publication timeframe (the difference between date of first publication and 2012). The publication timeframe was then used to calculate the average annual research output for each individual. Prior to the analysis, respondents were grouped into three funding categories, i.e. those who had received funding from the Focus Areas only, from THRIP only, or from both the Focus Areas and THRIP (either during the same year or sometime in their career). For the purpose of this study, THRIP was considered as proxy for industry funding (although strictly speaking, as mentioned earlier, THRIP is part industry and part government); while the Focus Areas funding was considered as proxy for government/public funding.

Close to half of respondents (47%) received funding from both the Focus Areas and THRIP programmes at some point in their career (Figure 7.2). Forty-two percent of respondents received funding from the Focus Areas programme only, while 11% received funding from THRIP only (Figure 7.2).

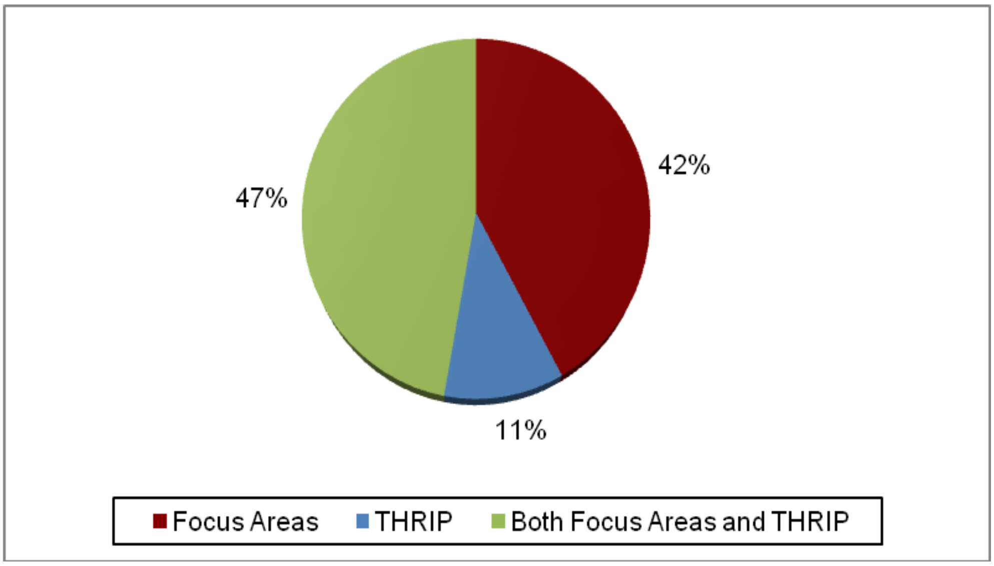


Figure 7.2. Breakdown of respondents by source of funding

7.2.1. Productivity by source of funding

The results of our analysis show the following:

- Researchers who received funding from both Focus Areas and THRIP produce more research outputs annually, than those who received Focus Areas only or THRIP only funding (Table 7.1). In particular, participants who received funding from both programmes produced more journal articles, conference proceedings, and technical reports, compared to the other two groups (Table 7.1).
- Academics who received funding from the Focus Areas only produce more than those who received THRIP funding only (Table 7.1), with the exception of conference proceedings, thus those who received funding from THRIP only produced more conference proceedings than those who received Focus Areas funding only.
- Industry-funded researchers (those receiving THRIP grant) produce fewer journal articles, books and chapters in books per year compared to NRF-funded researchers (those receiving Focus Areas grants). THRIP funded researchers also produce slightly more technical reports per year than Focus Area funded researchers.

Results of the One-Way Analysis of Variance (ANOVA), however, show that the differences reported are only statistically significant ($P < 0.05$) for the category of the average annual journal articles (Table 7.2).The difference in output of conference proceedings (with THRIP funded projects on average producing the highest annual output) is significant at the 95% probability level.

On the one hand, these results suggest that respondents who receive funding from both programmes have an advantage over those who receive funding from only one source because of the high amount of funding they accumulate. However, a comparison between those who received either the Focus Areas only or THRIP only suggest that the connection between funding and output, particularly in the public domain, is not a simple one. There are other factors that influence productivity outside funding. These will be explored later in the chapter. For example, while the THRIP group produced the least outputs annually in most of the outputs types, they produced more conference proceedings than the other two groups.

Table 7.1. Average annual research output by source of funding

Research Output	**Focus Areas Funding only (N = 74)**	**THRIP Funding only (N = 19)**	**Both Focus Areas and THRIP Funding (N = 83)**
Average funding per project (2001 – 2008)	R 202 876 (799 grants)	R 759 265 (164 grants)	R 1 057 142 (183 grants)
Journal articles	3.44	1.72	4.01
Books	0.09	0.02	0.07
Book chapters	0.34	0.13	0.29
Technical reports	0.23	0.26	0.67
Conference proceedings	0.52	1.41	0.92

Table 7.2. Results of ONE-WAY ANALYSIS OF VARIANCE (ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
Average annual journal articles published	Between Groups	81.772	2	40.886	5.574	**.005**
	Within Groups	1268.952	173	7.335		
	Total	1350.724	175			
Average annual books published	Between Groups	.065	2	.032	1.892	.154
	Within Groups	2.969	173	.017		
	Total	3.034	175			
Average annual chapters published	Between Groups	.699	2	.350	1.612	.202
	Within Groups	37.518	173	.217		
	Total	38.217	175			
Average technical reports	Between Groups	8.071	2	4.036	.959	.385
	Within Groups	727.674	173	4.206		
	Total	735.745	175			
Average annual conference proceedings published	Between Groups	13.672	2	6.836	2.914	.057
	Within Groups	405.888	173	2.346		
	Total	419.560	175			

7.2.1. Productivity by broad scientific field

On average, participants in Agricultural Sciences published the most number of journal articles per year (4.93), followed by those in the Health Sciences (4.03), with the Biological Sciences in third place with an average of 3.85 journal articles per year (Table 7.3). Researchers in the Social Sciences, Arts and Humanities, not surprisingly, showed the highest average number of books (0.25) and book chapters (0.81) published annually. Those in the Chemical and Physical Sciences produced an average of one technical report per annum, higher than other broad fields. With regard to published conference proceedings, participants in Engineering and Applied Sciences showed the highest average annual publication rate (2.81), followed by 0.58 for participants in Agricultural Sciences, and 0.57 for the Health Sciences (Table 7.3). These findings are generally as expected,

Tables 7.4 to 7.6 provide a further breakdown of participants' productivity by broad scientific field for each funding category. Although the sample size is fairly small, particularly when broken down by field, this sample represents the most productive academics in the system and therefore allows us to draw some preliminary conclusions.

Table 7.3. Average annual research output by broad scientific field

Broad scientific field	Journal articles	Books	Chapters in books	Technical reports	Conference proceedings
Agricultural Sciences (N = 23)	4.93	0.07	0.17	0.23	0.58
Biological Sciences (N = 62)	3.85	0.05	0.32	0.26	0.25
Chem & Physical Sciences (N = 29)	3.62	0.02	0.09	1.01	0.54
Eng & Applied Sciences (N = 31)	2.33	0.05	0.24	0.32	2.81
Health Sciences (N = 14)	4.03	0.10	0.31	0.53	0.57
SSA&H (N = 17)	2.03	0.25	0.81	0.54	0.11

Table 7.4. Average annual research output by broad scientific field, for researchers receiving funding from the Focus Areas only

Broad scientific field	Journal articles	Books	Chapters in books	Technical reports	Conference proceedings
Agricultural Sciences (N = 5)	3.63	0	0.07	0.17	0.50
Biological Sciences (N = 32)	4.02	0.03	0.28	0.22	0.25
Chem & Physical Sciences (N = 11)	3.98	0.05	0.16	0.03	0.39
Eng & Applied Sciences (N = 4)	2.09	0.07	0.05	0.11	4.04
Health Sciences (N = 7)	3.43	0.08	0.12	0.31	0.80
SSA&H (N = 15)	2.09	0.26	0.88	0.42	0.12

Table 7.5. Average annual research output by broad scientific field, for researchers receiving funding from THRIP only

Broad scientific field	Journal articles	Books	Chapters in books	Technical reports	Conference proceedings
Agricultural Sciences (N = 4)	2.09	0	0	0.29	0.22
Biological Sciences (N = 3)	1.60	0.04	0.38	0.42	0.62
Chem & Physical Sciences (N = 3)	2.02	0	0.08	0.04	1.78
Eng & Applied Sciences (N = 8)	1.49	0.01	0.11	0.17	2.33
SSA&H (N = 1)	1.61	0.09	0.26	0.94	0

Table 7.6. Average annual research output by broad scientific field, for researchers receiving funding from both the Focus Areas and THRIP programmes

Broad scientific field	Journal articles	Books	Chapters in books	Technical reports	Conference proceedings
Agricultural Sciences (N = 14)	6.20	0.12	0.25	0.23	0.71
Biological Sciences (N = 27)	4.02	0.07	0.39	0.33	0.21
Chem & Physical Sciences (N = 15)	3.68	0.01	0.05	1.93	0.40
Eng & Applied Sciences (N = 19)	2.87	0.07	0.32	0.46	2.65
Health Sciences (N = 7)	4.64	0.12	0.51	0.76	0.33
SSA&H (N = 1)	1.38	0.15	0.29	1.91	0

These results on productivity by field confirmed what we already know about publication patterns of various fields. For example, the high rate of conference proceedings in the Engineering and Applied Sciences, which include the Information and Communication Technology (ICT) discipline, is no surprise as academics in this field argue that conference proceedings is the preferred avenue for sharing their research findings over other common platforms such as peer-reviewed journals and books. The ICT discipline, in particular, is said to be “fast paced” such that new developments become outdated very quickly. Given that the process of submitting an article to a journal or publishing a book can be lengthy, results may become outdated by the time the journal or book is published. The high average annual articles by health scientists can also be explained by the large number of authors often writing a single journal article. It is not uncommon to find more than 50 individuals contributing to one journal article in the Health Sciences. The comparatively higher output in books and chapters in books by researchers in the Social Sciences is also in line with publication practices in these fields.

7.2.3. Productivity by age

Participants who are in the age group "56 to 60" produced the highest average number of journal articles annually (3.94), followed by those in the age group "51 to 55" (an average of 3.67 journal articles per year) (Table 7.7). The "56 to 60" age group also produced the highest average book chapters annually (0.37), followed by those who are between the ages of 46 and 50 (0.34) and the age group "45 and younger". Participants in the age group "61 and older" produced an average of 0.69 technical reports annually, the highest of all age groups (Table 7.7). One explanation for the relatively high productivity of respondents above 50 is the fact that they tend also to supervise more masters and doctoral students, on average, than other age groups (Table 7.8), providing them with the possibility of co-authorships with their students' publications.

Table 7.7. Average annual research output by age

Age group	Journal articles	Books	Chapters in books	Technical reports	Conference proceedings
45 and younger (N = 19)	3.62	0.08	0.33	0.34	0.88
46 to 50 (N = 27)	3.24	0.05	0.34	0.46	0.84
51 to 55 (N = 43)	3.67	0.07	0.23	0.32	0.88
56 to 60 (N = 29)	3.94	0.09	0.37	0.16	0.61
61 and older (N = 58)	3.30	0.07	0.28	0.69	0.80

7.2.4. Student training

Participants who received funding from both the Focus Areas and THRIP graduate more masters and doctoral students annually (1.1 and 0.5 respectively) compared to those who receive funding from the Focus Areas (0.86 and 0.39) or THRIP only (1.04 and 0.1) (Table 7.8). Those who received THRIP funding graduate more masters students per year than those who received Focus Areas funding. This finding is not surprising given THRIP's focus on student training.

