REVIEW OF THE WHITE PAPER ON SCIENCE AND TECHNOLOGY

science & technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

NACi

NATIONAL ADVISORY COUNCIL ON INNOVATION

Contents

Executive Summary

The objective of this project has been to review the progress of the Department of Science and Technology, and more broadly the Government, towards the implementation of the White Paper on Science and Technology (DACST, 1996). The White Paper defined a vision, a set of six high level goals, nine essential requirements and scores of specific initiatives, the latter divided into the six categories of Policy Formulation and Resource Allocation; Regulatory Policy; Financing at the Performance Level; Performance; Human Resource Development (HRD) and Capacity Building; and Science and Technology (S&T) Infrastructure. This summary considers progress firstly in respect of the broader objectives, and secondly with reference to the specific initiatives.

PROGRESS ON HIGH-LEVEL GOALS AND OBJECTIVES

Progress towards the attainment of the high level goals and requirements, including the important issues of reducing unemployment, providing safety and security, and working towards environmental sustainability, has been limited. Important indicators across a range of components including life expectancy, employment and standard of education remain at low levels (World Bank, 2015).

Although economic growth may have been consistent, it has certainly not been remarkable, with the Gross Domestic Product (GDP) increasing by between 2% and 3% annually over this period. Furthermore, based on the per capita data, economic growth has been minimal and highly exclusive. The labour market has been characterised by a shrinking of low-wage formal employment opportunities and higher earnings/better working conditions for white- and blue-collar workers. This divergence between conditions for unskilled vs skilled labour is an enduring feature of apartheid policies which specifically sought to establish and preserve high wages and protected incomes for the white minority. Furthermore post-1994 policies such as trade liberalisation and the promotion of a high-productivity growth path have favoured capital-intensive over labour intensive firms, resulting in rising real wages for the employed but higher levels of unemployment in 2014 compared to 1994.

One important mitigating factor counteracting this trend has been the increased payments of social grants, which have trebled in real terms since 1994 and now reach an estimated 17 million recipients from about 4 million in 1994. This development is recognised in the 2015 OECD report on the South African economy (OECD, 2015) which notes that:

> "South Africa has made great progress in reducing absolute poverty by rolling out social grants for pensioners, the disabled and children. Access to education, housing, water, electricity and other services has been greatly broadened. As a result, well-being has increased substantially."

It is apparent that path dependence remains a key determinant in the economy with relatively little change in several aspects. The post-apartheid state acquired a system of actors, institutions and policies which had historically paid little attention to the needs of the poor (Mariotti and Fourie, 2014). Although the new state has performed well in several respects including the management of knowledge, the ability to collect taxes, and the operation of a substantial welfare state, it has been deficient in development planning and implementation, and as a result largely ineffective as a developmental state. It has sustained a strong science and technology system, including several world-class universities, but has failed to prevent the erosion of its manufacturing sector or develop new medium- and high-technology industries with the result that the potential for innovation-led growth has been under-realised. Moreover key actors such as the economic elite have retained a powerful influence over policy to the extent that little changes to the distributional patterns of income have been possible.

The latter factor is central to this review and the proposed revision of innovation policy. Despite rising public investment in research and development, and by implication science and technology for innovation, outputs have been disappointing with limited growth in the key indicators such as patents and high technology exports. At a general level, this weak performance can be explained as a manifestation of the conflict between the demands of various constituencies, and in particular the fiscal tension between longer term policies/expenditure and shorter term welfare state programmes.

The need to manage this tension was identified in the 2007 OECD review of the NSI which noted the imperative for the NSI to deliver tangible benefits to the poor in order to secure sustained political support for science, technology and innovation (OECD, 2007).

Although innovation-led growth as a development strategy remains valid and is indeed a central principle of the National Development Plan, its implementation has been largely hindered by under-resourcing of business innovation, adverse labour market conditions, low levels of entrepreneurship and the slow response of the educational system to deliver human resources for a high-technology economy. All these issues will need to be resolved in the short term if significant progress towards a progressive and full employment economy is to be realised.

PROGRESS ON SPECIFIC INITIATIVES

Progress towards the implementation of the specific initiatives has been significant in all areas. The following table summarises the key achievements within each category.