Table 7.8. Average annual number of students supervised, by source of funding

Student training	Focus Areas only	THRIP only	Both Focus Areas and THRIP
Masters	0.86	1.04	1.1
Doctoral	0.39	0.1	0.5

7.2.4.1. Student training by age

On average, academics in the age group "51 to 55" graduate more masters and doctoral students annually (1.29 and 0.49 respectively), compared to the other two groups, followed by those who are in the age groups “36 to 40” and “41 to 45” (Table 7.9). Again, this is not a surprising finding given the profile of individuals in this age group. Also, this study did not separate out whether a respondent was the primary supervisor or the co-supervisor of the students listed in the CV. Sometimes academics get acknowledged as co-supervisors on masters and doctoral degrees even though they have spent an insignificant amount of time with the students, or for assisting only with a portion of the thesis (such as an analytical component). This was a limitation for this study as it could inflate the number of students supervised for some individuals.

Table 7.9.Average annual number of students supervised, by age

Age group	**Masters**	**Doctoral**
45 and younger (N = 19)	1.21	0.41
46 to 50 (N = 27)	1.07	0.41
51 to 55 (N = 43)	1.29	0.49
56 to 60 (N = 29)	0.69	0.39
61 and older (N = 58)	0.81	0.37

The next section reports on the findings of the in-depth telephone interviews conducted with 23 academics. The findings are grouped into five broad themes, each with several sub-themes: nature of research; research outputs; capacity building; organisation of research activities; and the academic’s opinion of the NRF.

First, a summary of responses from the 23 prominent academics interviewed (Table 7.10) is provided. The Table also provides some information about the individuals interviewed, including their area of study, host university, current age, and sources of funding.

Table 7.10.Summary of respondents' profiles and responses from telephone interviews

Code	Area of study	Funding programme: Focus Areas/THRIP/Both?	Other industry/private funding?	Does the research you undertake with industry funding differ from that which you conduct with public funding?	How do you describe the type of research you conduct with industry funding?	Who determines the scope/focus of research, yourself or the industry partner?	Does industry funding, compared to NRF funding, allow you to train more masters and doctoral students?
Ac1	Applied Mathematics	Both	Yes	No	Applied	Client	No
Ac2	Biochemistry	Focus Areas	Yes	Yes	Applied	Academic	Yes
Ac3	Biomedical Engineering	Both	Yes	Yes	Applied	Jointly - academic and industry partner	Yes
Ac4	Botany	Focus Areas	No	n/a	n/a	n/a	n/a
Ac5	Chemical Engineering	Both	Yes	No	Basic and applied	Academic	Yes
Ac6	Chemistry	Both	Yes	Yes	Applied	Academic	No
Ac7	Chemistry	Focus Areas	No	n/a	n/a	n/a	n/a
Ac8	Chemistry Education	Focus Areas	Yes	Yes	Development research	Client	No
Ac9	Computer Science	THRIP	Yes	n/a	Applied	Academic	Yes
Ac10	Entomology	THRIP	Yes	Yes	Applied	Industry partner	Yes
Ac11	Entomology	Focus Areas	No	n/a	n/a	n/a	n/a
Ac12	Genetics	Focus Areas	Yes	Yes	Management driven	Academic	Yes
Ac13	Geography	Focus Areas	Yes	Yes	Applied	Industry partner	Yes
Ac14	Heath Sciences/Virology	Focus Areas	Yes	No	Basic	Academic	No
Ac15	Human Genetics	Both	Yes	Yes	Applied	Industry partner	Yes
Ac16	Mechanical Engineering	Both	Yes	Yes	Basic and applied	Industry partner	Yes
Ac17	Mechanical Engineering	THRIP	Yes	Yes	Applied	Jointly - academic and industry partner	Yes
Ac18	Metallurgical Engineering	THRIP	Yes	No	Applied	Jointly - academic and industry partner	No
Ac19	Sociology	Focus Areas	Yes	Yes	Targeted	Client	No
Ac20	Sports Science	Both	Yes	No	Applied	Academic	Yes
Ac21	Palaeontology	Both	Yes	Yes	Applied	Academic	No
Ac22	Zoology	Both	Yes	Yes	Basic	Industry partner	Yes
Ac23	Zoology	Focus Areas	Yes	Yes	Basic and applied	Industry partner	Yes

7.3. NATURE OF RESEARCH

This section reports on how respondents define the nature of the research they conduct with funding from both the NRF and industry, respectively. Respondents reported different types of research engaged in, including applied, basic and development research. These definitions are described briefly below.

Applied research is mainly interpreted by respondents as addressing a predetermined problem often identified by the respective industry, or developing a product that will lead to commercialisation.

> *I see application is purely solving...now linked to an industrial project...is purely solving a problem they have. (Mechanical Engineer – Ac17)*
>
> *We try with the applied to link it to some kind of, in my case, medical issue, which is cancer and hormone replacement in my case. And so you make that connection, which means that when you do the research you have to ask the questions that relate to that.(Biochemist – Ac2)*

Some respondents further indicated that applied research does not allow for deviation from the project as set out at the start, even though there might be some interesting issues the researcher may come across in the process.

> *So if something else comes to that, which is interesting in terms of basic research but is not going to be helping you to answer the medical questions you do not pursue that actively because you do not have funding to do that. (Biochemist – Ac2)*

Basic research according to respondents is about generating and advancing knowledge.

> *Well I think basic research would probably be something that generates new knowledge but will not necessarily find an application that industry can use, you know, at least in a short period. (Human Geneticist – Ac15)*

As the response below shows, basic research is not understood to be about commercial value or outcome, although it does not rule out possible commercialisation

> *Well I would say, basic research implies learning more about specific object not necessarily with the aim to find a way to make money out of this. While the applied research that the industry wants is in terms of getting a product that they can sell. But you can do also basic research on the latter. And I would say that we do also basic research on the latter as well. So we don't do pure basic research, we do applied basic research as well as applied research. (Chemist – Ac6)*

Development research was described as research that focuses on developing a product that will be useful for a particular group, such as developing training manuals or textbooks.

> *Development means like creating some kind of product. So if I create materials, like, what people really need, say in the new curriculum, they need people to write material for learners. And it's very very hard work, it's very time consuming, and it's very...sort of...lot of attention to detail, but it's not original stuff in the sense that I make these material especially for learners and there's nothing I can gain in terms of research, you know, it's like writing textbooks. (Chemistry Educationist – Ac8)*

The outcome or outputs from development work are different from those arising from basic and applied research in the sense that they are not considered as "scholarly outputs", e.g. the writing of textbooks, and they do not advance an individual's research profile.

> *I can write textbooks also to earn money but it doesn't give me any help with my research profile. I can't list that amongst my list of publications. (Chemistry Educationist – Ac8)*

Having confirmed that respondents do indeed engage in different kinds of research and use different terminologies to describe their work, the next step was to test whether these kinds of research activities are linked to a particular type of funding, i.e. public versus industry. The next section therefore tests the proposition that the source of funding is related to the mode of knowledge production.

7.3.1. Making the link between the source of funding and the type of research activities

Fourteen of the twenty-three respondents indicated that there is a difference in the type of research they conduct with industry funding compared to the research they conduct with NRF funding (see Table 7.10), and that the research they conduct with industry funds is applied, and is aimed at addressing pre-determined problems, whereas the research they conduct with NRF funding is basic, fundamental, or curiosity driven.

NRF funding allows for basic/fundamental research, which contributes to knowledge generation

> *Everything I got funding from the government is fundamental research...I want to make a contribution to the academic environment while I'm doing the consultancy. (Geneticist – Ac12)*
>
> *I think I can say that my NRF research is more basic and my CANSA and MRC is more applied, obviously less applied than it would be for something like THRIP, or something like that, but certainly more applied than my NRF research, yes. (Biochemist – Ac2)*

> *I think quite a lot of the research is basic and is less than applied but where you get funding that is made available to you and they approach you then clearly in most cases there are...there is a request for policy implications. So the difference between, I mean in principle, it is not always this way but in principle the difference between NRF, which I think I was being curiosity driven even though they do have areas that they promote, it is more curiosity driven than research that is being commissioned by the Institute of Justice and Reconciliation, or an NGO, or the provinces, or in France. (Sociologist – Ac19)*

Most importantly, respondents indicated that NRF funding provided them with the freedom to choose the type of research they wanted to engage in. Thus, it provides them with "*flexibility in terms of your focus on the research and so on (Biomedical Engineer – Ac3)".*

> *[With] the NRF money I decide what research I want to do. It might be based on a national need or whatever and I decide how I'm going to do it. So I decide on my methodology and it's interest-driven from my side and I get the money and then I run research projects and I can graduate masters and doctoral students from that NRF money. (Chemistry Educationist – Ac8)*

> *With the NRF you have a little bit more freedom to do things that's maybe more fundamental and that companies will be reluctant to invest in because it's still very early stage research.(Mechanical Engineer – Ac16)*

> *The second main source of funding that I received was from the NRF,...it didn't matter whether it was applied or pure or curiosity [driven], and I was also fairly free to use the money in a sensible way to add components that were not in the original proposal but were relevant to it. So I had a fair amount of freedom in the NRF funding. (Zoologist – Ac23)*

On the other hand, industry funding is used for specific projects, identified by the industry partner, with the aim of addressing a pre-determined problem. Some industry-funded projects are conducted with the expectation that it will lead to commercialisation.

Industry funding is specific and targeted, and it is expected that the project must have immediate application

> *With contracted research...it's very very specific, based on their interest and their need. (Chemistry Educationist – Ac8)*

The companies, they would often have something very specific in mind that they want to do. (Mechanical Engineer – Ac16)

So the THRIP funding very much is product driven, it's driven by the commercial needs of the company. (Biomedical Engineer – Ac3)

Very often the nature of the work [for industry] is such that it's much less interesting, you know. (Zoologist – Ac23)

Funding from other sources [outside the NRF] is usually already targeted by them. (Sociologist – Ac19)

My stuff is all applied. Just about everything is applied. And in fact, it's very community-based. So it might be a little bit unusual, whereas typically industry funding goes towards stuff that's more market-related. Which means that my industry funders are allowing me to do very community-based work, which is a little bit unusual. (Computer Scientist – Ac9)

There were also some interesting responses that claimed that the research conducted from NRF funding, thus basic or fundamental research, is of higher quality than applied research.

Basic research is more rigorous and of higher quality than applied research

The distinction that I will make [between applied and basic research] is in terms of intellectual rigour, in terms of how you really need to think much more on the edge about your research, really think much deeper, much broader about what you're doing. I think that occurs more in the basic research because there's no signs or people that have gone previous. (Biochemist – Ac2)

The research that I do for NRF and Mellon, is very clearly driven by ideas. And that makes it intrinsically interesting to a wide audience. (Zoologist – Ac23)

This respondent elaborated by adding that applied research often is not new research but an improvement of work done before, or to produce a better product or outcome.

Applied research is not based on new ideas, and is of lesser quality

You know when you're doing applied research in some ways you are tweaking things that people have done before, and you're tweaking it to make it more optimal, to make it slightly better, you know, that kind of thing. (Biochemist – Ac2)

> *When I look at the quality of what is being done, I'm regularly dismayed by some of the applied science research. I feel it's being done to earn somebody a salary, it's not being done to generate the best answer. Time is constrained, you have a particular budget, and before you finish it you're looking for your next budget to keep yourself going, and all of this adds up to work that is very seldom published, work that is almost never peer-reviewed, work that very often is just simply shoddy. (Zoologist – Ac23)*

Other respondents also reported that they sometimes engage in work that is not of interest to them, but do so because it is a way to generate funding.

Source of funding influences the choice of research, i.e. academics choose a research area that will attract funding from industry

> *Industry funding is management driven. So people need a specific answer in terms of stock assessment for marine resources and all of that sort of thing, which is not my research interest, but it's a way to generate funding... I was driven by money and their questions. (Geneticist – Ac12)*

> *Quite early on in my career I decided to start working on mussels because it was gonna be easier to get funding because people prefer to give you money for research which had some sort of application. (Zoologist – Ac22)*

When asked about how he describes his research, a zoologist responded that research should not be categorised into basic or applied research, but that we should focus more on the calibre of research.

Context should determine how research is defined

> *First of all I don't personally believe that research should be categorised into whether you are doing applied or pure research, because it depends on the context of what you're working on. I believe much more that it's important to recognise the calibre of the research. (Zoologist – Ac23)*

There are also those who found it challenging to classify their research into one particular type of research, reporting that their research often involve both basic and applied research.

> *I think I focus more on basic research, but we work more on applied problems. So the basic research is done in order to support the more applied questions. So we feed into applied questions and I have in the past done some more applied research as well. But my preference and my focus is more basic research. (Entomologist – Ac10)*

We focus only on industry related problems. We don't do any fundamental research on its own. That does not mean however that in our research we don't address academic knowledge. (Metallurgical Engineer – Ac18)

I think we cover the full spectrum, I mean, often our basic research looks fairly theoretical but we have an idea in mind what it's going to mean one day when we implement it. So I think we do a fairly broad spectrum and it depends on the research project and the students, you know, how their interests lie, and how the projects work out. (Chemical Engineer – Ac5)

Industry funding and research autonomy

It was evident from the responses that industry partners are largely responsible for setting the scope of the work/research they want done. They determine priority areas and inform the academic partner. Some industry partners allow the academic to determine the course of work, i.e. how and what needs to be done to arrive at a solution, just as long as there is no deviation from the priority area.

It's primarily the industry partners [who] will tell us what the priorities are, but their priority lists are not very well defined. They rely to a large extent on us to basically tell them what it is about that applied problem that needs to be addressed. (Entomologist – Ac10)

Ja. I think the research is impacted by the partner, because they usually have...I remember with the deciduous fruit producers trust, every year we would have a meeting and then they would list their priorities for research within that year and for, say, a three year period.. So we had to make sure that we would address at least one or more of those priority area, otherwise I think they would not be interested, or it would require a lot of convincing from our side, to convince them to fund what we would like to do, but if they didn't see it as a priority we would be in trouble. (Human Geneticist – Ac15)

There were also respondents who indicated that they are in charge of determining the research agenda without the interference of their private sponsor.

It appears that I have quite a bit of autonomy. So I set the agenda. I mean I have been doing this for a number of years now, more than 10 years, and the agenda started out being more technical but then I saw how the technical agenda could be used for the benefit of communities and now the emphasis has changed to be more community focused than technical and the donor seem to be okay with that. (Computer Scientist – Ac9)

Although the sentiment was expressed that respondents believe they are in charge of their own research agenda, at the same time they need to design their projects such that it fits in with the broad research agenda of the potential sponsor.

> *Ja, of course we write the proposal. It means we sort of sketch out what we're going to be looking at the next year or the next two years or whatever. So within that, obviously I'm at liberty to decide where I'm going to go. What limits me is that I need to do this within the context of what I know the MRC will be able or will be interested in funding or what CANSA will be interested in funding. So I need to slant my project to encompass that, and I may be able to sneak in some little bits that I think is interesting but the majority of my grant needs to fit in within the parameters of their mandate. (Biochemist – Ac2)*

Other respondents avoid getting funding from sources that will dictate terms to them, and would rather approach a company with a proposal in place to request for funding.

> *I rarely get funding which comes with strings attached. Usually I'll get funding because I made an application to somebody...What we are doing there is saying "this is the project we're working on, would you like to fund it"? So to that extent I don't find that my research is shaped by the sources of funding because it's me going to the funders rather that the funders saying "we have money to work on something or other, would you like to do it"? It doesn't work like that for me. So I'm not bidding for funding on a fixed project, I'm actually going to funders and saying "this is my project, do you want to support it"? (Zoologist – Ac22)*

In some partnerships, the research agenda is determined jointly to the satisfaction of both the industry and academic partner.

> *It's a jointly determined scope. So I would have a say in that study and also the industrial partner would say "listen, I want you to look at this aspect or that aspect", and that's certainly the way I see it, both from the academic working with someone from industry or also how working with industry and collaborating with…you know, I have my ideas about what research I want done but I'm certainly sufficiently flexible to allow my collaborating colleague to determine what work should be done. (Biomedical Engineer – Ac3)*

> *It's actually combined effort. The industry partners say that "we have a problem to produce this, and this and this happens, and we want to solve that". Then we sit together with them and we say alright, let's formulate a research plan...it is really a collaborative effort between us and industry. In the end we want to satisfy their needs, but we also have an academic need to satisfy on our side. (Metallurgical Engineer – Ac18)*

It is clear from these interviews that respondents describe their research in different ways. Few terms were used to define research, including basic, applied, development, and targeted. One respondent said that his research was “management-driven”. There were also respondents who seemed to battle with classifying their research into just one type. When asked how she describes her research, this entomologist (Ac10) began her statement by saying: “*Ja...it's kind of difficult to answer*...”, and elaborated this by saying that “...*ok I think I focus more on basic research, but we work more on applied problems*”. There were also similar responses that show that respondents do not necessarily classify their research into one type. For example, a chemical engineer (Ac5) responded that “*I think we cover the full spectrum*”, while a zoologist (Ac22) said that “*a lot of the work we do can be used for applied purposes but it's not directly applied*”.

Nevertheless, these responses allow a few concluding points to be drawn about the source of funding and the nature of research:

- Most of the research conducted with industry funding is applied, described by respondents as research that addresses a pre-determined problem, and may also lead to commercialisation of a product. Industry funding does not allow for much deviation from the research focus set out at the start of the project.
- With public/NRF funding, respondents indicated that they are free to conduct any type of research, and often utilise this funding to pursue interest-driven basic/fundamental research. According to respondents, basic research is about advancing knowledge and does not have to lead to application or commercialisation.
- The line between basic versus applied research can be “fuzzy” in some cases.
- The calibre/quality of research is not the same for basic and applied research. According to some respondents, basic research is of higher calibre than applied research. Other respondents claim that applied research is not based on new ideas, but merely improves on what has been done previously.

The next section looks at how different sources of funding influence respondents' publication patterns.

7.4. RESEARCH OUTPUTS

The central question in this section is: do industry funded academics disseminate their findings in primary literature such as journals and books, or do they communicate their findings through technical reports, patents, and artefacts?

Dissemination of results from different sources

Respondents indicated that they communicate results from industry funding predominantly through technical or internal reports.

> *The industry partners do have a requirement...it's almost...it's a necessity to publish in popular language as well in certain publications like the SA Fruit Journal and Winelands magazines. In order to finish off a project we have to supply them with a popular publication of that research. That is a requirement in order to basically finish off our project. (Entomologist – Ac10)*
>
> *Usually the industry ones require an in-house report, so they require a report on what we do. (Palaeontologist – Ac21)*
>
> *When it is something that one can patent and that will give the industry company a competitive advantage, I think it will impact slightly on how you would disseminate the results, but first of all then you would have to register a patent and, you know, keep the results to yourself for a while before you can publish. (Human Geneticist – Ac15)*

One respondent indicated that sometimes she first has to check with the industry partner if it is okay for her to publish the results.

> *I think with the industry partner to...well this is you know, I realise, is that you first have to check with them, is it ok now to publish? And often they would agree because it's also good for them. (Human Geneticist – Ac15)*

On the other hand results from NRF funding are published in standard media such as journals and books, and are thus available in the public domain.

> *The NRF related projects we publish in peer-reviewed journals, and try and go for ISI listed journals. (Palaeontologist – Ac21)*
>
> *All the money we get from NRF and THRIP we use...the IP we generate from that we basically patent or publish it. (Chemical Engineer – Ac5)*
>
> *When it comes to the NRF or Mellon funding, I'm absolutely meticulous and insistent that the research is published in peer reviewed literature. (Zoologist – Ac23)*
>
> *With the NRF and the MRC, you can publish as soon as you have the results, unless you have stumbled upon something that is...you realise, you know, can be of commercial value, then of course you will first go the patent route. (Human Geneticist – Ac15)*

Having established from respondents that industry-funded projects typically result in an in-house report, and in some cases, the filing of a patent, I asked respondents whether they were restricted (by their sponsor) from publishing any part of their work in the public domain, e.g. in journals and books. Most respondents indicated that they do not encounter major restrictions from industry partners with regard to publishing their results in the public domain. In fact, some indicated that their partners encourage them to publish, with other industry partners even co-authoring the papers. However, there is a requirement that academics should submit their findings to the industry partner before they can publish them in journals or books.

Restrictions on the publication of industry-funded research in the public domain

> *Not at all, not at all. If anything they also encourage and they want you to publish and then to send them the publications, of course to acknowledge them, in very much the same way that the NRF does. (Biochemist – Ac2)*

> *There are no restrictions from my industry funding because I won't take the project unless I can have the freedom to actually publish it, because there's also student training. I use students to actually do it, and I feel strongly that they need to publish a paper otherwise what do they get out of it? It's not about the money. (Geneticist – Ac12)*

> *I have always been completely free. None of my funders have ever put restrictions on the work that I do. I guess that applies to people who might be involved in patents and that type of research. But for me the sooner I get my findings out into the international literature the happier they are. (Zoologist – Ac22)*

> *We have never...and I'm talking about the research that I'm involved in, never had any problems with the industry trying to limit whatever we publish. Obviously if we do publish we send them a copy of the paper beforehand, sometimes they want us to remove the company name or whatever, but these are small things.(Metallurgical Engineer – Ac18)*

Of those who indicated that they do encounter some restrictions, this is mainly in terms of the timeframe, where they are required to delay the publication for some time while the industry partner is in the process of filing a patent.

> *No, usually with the industry stuff...I mean they might have an embargo for a couple of years, they will eventually allow you to publish it, and that work that I have done with industry we've published it all, there has never been problems. It might have an embargo over a couple of years but if they funded it they are entitled to do that. And that's never been a problem, not for us. I know it has been a problem in some aspects of geology. (Palaeontologist – Ac21)*

Typically what we need to do in any case, is first of all to clarify with whoever provides the funding so that we can just make sure that there's not any proprietary information contained in that, in whatever we want to publish or anything that they might consider sensitive and so on. But otherwise there's no restrictions to do that because it's also in their interest that we do publish or disseminate whatever we learn. (Mechanical Engineer – Ac17)

One respondent said that there are restrictions with publishing the findings from industry-funded research, particularly when involved in research of an applied nature.

Yes, yes, with applied research, with the outside bodies. I mean we are even changing our policy in terms of the student publication of the thesis as well. We are making a small amendment to the official policy that we would at least allow two years before the thesis can be published...because when the student submits a thesis it gets published by the library, it goes straight onto the library shelves. (Chemist – Ac7)

Another respondent indicated that although he does encounter some restrictions, the impact is negligible because he (and the rest of his team) has "managed to get away with it".