CATEGORY	ACHIEVEMENT
Policy Formulation and Resource Allocation	*New Actors*: establishment (and ongoing operation) of the National Advisory Council on Innovation, the National Research Foundation, the Innovation Fund (now the Technology Innovation Agency), and the National Facilities for Research. *Department of Science and Technology (DST):* the DST has adhered meticulously to the terms of reference outlined in the White Paper. *Policy Support:* all the actions of the White Paper including annual research and development (R&D) surveys, the R&D Audit and the R&D Foresight Exercise, have been completed.
Regulatory Policy	*Intellectual Property:* promulgation of the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008, covering a framework for the more effective identification, protection, utilisation and commercialisation of intellectual property emanating from publicly financed research and development.
Financing at the Performance Level	*Incentives:* despite a gap in S&T policy on innovation incentives, many such schemes have been introduced by the Department of Trade and Industry (dti) and DST, including support for technology transfer, upgrading of capital equipment, and the R&D tax incentive. *Resources for Innovation:* the budgets of all departments involved as actors within the NSI have increased in real terms, led by the DST whose expenditure has increased by 900% since 2005/6.
Performance	*Management of public science, engineering and technology institutions (SETIs) and higher education institutions (HEIs):* the performance management of SETIs has been improved leading to more effective deployment of public resources in the performance of core SET functions. Changes include the replacement of input criteria with output criteria, a uniform framework, the role of line departments and unfair competition with the private sector. *International Partnerships:* extensive progress has been made in building international partnerships and opening the science system to R&D collaborations with a range of countries to mutual advantage.
Human Resource Development and Capacity Building	*Enrolments:* the numbers have increased from 632,719 candidates in 2001 to 938,201 in 2011, representing an increase in participation rates from 14% to 17% over the ten year period and levels of graduations rose to 160,000. It is likely that the national target of 18% participation rates by 2014 has been met (statistics not yet available).

CATEGORY	ACHIEVEMENT
S&T Infrastructure	*Scientific Equipment:* funding for scientific equipment has increased significantly with a total of R4.6 billion being invested over the period 2009/10 to 2013/14 (through the NRF). *Square Kilometre Array:* South Africa's success in hosting the SKA is a major achievement which will have many spin-off benefits including the upgrading of the broadband infrastructure. The SKA project is progressing and the first of the 64 antennas that will make up South Africa's new radio telescope, MeerKAT, was delivered at a special launch in March 2014. *National Facilities:* these facilities have been operationalised and are fulfilling an important role in HRD and R&D, including providing facilities for research, supervising post-graduate students, and hosting international conferences. *Statistical Services:* the R&D survey is completed annually and provides useful data to inform policy development.

Notwithstanding these achievements, there remain a number of critical areas where implementation has been ineffective and corrective attention is required. The most significant weaknesses remain in four key areas, namely HRD; effective inter-departmental coordination leading to greater policy cohesion and the achievement of a culture of innovation within Government; the promotion of an information society; and the use of government incentives for innovation. Further details follow.

CATEGORY	SPECIFIC INITIATIVE WITH EITHER LIMITED OR NON-EXISTENT IMPLEMENTATION
Policy Formulation and Resource Allocation	*Ministers Committee on S&T (MCST):* the MCST has been disbanded and not replaced. As a result, there are growing dislocations between government departments, a lack of commitment to making innovation central to national (economic and social) development and limited adoption of the concept of the NSI. In order to address this problem, the establishment of a National Council on Research and Innovation, chaired by the Deputy President, has been recommended (Department of Science and Technology, 2012a). This proposal has not been implemented, nor does it appear likely that the present administration will support such a body. *Information Society:* the adoption of the broadband policy document "South Africa Connect: Creating Opportunity, Ensuring Inclusion" is an important step, but South Africa continues to lag behind other middle-income countries in broadband access and e-government. Its efforts in this area need to be accelerated in order to ensure that open innovation and other benefits of the information society are realised. *Science Budget:* the recommendation of a Science Budget was never implemented, although the DST did produce a review of government's expenditure on science and technology activities (Department of Science and Technology, 2014a). At this stage the implementation of this recommendation is considered impractical but the DST needs to act quickly to find other ways of monitoring innovation expenditure and establishing overall coordination in the system.
Regulatory Policy	*Intellectual Property Office:* the ongoing status of this office as a non-examining authority means that the local system is open to abuse through the granting of exclusivity whether this is either warranted or legal. This issue still needs to be resolved. *Protection of the Environment:* there is no record of the DST engaging meaningfully with other departments on this issue although it is not clear how the DST would approach the White Paper objectives and remain within its mandate.