You know, you are quite right, but the reality is that we managed to get away with it. (Sport Scientist – Ac20)

One can conclude from this section that different sources of funding lead to different dissemination strategies – results from industry funding are published in internal reports and technical reports; while results from NRF/public funding are published in the public domain, such as journals and books. While respondents who received industry funding reported that they are not restricted from publishing their results in the public domain, i.e. in journals and books, in some cases they have to delay their publications to allow for the filing of a patent, for example. NRF funding allows for the findings to be published in journals and books as the results become available.

One of the advantages of industry funding that respondents pointed to was better support for student bursaries compared to NRF bursaries, which contributes significantly to capacity building in the system.

7.5. CAPACITY BUILDING/STUDENT TRAINING

Student training or supervision, particularly at masters and doctoral levels, is often used together with the publication profile to measure a researcher's productivity. Furthermore, it is known that researchers get to be co-authors on work produced by their postgraduate students. Therefore it can be assumed that the more students an individual supervises, the more research outputs they can produce. Having access to funding, particularly from various sources such as industry, is crucial to attracting postgraduate students, as this respondent confirmed:

> *Oh no question, Ja. It's all cumulative, cause the more money you have the more students you have, the more students you have the more they can apply for other grants and so on. So yes it is cumulative. (Sport Scientist – Ac20)*

In South Africa, student bursaries for postgraduate studies are provided mainly by the NRF, but the bursaries available are not sufficient to meet students' living costs. There are two types of bursaries available from the NRF: (1) the grantholder-linked bursary, which is linked to the researcher's project (thus, a student gets this bursary through the supervisor, and does not apply directly from the NRF); and (2) the free-standing bursary, which is awarded to a student on the basis of merit and is not linked to the researcher. The free-standing bursary is competitive, and is of higher monetary value than the grantholder linked one. During the interviews, participants were asked if industry funding allows them to train more or less masters and doctoral students, and respondents confirmed that industry funding allows them to train more such students.

More masters and doctoral students are trained through industry funding

> *Yes, very definitely, because of the strong funding base. They don't supply bursaries as such but they give us a bursary amount that we can use as a bursary...So we can basically say to the industry, we want to spend x number of our money on student training, and then we would use the THRIP money to buy like equipment and computers so that the students can be effective as students. So I would say it's a huge part of being able to attract students to Entomology. They like the industry connection because they see it as a way to obtain employment in future. (Entomologist – Ac10)*

> *Oh more. Ja. I mean I couldn't do it without industry funding. And especially like I said before the THRIP funding...because the THRIP funding allows for honours, and honours is my pipe-line basically, for masters and PhD. (Computer Scientist – Ac9)*

> *Way more. So there's no doubt that it was beneficial to capacity building, and especially, I mean I have to also say that I've just trained black students from Kenya and, specifically on Marine Management South West project, it's industry money which they've paid for everything, and it's capacity building for Africa, you know, so it's not only for South Africa. (Geneticist – Ac12)*

Furthermore, partnership with industry provides the students with an opportunity to interact with the world of employment, giving them exposure to what happens in the workplace. In addition, these partnerships provide the students with employment opportunities after completing their studies.

> *Ja, I think definitely. The industry money is very important. I think it's also important for our engineering postgraduate students to engage with industry, to see how they operate, how a company works and what is expected from them. (Mechanical Engineer – Ac16)*

Some respondents indicated that they do not involve students on their industry or commissioned projects due to tight (often very short) deadlines within which they need to deliver results for industry.

> *Well it will be less because they don't give you money for bursaries, they just give you money to do the research. And they are more or less...I guess, if they gave me a very big project I could sub-contract parts of it but it wouldn't involve...the training of students has its own rhythm and it doesn't necessarily fit in with the kind of deadlines that an organisation that's paying for work would want. (Chemistry Educationist – Ac8)*

> *I mean in general it depends on the project. Sometimes people come and say we want you to do something in the next four five months, and I mean I can say yes or no but if you say yes then you have to get people to help, and these people who help are sort of taken away from things. So it helps capacity in a general sense but sometimes it is against the interest of particular students in terms of her or his thesis. (Sociologist – Ac19)*

Other respondents decide not to involve students in their projects (particularly privately funded ones) because they are afraid that the student will make a mistake which could cost them their sponsorship. An Applied Mathematician had the unfortunate event where a masters student made a mistake on a project.

> *Ok, another issue. My primary issue…I'm gonna give you the background, it's a difficult question, my primary task in working in areas where answers are needed, be it at the government, or be it private industry and so forth, they want an efficient, an effective, and reliable answer. And there is a problem with students because students, before they have had sufficient experience and training, are not capable of doing that. I learned the hard way with being embarrassed by an MSc student, you know, I got them some extra money by putting them unto a project, and they just weren't capable of doing it and I felt embarrassed for the company that I haven't produced them a product. They are not interested…and the company is unforgiving, you know, you've to produce the goods. (Applied Mathematician – Ac1)*

Furthermore, this particular respondent believes that when it comes to student training, we should focus more on quality rather than quantity.

> *With students, I'd rather take few and take quality so I produce something that will make an impact. If you look at it, I put it this way, I have been, in the last 25 years, three of my MScs, and this is throughout engineering and science at this university, three of my MScs in the last 25 years have got the S2A3 prize for the best MSc thesis… that's more than 10% that have rated the best MSc thesis in the faculty, you know, it is a question of quality. I'm very against, it's another complaint I have with NRF, and I think the whole question of "what exactly are we funding all these extra researchers to do"? We fund them through an MSc, a PhD, to do what? Where is the evaluation that I'd like to see of people who've been funded over the 30 years, who've been funded to do higher degrees by the NRF and its precursors, do they think that was useful? Is it a good spender of money? Shouldn't we be going for more quality and less quantity? Because for a lot of these people, they are not gonna get permanent jobs in research when they've got their PhDs. (Applied Mathematician – Ac1)*

One respondent, however, believed that students should be allowed to make mistakes on a project as it is part of a learning process.

> *We expect every student to be the best in the world, that's it, and that's what we teach them. We said you can be the best in the world and we expect it from you, and then we allow them just to fly, and as soon as you give students the self confidence that they can do it, they go. Many people I find in my position they are fearful that the guy is gonna make a mistake so they've always got to be looking over his shoulder and so on, and I don't, I say accept responsibility, if you make an error as you will, just say I'm sorry I made a mistake, that's fine let's move on...but it's definitely that we do not have a pyramidal structure and the students are the most important people here, we are providing them with a service, I'm not the most important person, the staff are not the most important people, we look after the students so they can feel special and give them every opportunity to be world-class and then they produce the work and we don't have to do anything. (Sport Scientist – Ac20)*

It also emerged during the interviews that certain disciplines face difficulties in attracting postgraduate students. During an interview with a palaeontologist, I asked him why he had supervised such a low number of postgraduate students (12 masters and 12 doctoral students), for someone who has been in academia since the early 1980s, and is also a director of a research institute. I questioned whether the list of students supervised presented in his CV was outdated.

> *No no no you are 100% right. That probably, internationally, by international standards is very big for palaeontology because we don't get many students. And you must remember we don't have an undergraduate degree in palaeontology, because there are so few positions for*

> *palaeontologists in the world. If you look at the number of positions for palaeontologists in South Africa, it is probably about 18 positions at the moment? So it's not...if we produce too many students they are not gonna get jobs in palaeontology, and students aren't stupid, they will come in and say "well you know, where's this gonna lead me"? So in terms of the number of students that I've produced it is quite high for palaeontology, and that's right here in South Africa and around the world. In fact it is quite exceptional. (Palaeontologist – Ac21)*

While industry partners may provide funding that allows for higher bursary amounts compared to NRF bursaries, it turns out that some academics do not pass this benefit on to the students. Instead, they prefer that all students who are at the same level, say all masters students, receive the same bursary amount.

> *We try to give the students at least the same. We don't pay a student more than the NRF pays from industry money, because we don't want to create a situation in the group where some student gets more than the others. So if we get money from the company we budget for exactly the same as the NRF grants and we rather take two students than giving one more. (Chemist – Ac6)*

> *That's a very tricky one. I try and keep all my students at the same level because otherwise...I don't want two students working in the same lab and one is getting more than the other. What it does mean is I can top students up a little bit, but again I'm a bit cautious about that because I don't want to get into a situation which, I don't know, it's like football teams, you know, you can buy the best students 'cause you've got more money than anybody else. I don't...I have an ethical problem with that. (Zoologist – Ac22)*

7.6. ORGANISATION OF RESEARCH ACTIVITIES

While the issue of how academics organise their research activities was not a focus of this study from the beginning, it emerged during the interviews that some of the academics being interviewed hold Research Chairs, and others are Directors of a research centre or institute. This prompted me to ask respondents about the advantages of having a Research Chair or a research centre/institute. Generally, the biggest advantage of organising research around a centre, an institute, or having a research chair, is that academics' funding is secured for a longer period (about five years) and they do not have to apply to the NRF on an annual basis. This is important as it gives academics a sense of stability and sustainability. Secondly, academics have the freedom to conduct their research without much interference from management, for example. Four sub-themes emerged from responses on the organisation of research activities.

Sustainability or continuity of funding

> *There are huge advantages to having the Research Chair. One of them is that your source of funding is assured for five years, so you don't have to spend a lot of time looking for funding...so you are secure. (Zoologist – Ac22)*

> *I think the most important thing to be able to do research is you need to have a continuity of funding...And so the SARCHi chair is important from that point of view that you do know that there is a continuous source of funding, and that helps a lot. (Biochemist – Ac2)*

> *Ok, we see there's the NRF Chairs and there's the Centres of Excellence, which is very good initiative I think, it is an excellent initiative. You know because that gives you a bit of stability. (Health Scientist – Ac14)*

> *More resources were available [through the Research Chair]. And also you could plan better because you are getting the funding for five years, and you could then spread your work on a five year project plan and not just one or two years. (Chemist – Ac7)*

Better funding for Research Chairs and Centre of Excellence

Not only do respondents receive better funding through the Chair or for the Centre, but by virtue of being a Research Chair of a Director or a Centre/Institute, they can attract funding from other outside sources more easily than someone who is in a lower position.

> *You know if you're a director you're the boss. It's like being in a similar situation as the Vice-chancellor of the university. The chancellor of the university walks in and says our vision for the university is this and this. Funding bodies will generally supply him with funding more easily than somebody lower down. (Palaeontologist – Ac21)*

Respondents also indicated that working within a centre or as a Research Chair allows them to work within a broader research focus.

> *The other major advantage [to having a Research Chair] is that you set a broad area that you're going to work in. (Zoologist – Ac22)*

Another significant advantage is the research freedom that respondents have when their research is organised around a team such as that found in research centres or institutes.

> *One of the points in our institute is that it did give us freedom from the university so that we could do things that might have been difficult if people had been looking all the time, going through massive committees and so on. (Sport Scientist – Ac20)*

> *There's no micro-management [when you have a Research Chair]. (Zoologist – Ac22)*

However, with the research freedom comes a lot of responsibilities, particularly on the part of the Research Chair or the Director who has to ensure that each member of the team has sufficient funding, among other things.

> *It [the Research Chair] does have responsibilities also because then you have got to see that the people under you have got sufficient funding to operate. (Palaeontologist – Ac21)*

7.7. ACADEMICS' OPINIONS ABOUT THE NRF

As indicated earlier, NRF funding is being considered here as a proxy for public funding. While there are other public funding agencies in the country, such as the Medical Research Council (MRC) and the Agricultural Research Council (ARC), these agencies are focused on supporting particular fields, i.e. the health sciences and agricultural sciences, respectively. The NRF, on the other hand, provides support across all fields, and as a result supports more academics than any other agency in South Africa. Anecdotal evidence suggests that academics view the NRF as the primary source of public support in the country, as one respondent indicated: "*there's only one game in town in this country for researchers, and that's the NRF* (Applied Mathematician – Ac1)*"*. Although there was no direct question asked to respondents about their motives for choosing to apply for industry funding, they were asked for their opinions about the NRF in the hope that their responses would shed some light on their motives. Interestingly, most academics began to give their opinion of the NRF early in the interview, before they were even asked to do so. The responses to this question are grouped into the several sub-themes that emerged during the interviews.

NRF plays an important role in the system

Respondents acknowledged the crucial role of the NRF for the development of the country's science system. Some even attributed their own personal development to the support they received from the agency.

> *Ja, I think the NRF is playing a very important role in the funding of public research, a vital role. (Biomedical Engineer – Ac3)*
>
> *I'm grateful that it's there, I think it's great. (Computer Scientist – Ac9)*
>
> *I mean it's incredibly beneficial. It has really upgraded our section hugely. We wouldn't be an effective team without it. (Entomologist – Ac10)*

Furthermore, some respondents believe that the NRF's systems have improved in recent years.

> *I must say that the NRF...I've been in the system for a very long time...being a student, coming right through...it's definitely improved, it's a lot more streamlined, a lot easier to access funding. (Heath Scientist – Ac14)*

Despite these compliments, there were several complaints and dissatisfaction highlighted during the interviews. The most common complaint about the NRF was the limited amount of funding awarded to researchers. In some cases, individuals receive less money than they applied for, to an extent that they need to reduce the scope of work. Furthermore, respondents indicated that they are discouraged from applying for future funding due to the low funding they will receive in return.

Funding distributed through the NRF is limited

> *Unfortunately the level of funding which they have at their disposal to hand out to university researchers doesn't in any way near match the requirement. (Biomedical Engineer – Ac3)*

> *Well, I don't know what's going on with the NRF, but the feeling that I got was that the money available from them is very very limited, it's not even worth my time to try to apply because there's just too many people applying and they don't have money to support. (Mechanical Engineer – Ac16)*

> *I think we're all feeling that it seems to be getting less and less. I'm not sure why it is getting less and less? I have heard that they haven't had increases in their allocation from the government, you know? (Biochemist – Ac2)*

> *Well I mean, I think they don't get enough money so we don't get enough money. So we've always got to cut down our project, and the student funding is insufficient. (Chemistry Educationist – Ac8)*

> *Ja, it's far too little. That's obvious, I think. It must get up to sort of 2% of the GDP or something. (Sport Scientist – Ac20)*

Interviewees also commented on the way the NRF is organised (or disorganised). The reasons for dissatisfaction ranged from the amount of paperwork that academics have to complete when applying for funding, to the way they rate proposals, and also the delayed communication with applicants on the outcome of their grant proposals.

Disorganised and bureaucratic administrative process

Well regarding the NRF generally it's very disorganised...It would just be nice, you know, to have a flow of the administration a little bit easier and a little reliable...It's very very difficult to plan your research with the NRF. (Entomologist – Ac10)

I don't know how they rate proposals and exactly how they evaluate them and their budget and everything. The way it's going at the moment, it's not working, that's for sure. It's not working for me, at the moment. (Mechanical Engineer – Ac16)

I think they've made some stupid decisions in their admin, you know some of the things they ask for are ridiculous, you know, they're too bureaucratic, but I think the whole idea is excellent but there's a refusal to understand the fundamental difference between fundamental and applied research.(Applied Mathematician – Ac1)

My impression of it is that it's a bit too much paper work, and too many people are involved. (Computer Scientist – Ac9)

It took them quite a while a few years back to make the final decisions so that the final allocations that we got were quite late into the year. (Mechanical Engineer – Ac17)

When I started research..., people where relatively sure, you know, if you were doing consistent research that you would get funding to do this. That seems to be disappearing. (Biochemist – Ac2)

In recent years, the NRF has introduced various funding mechanisms which are viewed by academics to be great initiatives. These include the prestigious South African Research Chairs initiative – SARCHi (simply referred to as Research Chairs) and the Centres of Excellence (CoEs). The SARCHi and CoEs programmes award large grant amounts annually: for example, a Research Chair receives about R2 million per annum for research activities and related running costs. However, there are concerns that too few individuals receive grants through these programmes.

Large grants are awarded to few researchers in the system

I think that focusing money into something like Research Chairs is a very effective way of using money, but the downside is that you concentrate all the money in very few people. (Zoologist – Ac22)

> *I think a lot of money is going into big projects and big collaborative work, whereas younger guys who are just starting off are getting cut back a bit....whereas they could get five young Thuthuka projects and get the same number of outputs than one chair. So they have the shift towards Chairs and getting a lot of outputs and so forth...and I think a lot of people feel marginalised by that as well. (Chemist – Ac7)*

There were also concerns that the NRF provides better support for emerging researchers, i.e. those in their early stages of development, through programmes such as Thuthuka, but neglects researchers who are at an established stage.

Better support for emerging scholars than established scholars

> *If you are an established researcher who has already proven that you can produce, they don't support you, which kind of makes it more and more difficult, you know, for the more established people. (Mechanical Engineer – Ac16)*

> *I think the one problem is when you are starting off they seem to encourage you and support you and everything, but then they sort of say...ok I suppose they sort of feel that you can now get funding from outside, you know, but I think we're doing South African research and I think we should be getting from our government, we should be getting supported. (Health Scientist – Ac14)*

> *I think the balance of funding (outside the Research Chairs and the Centres of Excellence), particularly for the established researchers, is actually quite too low at the moment and needs to be expanded. I think there's quite a lot of money for young researchers. (Entomologist – Ac11)*

7.8. DISCUSSION AND CONCLUDING REMARKS

This chapter provided empirical evidence on: (1) the increase in industry or third stream funding for university research in South Africa; (2) the impact of industry funding on scientific productivity as well as on capacity building; and (3) the link between the source of funding and modes of knowledge production among South African academics. While studies of this nature have been done in other parts of the world, this to my knowledge, is the first study that addresses these issues directly for the South African system.

7.8.1. Increase in industry funding for university research in South Africa

Similar to developments in other parts of the world, the South African science system is also witnessing an increase in industry funding for university research. Twenty of the 23 academics interviewed in this study reported that they receive funding from industry or other private sources, including NGOs (non-governmental organisations). Some of these academics indicated that industry or private donor funding has become their only sources of funding, thus, they no longer apply for funding from the NRF. This finding is in line with results of studies done in other parts of the world as presented in Chapter 4 of this thesis. Examples include Germany (Meyer-Krahmer & Schmoch, 1998; Hottenrott & Thorwarth, 2011), Canada (Crespo & Dridi, 2007), and Spain (Manjarrés-Henríquez *et al*., 2009). These studies show increases in industry funding for university research in their respective countries.

It is clear from the interviews that even though academics are looking for funding outside the NRF, they still consider the NRF as a critical player in the science system. One respondent even referred to it (the NRF) as "*the only game in town*". Responses about the state of NRF funding provided some insight into possible motives for academics choosing to apply for industry/private funding. These include: limited funding received from the NRF; bureaucratic administrative processes; and poor support for established researchers. The limited funding awarded by the NRF can be attributed to the fact that the core grant allocation to the NRF through the Department of Science and Technology (DST) has not grown over the years in line with the growth in demand for research funding. One therefore needed to establish the impact of this shift on the science system, particularly on scientific productivity and student training.

7.8.2. Impact of industry funding on scientific productivity and capacity building

In terms of the impact of industry or private funding on research productivity, the available literature is divided. There are studies that show the positive impact of industry funding on scientific productivity, i.e. that industry-funded researchers produce more research outputs such as journal articles and books than those without industry funding. Examples of these studies include Landry *et al*. (1996), Harman (1999), Hicks & Hamilton (1999), Godin & Gingras (2000), Van Looy *et al* .(2004); and Gulbrandsen and Smeby (2005). However, there are also studies that argue that industry funding impacts negatively on scientific productivity, particularly with regard to outputs that are published in the public domain, i.e. journal articles and books, e.g. Blumenthal *et al*. (1996) and Poyago-Theotoky *et al*. (2002).

This part of the study tested the proposition that respondents who received industry funding produced more research outputs than those who only received government funding. In addition, it was hypothesised that industry-funded individuals supervise more masters and doctoral students than their counterparts. As indicated at the start of the chapter, participants were divided into three groups: those that only received government funding (through the Focus Areas), those that only received industry funding (through THRIP), and those that received both government and industry funding. We found that the last group, i.e. those who received funding from both government and industry, recorded more average annual outputs than the other two groups, and that they have graduated more masters and doctoral students per year than those who only received funding from only one source.

This finding suggests that it is the large amount of funding accumulated from more than one source that contributes to high scientific productivity and high student output. However, it should be mentioned once again that this analysis is based on small numbers even though the sample is representative of the top or most productive academics in the country.

However, some interesting results were found when participants who only received funding from either the Focus Areas or THRIP were compared: participants who received the Focus Areas grant published more than those who received the THRIP grant despite the fact that it is the latter group that received much higher grant amounts on average than the former (see figure 6.2 – Chapter 6). This finding is consistent with the study by Hottenrott and Thorwarth (2011), which found that increased industry funding among German academics resulted in a decrease in the quantity and quality of publications.

We also looked at scientific productivity by age, and found that the highest average annual journal articles were produced by participants who are nearing retirement age, i.e. those in the age group “56 to 60”. The highest average annual students graduated, at both masters and doctoral students, were also produced by slightly older participants who were in the age group “51 to 55”. This finding can be attributed purely to the profile of individuals in this age group, i.e. that they are established researchers. In addition, one suspects that respondents above the age of 50 increase their publication profile by co-publishing with their post-graduate students. The correlation between the number of students supervised and number of publications requires further attention.

In addition to academics, another group of beneficiaries of industry funding are postgraduate students, through bursaries and scholarships. As such, this study also determined whether industry funding impacts positively or negatively on capacity building, i.e. the training of students at masters and doctoral levels, in particular. The production of suitably qualified postgraduate students is important given the challenge that has already been mentioned above – that of an ageing academic population. Postgraduate bursaries from the NRF are largely inadequate to meet students' cost of living, and often have to be supplemented by funding from other sources. Funding from industry is much higher and covers the student's study fees and related costs, which enables the student to focus on his/her studies and subsequently making possible a higher success rate. More than half of respondents (13) confirmed that they have trained more masters and doctoral students because of the higher funding base that they get from industry funding. In fact, some also pointed out that they couldn't train the number of students they do without industry funding.

One of the main aims of this study was to establish if there is a link between the source of funding and the type of research activities.

7.8.3. Link between the source of funding and modes of knowledge production

Previous studies conducted elsewhere in the world, e.g. by Godin and Gingras (2000), and Gulbrandsen and Smeby (2005), found that industry funding is often awarded for projects aimed at addressing a pre-determined problem that will, in the end, benefit the company providing the funding. This is in line with what was found in this study – respondents described the research they conduct with industry funding as applied, aimed at addressing a particular problem identified by the industry partner. The research focus is set by the industry partner, with limited opportunities for the academic to deviate from the initial focus. However, it also emerged that there are companies that do invest in university research without expecting any return from it, particularly if the funding is aimed at students. On the other hand, respondents utilise NRF funding for basic/fundamental research. Thus, NRF funding enables academics to pursue projects that are simply of interest to them and would add to the pool of knowledge without any potential for application or commercialisation. Interestingly, there were respondents that indicated that their industry-funded research, which is mainly applied, also involves an element of basic or fundamental research. Respondents added that the basic/fundamental part of the project is needed in order to understand the problem they have to address. This finding supports the argument in previous studies that basic research or fundamental research provides a foundation for applied research, and that research is continuous (Albert, 2003).