CATEGORY	SPECIFIC INITIATIVE WITH EITHER LIMITED OR NON-EXISTENT IMPLEMENTATION
Financing at the Performance Level	*Tax Incentive:* based on a survey of the applicants, it is apparent that the tax incentive has some limitations, particularly in enhancing further innovation and promoting linkages between firms/science councils and firms/ universities. A review of the impact of the R&D incentive on R&D activity of the recipients of the incentives is recommended, not only to improve the incentive, but also to determine overall policy to enhance R&D in the private sector, and to enhance linkages between the private sector and other R&D performers. *Public Procurement:* the White Paper failed to define a clear policy for how public procurement might enhance STI. Since its publication, this matter has been addressed and current public procurement policies are focused on enhancing local production, particularly in manufacturing. However more recent advances in how public procurement can be used to bring innovative solutions into the activities of government have not yet been introduced. Further attention to this area is highly recommended.
Performance	*Defence R&D:* this budget is about R460 million per annum with the total expenditure on science and technology activities being about R500 million. Cooperation between the responsible departments (DST and DoD) has not been sustained and there is no joint planning at present. This remains an important area for policy.
Human Resource Development and Capacity Building	*HRD Strategy:* the notion that education and training will resolve the problems of unemployment because it will build economic capability and simultaneously resolve the problem of unemployment/jobs is simply untenable. The country needs a wider HRD strategy that is based on a broad range of skills. *STEM Performance:* the number of school leavers with acceptable mathematics and science literacy levels is low and South Africa was placed last out of 144 countries in the Global Competitiveness Index *Enrolments:* Although the national target of 18% participation rates by 2014 has been met, the gains are substantially uneven; participation rates for women (20%) are higher than men (15%), with African men having the lowest rate at 11%. More needs to be done in this area.
S&T Infrastructure	*Information Infrastructure:* see earlier comment on the information society

Weaknesses and deficiencies in implementation do not reflect solely on the performance of the DST and should not be interpreted as a reason to abandon the policies as broadly outlined in the White Paper and the subsequent DST strategies. The lack of progress reflects more generally on the intractable nature of the problems, the historical context for the country and the slow pace of delivery from other Government departments. Innovation, and specifically innovation policy, has an ongoing and important role in the attainment of these high level goals and must remain central to the overall actions of Government in achieving these goals.

However certain revisions are recommended. In an accompanying report (Walwyn et al., 2015), we discuss how the context for innovation in South Africa and how the practice of innovation policy has changed in the last twenty years. These reports are then combined in a synthesis report which attempts to define a revised policy framework as a guide for the DST in the preparation of its next Decadal Plan.

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List of Abbreviations

ABET	Adult Basic Education and Training
BRICS	Brazil, Russia, India, China and South Africa
CBD	Convention on Biological Diversity
CIPRO	Companies and Intellectual Property Registry Office
DACST	Department of Arts, Culture, Science and Technology
DHET	Department of Higher Education and Training
DST	Department of Science and Technology
dti	Department of Trade and Industry
DUI	Doing, Using and Interacting
GDS	Growth and Development Strategy
GERD	Gross Expenditure on Research and Development
HEI	Higher Education Institution
IDC	Industrial Development Corporation
IPAP	Industrial Policy Action Plan
Mbps	Megabits per second
MCST	Ministers Committee for Science and Technology
MTEF	Medium Term Expenditure Framework
NACI	National Advisory Council on Innovation
NIPF	National Industrial Policy Framework
NRF	National Research Foundation
NSI	National System of Innovation
PFMA	Public Finance Management Act
R&D	Research and Development
S&T	Science and Technology
SET	Science, Engineering and Technology
SETI	Science, Engineering and Technology Institution
SME	Small and Medium Enterprise
STI	Science, Technology and Innovation
ST4I	Science and Technology for Innovation
TIA	Technology Innovation Agency
TRIPS	Trade-Related Aspects of Intellectual Property Rights
WTO	World Trade Organisation

THE NATIONAL SYSTEM OF INNOVATION (NSI)

The NSI can be considered as a set of functioning institutions, organisations and policies which interact constructively in the pursuit of a common set of social and economic goals and objectives. The three key objectives of Government can then be thought of as existing (DACST, 1996):

- to ensure that South Africa has in place a set of institutions, organisations and policies which give effect to the various functions of a national system of innovation
- to ensure that there is a constructive set of interactions among those institutions, organisations and policies and
- to ensure that there is in place an agreed upon set of goals and objectives which are consonant with an articulated vision of the future which is being sought.

In a presentation to the Parliamentary Portfolio Committee on Science and Technology in August 2015, the Director General noted that the "NSI remains an ideal for which South Africa continues to strive" (Mjwara, 2015).