The results above confirm that the source of funding influences the choice of research activity. That is, there is a link between the source of funding and the mode of knowledge production among South African academics, and this is evident across various fields of study. This finding bears more consequences for some fields of study than others. For example, many of the engineering sciences engage in research that would be of interest to industry, and therefore partnerships with industry will not change the course of research for these academics. However, there are fields were academics have to "slant" their research focus in the direction that will attract industry funding, and in some cases the academic would not have followed that direction if it were not for purposes of funding. For example, a geneticist (Ac12) responded that he has taken on projects in the past that were "not my research interest, but it's a way to generate funding". This finding (and the rest of the findings in this chapter) points to several potential implications, and perhaps long-term consequences of industry funding for university research. These implications include:

- The "next generation of academics" could increasingly move away from engaging in basic/fundamental research i.e. research that adds to the pool of knowledge, and focus on applied research that leads to commercialisation with high monetary returns. Therefore research could increasingly be treated as a commodity. A previous study by Welsh and colleagues (2008) found that increased interaction with industry "*can restrict communication among scientists*.
- Increased interaction with industry could result in conflict of interest for the academic, particularly in cases where the academic receives the bulk of funding from one particular company as they might be beholden to the sponsor. It was evident during the interviews that conflict of interest is already a problem in some industries and needs to be explored further.

CHAPTER 8: GENERAL CONCLUSION

8.1. INTRODUCTION

This thesis has shown that countries around the world, including South Africa, have been witnessing an increase in third stream funding for university research over the past 3 – 4 decades. This increase is in part, due to decreasing support available from government sources. Studies have also been conducted on both the positive and the negative impacts of this increase in third stream funding on science systems globally, particularly the impact on scientific productivity. This study makes several important contributions to knowledge production. The first major contribution is that it provides a reconstruction of the history of research funding in South Africa, which has not been done before. The second major theme that emerged out of this study concerns the relationship between funding sources and modes of knowledge production and dissemination.

8.2. HISTORY OF RESEARCH FUNDING IN SOUTH AFRICA

Research funding in South Africa dates as far back as 1911 through the Royal Society of South Africa, and this can be considered as the first form of agency funding in this country. In 1918, the function of providing research funding to universities and museums was transferred to the Research Grant Board (RGB). Initially, the RGB reported to two ministries – the Ministry of Education, and the Ministry of Mines and Industries. The link to the Ministry of Education is perhaps not unexpected due to the main role of the RGB, thus providing funding to universities. However, it is the connection with the Ministry of Mines and Industries that is particularly interesting, and the fact that, ultimately, the RGB reported only to this Ministry. A closer look at the list of projects funded by the RGB between 1919 and 1935 leads to some significant conclusions. Some of the projects supported during this period (1919 – 1935) can be classified as applied research. Examples include:

- Relative values of locomotive smoke box-char and various wood-charcoals as fuel for suction gas engines (WSH Cleghorne, 1919).
- Effect of dust, fumes, etc. underground on the lungs (B Pirow, 1921).
- The use of alcoholic fuels and mixtures in motor vehicle engines (D McMillan, 1925).

Furthermore, in 1925 a grant was awarded to JB Robertson for the development of provisional patent No. 22 of 1926, filed 8.1.26, dealing with refining (possibly also extraction) of platinum and platinum metals. Also in 1926, funding was awarded towards the establishment of an artistic ceramic industry in the country.

This is an important observation as it points to the fact that applied research has been taking place in South Africa for decades, therefore disputing the common belief that research in the earlier years was all blue-sky.

Since 1918, the funding landscape in South Africa changed significantly with the introduction of new agencies, often taking over the funding function from a previous agency. For example, when the Council for Scientific and Industrial Research (CSIR) was formed in 1945, it took over part of the funding function of the National Research Council and Board, which had been formed in 1938. This shift also led to an important development – the establishment of the National Council for Social Research (NCSR) in 1946, which would provide funding for social science research henceforth (the CSIR provided funding to researchers in the natural sciences only). The NCSR is a predecessor of the Human Sciences Research Council (HSRC) as we know it today. Nineteen forty-five marks another critical point in the history of research funding in the country – the start of a differentiated funding system, along broad scientific fields.

The CSIR had a two-fold mandate: conducting research in its own laboratories, and providing funding for research conducted at university laboratories. Two significant developments occurred under the CSIR. The first development was the introduction of Research Units in universities, which started in the 1950s. Thus the organisation of research around a team, led by one individual, was recognised as critical for the development of a science system over half a century ago. By the 1960s, the following Research Units had been introduced: Chromatography (University of Pretoria); Cosmic Rays (Potchefstroom University); Geochemistry (University of Cape Town); Marine (Oceanographic Research Institute) Natural Products (University of Cape Town); Oceanographic (University of Cape Town); Palynology (University of Orange Free State); Solid State Physics (University of Witwatersrand); and Desert Ecological (Namib Desert Research Station). There are several advantages of conducting research within a team, such as having access to shared expensive equipment; being able to bring in funding from various sources, co-supervision of students; and co-authoring of publications.

The second key development under the CSIR, during the late 1970s, was the identification of research areas on which a significant portion of the funding would be focused. The aim of such a decision was to provide funding for research that would address problems of national importance – problems that needed a multi-disciplinary approach. The projects needed to be in the following broad scientific areas: Marine Sciences; Antarctic Research; Geological

Sciences; Space and Atmospheric Sciences; Environmental Sciences; Aquaculture; Energy; Microelectronics; Materials; Waste Management; and Renewable Feedstocks.

The funding mandate of the CSIR grew over the years along with the growing demand for research funding. In 1984, the role of providing funding to university researchers and bursaries to students, was subsequently transferred to a separate, dedicated body called the Foundation for Research Development (FRD). The establishment of the FRD as an autonomous body in 1990 through and Act (no. 75 of 1990) marks another significant milestone in the history of research funding in South Africa, as it soon became the largest research funding agency of its time. It was also under the FRD that the rating system was developed. As the review of the rating system earlier in this thesis shows, the scientific community remains divided on the purpose of the rating system (which is unique to South Africa) and whether it adds any value to the science system. When the rating system was introduced in 1985, it was linked to the funding of individual researchers. This changed in 1996 when researchers no longer needed to be rated in order to apply for funding.

The FRD only supported the natural sciences and engineering, while researchers in the social sciences were supported by a separate structure, the Centre for Science Development (CSD) located within the HSRC. The CSD was also established in the 1990s, around the same time that the FRD obtained its autonomous status.

A second critical point in the history of the FRD was the launch of the Technology and Human Resources for Industry Programme (THRIP) in 1992. Based on a triple helix model of government-industry-academia partnership, and reporting to the Department of Trade and Industry, THRIP was established to provide funding for applied type research particularly in the engineering sciences. It was indicated earlier that some of the research funded under the RGB between 1919 and 1935 can be categorised as industry-related projects. However, it took nearly 77 years for a dedicated programme, THRIP, to be established with the sole purpose of providing industry funding for applied research. THRIP continues to support researchers to date, under the National Research Foundation (established through the merger of FRD and CSD in 1999).

The introduction of THRIP provided a huge boost for industry-related research in the country. Over the years, both government and industry have invested significant funds into the THRIP programme, as shown in Figure 8.1. In addition, there has been an increase in third stream funding for university research in general, outside the THRIP partnerships.

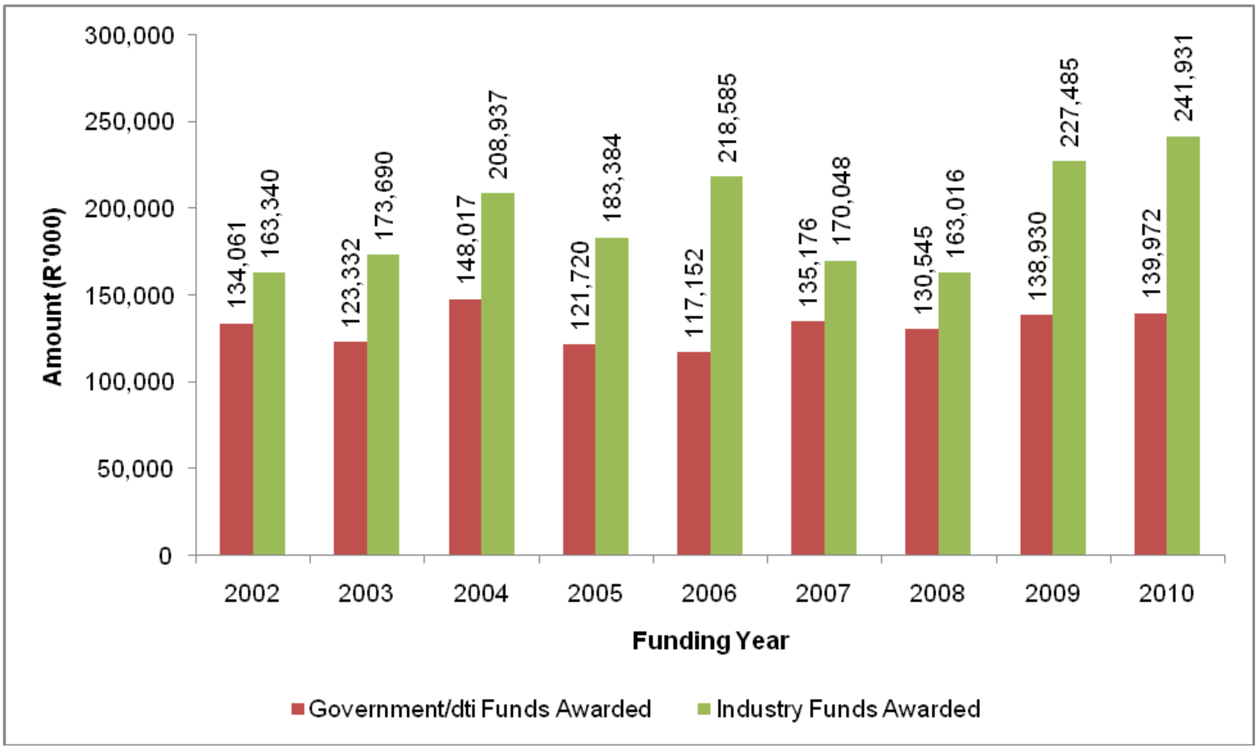


Figure 8.1. Government and industry spending on the THRIP programme between 2002 and 2010 (*Source*: THRIP 2011: 15).

8.2.1. The increase in industry funding for university research

Studies conducted in other parts of the world, including: Connolly (1997), Meyer-Krahmer and Schmoch (1998) and Crespo and Dridi (2007), report that there has been a significant increase in third stream funding for university research. The analysis here of the Curricula Vitae (CVs) of 176 prominent academics revealed that 83 of those who listed their sources had received funding from sources other than the NRF, either from industry, NGOs, or foreign countries. Only one participant (who is in the field of sociology) listed the NRF as her main source of funding, with some additional funding from the host university. Similarly, responses from the telephone interviews showed that 20 of the 23 respondents, selected from across various disciplines, have received funding from industry or other private sources outside of the NRF. These findings are consistent with previous studies that there is an increase in third stream funding for research in South African universities. This trend is evident across universities and various fields of study, including agricultural and biological sciences, engineering sciences, health sciences, and the social sciences. Those in the social sciences, for example, receive private funding from NGOs and agencies in other countries.

The provision of industry funding for university research happens within the context of a partnership, which benefits both parties. While academics receive the much needed funding, industry taps into the knowledge and expertise that the academic has.

There could be several potential reasons why academics are increasingly applying for funding from industry. This study, however, did not directly address these reasons or the motives behind academics entering into partnerships with industry. During the interviews, respondents indicated that the inadequate funding provided by the NRF poses a serious challenge, and that industry funding is often at a much higher level and is sufficient to meet their research needs. It also seems that academics find that there is insufficient stability with NRF funding, as this response shows:

> *I think that's a major thing that we researchers find is the stability, we can't plan 10 years ahead, you know what I'm saying? I can't say I now, ok I now want to start placing somebody who can continue as a professor in my place, but I can't...I can't find a post that I can fund him or her to carry on from me, because to keep somebody in a place you've got to be able to offer them five to ten years funding. From year to year it's a bit unstable, and people aren't prepared to do that, you know. (Health Scientist – Ac14)*

A recent study by Ankrah *et al*. (2013), which focused on the motives for academics to enter into relationships with industry, found that stability was the number one motive why academics engage in partnerships with industry, followed by access to funding. It is therefore necessary to conduct further research on this topic, i.e. academics' motives for engaging in university-industry partnerships.

The impact of industry funding on the mode of knowledge production, and ultimately on scientific productivity, has been discussed in detail in previous studies (and reviewed in Chapter 4 of this thesis) and is also the second major theme of this study.

8.3. SOURCE OF FUNDING AND MODE OF KNOWLEDGE PRODUCTION

8.3.1. The Mode 2 thesis

Chapter 3 of this study discussed in detail the 1994 book by Michael Gibbons and his colleagues, which claimed that there is a rise in a new mode of knowledge production across various parts of the world – Mode 2. The Chapter also reviewed the international literature around the Mode 2 debate. The Mode 2 thesis included five propositions: that Mode 2 research is produced within the context of application; that a Mode 2 project involves a transdisciplinary team of researchers; that there is heterogeneity and organisational diversity within the team; that Mode 2 research is socially accountable and is reflexive; and that the process of quality control involves a wider range of criteria. Gibbons *et al*. (1994) also highlighted four "key drivers" that have contributed to the rise in Mode 2. They argue that:

- Mode 2 has resulted in knowledge being treated as a commodity, and research is being produced with the aim of commercialisation (*marketability and commercialisation of research*);
- After the Second World War, the university sector witnessed what is referred to as the *massification of research and education*. A significant shift brought on by this "massification", Gibbons *et al.* (1994) argued, was that the university is no longer the only place for knowledge production, and hence it is losing its monopoly. While critics of the Mode 2 thesis agree that there has been an emergence of other sites of knowledge production outside the university, they disagree that the university is losing its monopoly as a result of this shift;
- Following the massification of research and education, universities in particular began to expand their mandates (*reconfiguring institutions*). This included the creation of spin-off companies, increasing international collaborations between academics and increasing inter-disciplinary collaborations;
- Due to the nature of knowledge produced under Mode 2, it requires a different management style and different criteria for quality control compared to Mode 1 knowledge. Thus, we are said to be moving *towards managing socially distributed knowledge*.

Literature on the Mode 2 thesis (although somewhat limited[36]) indicates that the community is divided on this issue. There are studies that agree with the Mode 2 claims, and those that disagree. On the other hand, there are also studies that suggest that Mode 1 and Mode 2 coexist in a single discipline. The proponents of Mode 2 agree that knowledge is increasingly being produced within the context of application; that there are market demands that influence the process of knowledge production; that there is increasing private funding for research due to diminishing public funding; and that multi-disciplinary research is common in Mode 2 research, as well as collaborations between university and the industry. On the other hand, the greatest criticism is that Mode 2 is not a new phenomenon as claimed by Gibbons and his colleagues. Critiques argue that researchers have been producing knowledge within the context of application for decades, long before its popularisation by Gibbons *et al*. The

[36] Less than 30 articles were found at the time of conducting the literature search.

publication of *The New Production of Knowledge*, however, was significant in that it created a dialogue and forced researchers to think about the way we produce knowledge and the kinds of knowledge we produce.

It is undoubtedly true, as the proponents of the Mode 2 thesis suggest, that there is an increasing trend to engage in applied research, both globally and in South Africa, and as a result there has been an increase in third stream funding for research. However, it cannot be denied that applied types of research have been taking place for decades. In South Africa, for example, RGB has been supporting applied research since as early as 1919.

The argument by Gibbons and colleagues (1994) that the “key drivers” of Mode 2 described above will lead to diverse sources of research funding, was the focus of our second major theme of the study, i.e. to establish whether there is a link between the mode of knowledge production and funding.

8.3.2. Link between the source of funding and mode of knowledge production

Chapter 4 provided a review of studies that looked at the rise of industry funding for university research, both globally and within the South African system. It discussed the consequences of industry or third stream funding for research, and found that both parties, i.e. the funding partner (industry) and the university, benefit from this exchange. Industry provides the resources while the university provides the knowledge. But it was also found that engaging with industry could result in negative consequences, such as an increased concentration of resources, disproportionate incentives for a short-term foreseeable research endeavour, changing incentive structures, and cumulative and self reinforcement phenomena (Geuna, 2001).

Many of the studies of the impact of industry funding on scientific productivity (discussed in Chapter 4) showed that industry funding improves scientific productivity (see for example Harman, 1999; Hicks and Hamilton, 1999; Godin and Gingras, 2000; Van Looy *et al*. 2004; Gulbrandsen and Smeby, 2005; and Goldfarb, 2008). On the other hand, Hottenrott and Thorwarth (2011) found the opposite – that having a larger share of research funding from industry reduces productivity.

So far it has been established that trends occurring in other parts of the world, for example, the emergence of Mode 2; and the rise in industry funding for university research, are also evident within the South African science system. In order to establish if funding influences the mode of knowledge production, specific questions were asked during the interviews. First, would respondents say that the research they have undertaken with industry funding is different from the kind of research they have conducted with public funding? The second, or follow-up question was: how would you describe the type of research you conduct with industry or other private/non-NRF funding? Respondents confirmed that there is a difference in the type of research they have conducted with industry funding compared to that which they conducted with NRF/public funding. Second, research conducted with industry funding was generally described as applied or problem-oriented research (while public funding is utilised for basic/fundamental or curiosity-driven research). Previous studies that found similar results elsewhere in the world include: Godin and Gingras (2000), and Gulbrandsen and Smeby (2005).

It was also found that some respondents struggled to categorise their research into just one type, i.e. basic or applied, reporting that their projects involve both basic and applied research, with the basic research informing the applied research part of the project. The response below illustrates such uncertainty about the type of research conducted.

> *Ja...it's kind of difficult to answer. Okay I think I focus more on basic research, but we work more on applied problems. So the basic research is done in order to support the more applied questions. (Entomologist – Ac10)*

Thus, the distinction between basic and applied research is not self-evidently clear. This is consistent with the argument by Albert (2003), for example, who states that basic research or fundamental research provides a foundation for applied research, and that research is continuous. There were also respondents who used other terms to describe the research emanating from industry funding, such as development research, management-driven research, and targeted research. These results suggest a link between the source of funding and the mode of knowledge production among South African academics across various fields of study. Thus, industry funding leads to applied research, while public funding is utilised for basic/fundamental research. However, a comparison of scientific productivity among the three groups in this study (those who received Focus Areas funding only, THRIP funding only, or both Focus Areas and THRIP) revealed interesting results. Although already highlighted earlier, it is worth repeating that the Focus Areas funding is considered in this study as a proxy for government funding, while THRIP is considered as a proxy for industry funding.

We found that respondents who received funding from both the Focus Areas and THRIP, concurrently, produced more average annual research outputs than those who only received funding from one source. This suggests that the large amount of funding obtained from more than one source results in high productivity. On the other hand, when one compares those respondents who received funding from the Focus Areas only or THRIP only, it was found that academics who received THRIP (industry) funding published fewer outputs annually than those who received Focus Areas (public) funding, particularly journal articles, books and books chapters. This is despite the fact that the average THRIP grant is much higher than the Focus Area grant (as shown in chapter 6). Therefore in the case of respondents who only receive funding from one source, the high amount of funding does not lead to high annual outputs, particularly those outputs published in the public domain. However, respondents who received funding only from THRIP published more conference proceedings, and slightly more technical reports than those who received funding from the Focus Areas only. This is not a surprising finding, because we know that results from industry funding are often published in technical or internal reports and less in the public domain such as journals. Furthermore, conference proceedings are the most common mode of publication for researchers who receive the bulk of THRIP funding, i.e. those in the engineering and ICT fields. In the ICT discipline in particular, one respondent indicated that the process of publishing in conference proceedings is just as robust as the process used by journals, and much faster.

> *In the computer science and engineering areas we typically run our conference paper submission process very similar to the way journals are run, but it happens much faster. So for example, our conference papers are not accepted based on an abstract, they are accepted on a full paper, usually with double-blinded review, there's usually only one level of revision required instead of...with a journal it could be two, three, four, you know. With a journal it goes on for...it could last a couple of years. So I think a lot of it has to do with time-frames. (Computer Scientist – Ac9)*

Respondents said that the industry partner does not restrict them from publishing results in the public domain. However, there is an expectation that the partners will first explore the filing of a patent, or the possibility of commercialisation. This often leads to time delays in terms of publishing in a journal, for example. This finding can be interpreted as constituting a "restriction" despite what the respondents said during the interviews.

The study revealed several important areas/topics that could not be actively pursued within the scope of the study, but are worth further investigation. These possible areas for further research are outlined briefly under the sub-sections below.

8.4. POSSIBLE AREAS FOR FUTURE RESEARCH

8.4.1. Industry funding and conflict of interest

One of the interviewees spoke about the problem of conflicts of interest among academics in his area of study, i.e. sports science, in particular the sports drink industry. Similarly, a biomedical engineer made reference to a similar the challenge regarding conflict of interest.

> *Ja ja…I think there is a conflict of interest inevitably when an academic finds research leading to industrialisation. And that conflict can be time, in other words you have a full time job at the university, you need to teach your students and publish your research, and you are conflicted because of time and it means that you aren't able to devote what business might require. And I discovered that conflict maybe about ten, twelve years ago when I first got funding from the Innovation Fund. (Biomedical Engineer – Ac3)*

A survey by Welsh and colleagues (2008) among academics in Agricultural Biotechnology at nine universities in the United States found that among other things, university-industry relationships leads to "increased conflicts of interest among university scientists". A study around funding and potential conflicts of interest within the South African science system would therefore be worthwhile.

8.4.2. Commercialisation of university research

Henry Etzkowitz and his colleagues (2000) refer to the commercialisation of university research as "the rise of the entrepreneurial university". According to these authors, "the entrepreneurial university encompasses a third-mission of economic development in addition to research and teaching". Nevertheless, while entrepreneurialism should be encouraged among academics due to its demonstrated benefits, it is important to determine the consequences of such developments, in detail, on the science system. A study in this area should look at, among other things, how one can maintain a balance between contributing to the pool of knowledge, while at the same time engaging in research that would benefit the lives of people through commercialisation.

8.4.3. Post-graduate student funding: quantity versus quality

The NRF plans to increase the number of doctoral graduates from an annual figure of about 1300 in 2010 to 6000 by 2020 or 2030, depending on availability of adequate resources (NRF, 2011). During the interviews, there were respondents who questioned whether this is necessary. The assumption by the NRF is of course that these graduates will provide a pool for future academics given that the country has a challenge of an ageing academic population. However, anecdotal evidence suggests that young people in the country do not see a career in academia as attractive for various reasons. One respondent in particular indicated that we should be focusing on the quality of the students we produce rather than the number that graduate.