INNOVATION

In this document, innovation is defined as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations, where 'new' means new to the world, new to the country or new to the firm and the latter are defined as follows:

- new to the world: when a firm is the first to introduce an innovation for all markets and industries, domestic and international
- new to the market: when a firm is the first to introduce the innovation in its particular market
- new to the firm: when a firm introduces a product, process or method that is new to that firm, or significantly improved by it, even if it has already been implemented by other firms

Source: OECD and Eurostat (2005)

Chapter 1
Introduction

The White Paper on Science and Technology (White Paper), published in 1996, was a seminal document in many respects, acting as a blueprint for the subsequent actions of particularly the Department of Science and Technology (DST), formerly the Department of Arts, Culture, Science and Technology, and more broadly the actions of Government. However the document is now almost 20 years old and much has happened to necessitate its review within a framework of changes in the policy context, both local and international, and trends in innovation theory.

In this study, such a review has been undertaken. The detailed recommendations of the policy have been listed and individually assessed in terms of the extent of implementation and ongoing relevance to the national system of innovation (NSI). In a subsequent report, the outcomes of this review are assessed against the trends in innovation theory and practice, and a set of high level recommendations for future policy covering science, technology and innovation has been presented.

An examination of the extent to which the policy initiatives of the White Paper have been implemented should take account of the sentiments expressed by members of the Government Executive at the time of its publication. For instance, the preface makes reference to the authoritative pronouncements of President Mandela, who emphasised the Government's commitment to the creation of a 'people-centred society' in which liberty, the goals of freedom from want, hunger, deprivation, ignorance, fear and suppression were to be regarded as binding covenants on the government as guarantees of 'human dignity.' In his introductory letter, the then Minister of Science and Technology, Dr Ben Ngubane, expressed the view that:

> "The vision (of this White Paper) is one where, on the one hand, South Africa uses science and technology to become economically competitive on a global scale, and on the other hand to provide essential services, infrastructure and effective health care for all South Africans. We believe that this is best done by embedding our S&T strategies within a larger drive towards achieving a winning National System of Innovation. In such a system, institutions such as universities, technikons, science councils, private sector research laboratories and market intelligence divisions would cooperate in a nationally optimal way towards solving real problems, whether these occur in industry, agriculture, defence or basic research."

The Deputy Minister in turn chose to emphasize that:

> "Technology has been a determining factor in human history since time immemorial and in the 21st Century this will be so to an even greater extent. It is imperative that South Africa makes the right choices, sometimes difficult, to enhance our adoption and mastery of the technologies which will assist us in becoming a competitive nation."

These instructive remarks emphasise the importance of a systemic approach to innovation, encompassing a range of cooperating institutions which share a common objective of resolving 'real problems,' recognise the critical role of technology in human development, acknowledge the need to make sensible choices in the adoption of appropriate technologies for national development, and together advance the development of scientific knowledge and capability as intrinsic to the human condition and its cultural evolution.

The statements are further amplified in the preamble to Chapter 1 of the White Paper, which re-states a view of the future where "all South Africans will enjoy an improved and sustainable quality of life; participate in a competitive economy by means of satisfying employment; and share in a democratic culture". These injunctions are reinforced by a set of propositions about how the above vision will be achieved through a coordinated and integrated approach to technological and social innovation; effective collaborations and partnership, scientific approaches that are multidisciplinary (referring

particularly to the wide range of natural and social sciences); engaging stakeholders especially representative of those who were formerly marginalised; urging consultative approaches to decision-making in the realm of policy; regarding knowledge as critical to national development; and supporting innovation that is fundamental to sustainable economic growth, employment creation, equity through redress and social development.

Innovation is similarly regarded in the broadest possible social and scientific terms in Chapter 1, and as responsive to the social vision represented in the approaches above. The singularly important concept in these pronouncements is the idea, firstly, that freedom is to be conceptualised in the broadest and most inclusive terms especially by reference to those attributes of social and individual life which provide the fullest expression of human rights and the dignities associated with them. Secondly, they stress the importance of the 'means and methods' through which these goals are to be achieved.

These sentiments were not surprising especially as they echoed both a rejection of the narrower approaches to development and an affirmation of a wider approach premised on the democratic, participative and inclusive approaches to social, political, economic and cultural development. The propositions were critically important to the ends to which government's commitments were directed, as much as to the democratic means by which these were to be achieved and echoed similar ideas which were critical of approaches to development more narrowly directed at particular ends unconstrained by the means of their achievement.

This report is structured according to Part 2 of the White Paper, with six main chapters (3 to 8) covering Chapters 5 to 10. For each chapter, the specific initiatives are listed and progress with respect to implementation presented. In addition, Chapter 2 covers a high level review of Part 1 of the White Paper, with comments on the overall sentiments within this section and the difficulties with implementation. The report concludes with a summary of the extent of implementation across all initiatives with a specific focus on the items which are not yet implemented or are substantially incomplete. The latter gaps form a starting point for the subsequent report on changes in science and technology policy and practice, and possible recommendations for the high level framing of a new decadal plan for the Department of Science and Technology.