> *With students, I'd rather take few and take quality so I produce something that will make an impact...it is a question of quality. I'm very against, it's another complaint I have with NRF, and I think the whole question of "what exactly are we funding all these extra researchers to do"? We fund them through an MSc, a Phd to do what? Where is the evaluation that I'd like to see of people who've been funded over the 30 years, who've been funded to do higher degrees by the NRF and its precursors, do they think that was useful? Is it a good spender of money? Shouldn't we be going for more quality and less quantity? (Applied Mathematician – Ac1).*

8.4.4. The role of the DHET subsidy policy on the mode of knowledge production

The Department of Higher Education and Training (DHET)'s *Policy and Procedures for Measurement of Research Output of Public Higher Education Institutions* – discussed in Chapter 2 – has over the years become critical actor in the country's science system. Currently, the DHET distributes over R2.3 billion to public universities annually for research outputs produced in the previous year (journal articles, books and book chapters, as well as peer-reviewed conference proceedings). The subsidy funding is not meant as project funding, but rather as a "reward" for scientific productivity. While the DHET awards the subsidy to universities, this money is managed differently by the different universities. For example, some universities give part of the subsidy money to researchers who produced publications in that particular year, and the money is paid into the researcher's personal bank account; while others allocate a portion of the money into an individual's "research account", to be used on research-related activities such as conference attendance. It is known that academics now plan their research "around" the subsidy money – thus, they plan their research in a way that would result in subsidy-earning outputs.

The unintended consequence of this behaviour is that academics will increasingly engage only in research projects that will lead to outputs that are subsidised under the DHET policy.

That is, researchers could focus more on the basic/fundamental research that can be published in the public domain much easier and faster than the problem-solving/applied type of research that leads to publications such as patents and technical reports (currently not subsidised by the DHET). Academics are already under pressure from their universities to increase their publications that will earn higher subsidy funding from the DHET. Further research is therefore needed to determine the medium to long term consequences of the DHET policy on the South African science system, also given the fact that no other country in the world has a similar policy.

This study set out to answer one central question, whether the mode of knowledge production is influenced by the source of funding: government versus industry funding. That is, we wanted to establish if researchers' choice of research was influenced by where their funding is coming from. A major challenge in this study was finding a methodology that would best answer such a complex question. The concept of "mode of knowledge production" is not necessarily a commonly used concept among academics. Therefore, it would be challenging for most academics to complete a questionnaire, for example, where they are being asked "what is your mode of knowledge production"? Through analysing researchers' CVs, I was able to determine their annual average scientific productivity, as well as the number of postgraduate students they have supervised during their career. However, the limitation of this method was that we could not determine the mode of knowledge production utilised by individual researchers from the information provided in their CVs. In addition, some CVs did not contain information on all sources of funding, an important piece of information for this study. Some CVs provided details of patents published, which could be taken as proxy for applied research, but these were very few. We therefore conducted follow-up interviews with a sample of academics, allowing us to ask them about their research activities, their sources of funding, and how they generally describe their work. More specifically, our main aim was to find out if academics describe differently research funded by different sources.

Overall, the findings of this study show that there is no clear cut conclusion about the influence of funding on the mode of knowledge production. We could not prove that the two factors, that is, funding and mode of knowledge production, are related in a linear fashion. This is a much more complicated situation that requires more investigation. There are other factors that could influence scientific production outside the amount and source of funding. One important factor that is known to have a positive impact on productivity is interactions or collaboration with peers. It is commonly known that the more collaborations an individual has, the greater their opportunity of co-authorship, and thus making them appear more productive than those with less collaborations. In the final analysis more research, especially of a qualitative kind, is needed to address these questions.

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ANNEXURES

Annexure 1. List of individuals interviewed to gain understanding of the funding landscape

Name	Date, and venue	Capacity
Dr Reinhard Arndt	29 October 2008, Pretoria	Former Vice-President, CSIR
Dr Chris Garbers	30 October 2008, Pretoria	Former President, CSIR
Dr Gerhard Von Gruenewald	7 November 2008, Pretoria	Former Vice-President, FRD
Dr Rocky Skeef	11 November 2008, Pretoria	Former Manager, THRIP (and current Executive Director, NRF)
Dr Khotso Mokhele	2 December 2008, Johannesburg	Former (and first) President, NRF
Dr Liz Lange	9 March 2009, Pretoria	Former CSD employee
Dr Hendrik (Bok) Marais	11 March 2009, Pretoria	Former (and founding) Executive Director, CSD
Prof Cheryl de La Rey	1 April 2009, Pretoria	Former Executive Director, CSD
Mr Mmboneni Muofhe	21 July 2012, Pretoria	Former Manager, THRIP
Dr Bernard Nthambeleni	1 October 2013, Pretoria	Executive Director, NRF

Annexure 2. Description of rating categories used in 1984/85 (FRD, 1985)

Category	Description
A	Researchers who are without any doubt accepted by the international community as being amongst the leaders of their field. Researchers who are accepted by the international community as being amongst the leaders in a rather narrow field, or others with a broader range with strong claims to a leadership role.
B	Others, not in category A, but who nonetheless enjoy considerable recognition as independent researchers of high quality.
C	Proven researchers who, as individuals or as members of a team, have maintained a constant level of research productivity and whose work is regularly made known internationally.
D	Researchers, not in C, but showing promise of qualifying for support in the future.
E	Level of recent work does not qualify support.
Y	Young researchers who are potential high fliers.

Annexure 3. Description of rating categories used currently (Facts & Figures, 2007)[37].

Category	Description	Short Description
A	Researchers who are unequivocally recognized by their peers as leading international scholars in their field for the high quality and impact of their recent research outputs.	Leading international researchers
B	Researchers who enjoy considerable international recognition by their peers for the high quality and impact of their recent research outputs.	Internationally acclaimed researchers
C	Established researchers with a sustained recent record of productivity in the field who are recognized by their peers as having: - Produced a body of quality work, the core of which has engagement with the field. - Demonstrated the ability to conceptualize problems and apply research methods to investigating them.	Established researchers
L	Persons (normally younger than 55 years) who were previously established as researchers or who previously demonstrated potential through their own research products, and who are considered capable of fully establishing or re-establishing themselves as researchers within a five-year period after evaluation. Candidates should be South African citizens or foreign nationals who have been resident in South Africa for five years during which time they have been unable for practical reasons, to realize their potential as researchers. Candidates who are eligible in this category include: - black researchers - female researchers - those employed in a higher education institution that lacked a research environment - those who were previously established	Late entrants into research, preferable younger than 55 years

[37] These categories are now applied across researchers in all disciplines, including the social sciences and humanities.

Category	Description	Short Description
	as researchers and have returned to a research environment.	
P	Young researchers (normally younger than 35 years of age), who have held the doctorate or equivalent qualification for less than five years at the time of application and who, on the basis of exceptional potential demonstrated in their published doctoral work and/or their research outputs in their early post-doctoral careers are considered likely to become future leaders in their field.	NRF Presidents Awardees, preferable younger than 35 years
Y	Young researchers (normally younger than 35 years of age), who have held the doctorate or equivalent qualification for less than five years at the time of application, and who are recognized as having the potential to establish themselves as researchers within a five-year period after evaluation, based on their performance and productivity as researchers during their doctoral studies and/or early post-doctoral careers.	Promising young researchers, preferable younger than 35 years

Annexure 4. List of major, current funding opportunities in the NRF (new opportunities[38] in **bold**). Source: NRF, 2007.

Broad Investment Area	Specific Funding Opportunity
Established researchers	SARChI
	Incentive funding for rated researchers
	Phase out of direct support for Ps
	KIC - Travel and events support
Human Capital Development and unrated researchers	Support for unrated researchers
	Thuthuka
	Research Niche Areas
	PhD Programme
	Free Standing Scholarships (PD, D, M, H)
Strategic Knowledge Fields	Curiosity Driven Research
	Phase out of FAPs
	KF Development Grants
	IKS
	SABI, MCM, SANC
	AOP
	Multi-wavelength
	SANAP
	AGAP
	Competition
Strategic Platforms (Including research at the National Research Facilities)	"HEI" Researchers working at Facilities
	Funding formula for Facilities
	CoEs
	ACEP
	NIThP
	Equipment mobility
	National Research Equipment Programme
	National Nano-Equipment Programme
	National Laser Centre
International Initiatives	von Humboldt
	ISL - Bilaterals
	ISL - Bi-nationals
	Royal Society
	IAEA

[38]New opportunities/funding programmes were introduced in 2008.

Broad Investment Area	**Specific Funding Opportunity**
	KISC
	ICSU
	Regional co-operation fund
	Focus on Africa
Applied & Industrial Research & Innovation	THRIP
	Industrial CoE
Community engagement research	Research into community outreach

Annexure 5. Letter to the National Research Foundation requesting funding data

Dr Gansen Pillay
Vice-President: RISA

Dear Dr Pillay

Request for NRF historical funding data for doctoral study purpose

This is to confirm that Mrs NM Luruli, student number 13422537, is a registered student in the DPhil Science and Technology Studies programme at Stellenbosch University. The main aim of her doctoral study is to determine if there are significant differences in the modes of knowledge production undertaken by NRF-funded versus industry-funded researchers. In this regard, I would like to request access for her to funding data from two NRF Programmes, i.e. THRIP and the Focus Areas Programme for the period 1999 – 2008 (ten years). In particular, the following information if possible:

1. Biographical details of grant-holders
2. Title of the project
3. Area of study (field and/or discipline)
4. Amount of grant awarded
5. Details of publications produced
6. Number of students supervised

Data received will be treated with the necessary confidentiality, and it will only be utilised for her doctoral study.

Your consideration of this request will be highly appreciated. Please contact the postgraduate programme co-ordinator, Ms. Marthie van Niekerk, if you have any further queries. Mrs Luruli can be contacted on 012-312 5378 / 084 517 8132 / Email: luruli.n@dhet.gov.za or nluruli@gmail.com

Yours sincerely,

Prof Johann Mouton (Doctoral Supervisor)

Annexure 6. Letter to academics requesting their curriculum vitae

RESEARCH FUNDING AND MODES OF KNOWLEDGE PRODUCTION

Dear Respondent

I am currently busy with doctoral research at the University of Stellenbosch's Centre for Research on Evaluation, Science and Technology (CREST) under the supervision of Professor Johann Mouton. The primary aim of my doctoral thesis is to determine if there are significant differences in the mode of research utilised in projects funded through the National Research Foundation (NRF) and those funded by industry/private sector. The study will also investigate, among other things, differences in sources of funding (public versus industry/private sector); the nature of collaboration; and publication patterns (types of publications, where the work is published etc.).

The information required for my study is usually contained in the CV's of scientists and scholars. Therefore, rather than sending you a questionnaire, my request is simply that you send me your most up to date detailed CV. After we have received and analysed the CV's I will then select a sample of scholars with whom I would then like to conduct a short 15-minute telephone interview. If you do decide to send me your CV, please also indicate in the box below (or by return e-mail) if you are willing to be contacted for such a telephone interview.

I would appreciate it if your CV could reach me by Friday, 10 August 2012. Your CV will be treated with the necessary confidentiality and I can confirm that it will be used for the purpose of this study only. All my analyses will be at the aggregate level only and no information at the individual level will be presented or made public.

If you have any queries, you are welcome to contact me at (012) 312 5378/ 084 517 8132 or luruli.n@dhet.gov.za. You may also contact Prof J Mouton at Jm6@sun.ac.za.

Your participation in this study is highly appreciated. Thanking you in anticipation.

Yours sincerely.

Ms Ndivhuwo Luruli Prof Johann Mouton (Doctoral Supervisor)