It is noted that this review covers primarily the performance of the DST in respect of the White Paper specific initiatives; it is not a review of all government departments nor does it review in detail the overall performance of the NSI since 1996.

Chapter 2

Vision, Goals, Requirements and Systems

In this chapter, Part 1 of the White Paper is reviewed. This part can be divided thematically into three main categories, namely the expression of vision, goals and objectives (referred to as the 'requirements'), the definition of innovation and the rationale for adopting the national systems of innovation approach, and finally a guide to Part 2 of the document. In reviewing the country's progress towards the realisation of these goals, we have initially chosen to present the goals and discuss the White Paper's conceptualisation of innovation, the national system and the principal objectives. We then present a review of the overall system (and particularly economic) performance vs these goals and follow with a discussion of the response from all actors (also referred to as stakeholders) to the concepts and the associated objectives, covering in particular the issues of competitiveness, employment, human resource development and information society.

2.1 OVERVIEW OF THE VISION, GOALS AND REQUIREMENTS

The vision of the 1996 White Paper aligns even today with the persistent goals of government since 1994, where the latter cover improving the quality of life (or more narrowly defined as reducing poverty), raising employment, and removing inequality (or sharing in a democratic culture). The path of progress towards this vision is well defined in the White Paper's goals which include the establishment of an efficient and co-ordinated national system of innovation, with stakeholders highly networked, an integral part of a more inclusive approach to policy and resource allocation, and creatively involved in the use of knowledge of all kinds, but particularly science and technology, for the development of innovative solutions to challenges in economic growth, equity redress, environmental sustainability and social development.

These goals remain valid even today. Despite progress in many areas, the achievement of the vision, of higher levels of innovation, of greater economic equality, even of the acceptance more broadly within government of the importance of innovation, is substantially under-realised. At least part of the problem can be assigned to government's failure to implement the White Paper's requirements for S&T policy, the details of which are covered in Section 2.3 of this report.

These requirements are perhaps more readily understood as a set of objectives to be shared between all the government departments. Although most of the specific initiatives listed in Part 2 of the White Paper relate specifically to the actions of the DST, the achievement of the goals and objectives as stated in Part 2, including the requirements, would only be possible if the other stakeholders simultaneously fulfil their respective roles. For instance, realising the goals of environmental sustainability will require effort from the Department of Environment, the DST, the dti, National Treasury, the private sector, civil society and others. Achieving these goals will depend not only on the DST's efforts, but the extent to which these efforts are supported more broadly within government and the private sector.

In the following sections, we provide a high level overview of the NSI and then review progress of the NSI and more generally the country itself towards the realisation of the 'requirements' underlying S&T policy as stated in Chapter 2 of the White Paper. The relevant requirements have been selected as promoting competitiveness and employment, developing human resources, working towards environmental sustainability, promoting an information society, and knowledge generation.

Each area is discussed in more detail following the overview.

2.2 PERFORMANCE OF THE SYSTEM

Considering the diversity and complexity of the NSI, with its large number of actors, institutions and networks, it is impractical in this study to provide a comprehensive review of the system's performance. Instead we have followed the structure of the 2007 OECD report on South Africa's NSI, and updated the main categories as defined in this report (OECD, 2007), including economic performance (Section 2.2.1), policy challenges (Section 2.2.2), business innovation (Section 2.2.3), and institutions/governance (Section 2.2.4).

2.2.1 Economic Performance

Government's economic policy over the period 1994 to 2014 has been variously described but has generally followed a strategy of macroeconomic stability with inflation targeting and fiscal consolidation which would support the establishment of a competitive, fast-growing economy, thereby ensuring sufficient jobs for all job-seekers, and simultaneously allow for the redistribution of income and opportunities in favour of the poor (South African Reserve Bank, 2013). The policy has been partially successful with inflation and key interest rates falling from between 12% and 16% in the early nineties to about 5% by 2012.

However progress in other respects has been poor. Although economic growth may have been consistent, it has certainly not been remarkable, with the Gross Domestic Product (GDP) increasing by 2% to 3% annually over this period (see Figure 1).[1] Furthermore, based on the per capita data, economic growth has been minimal and highly exclusive. Indeed several of the main conclusions of the 2007 OECD report and the key findings of a subsequent OECD study of the economic conditions in South Africa (OECD, 2015) remain valid, with progress noted at the level of social grants and access to public services, but with limited achievement in key areas including unemployment and economic equity. To quote from the 2015 OECD survey:

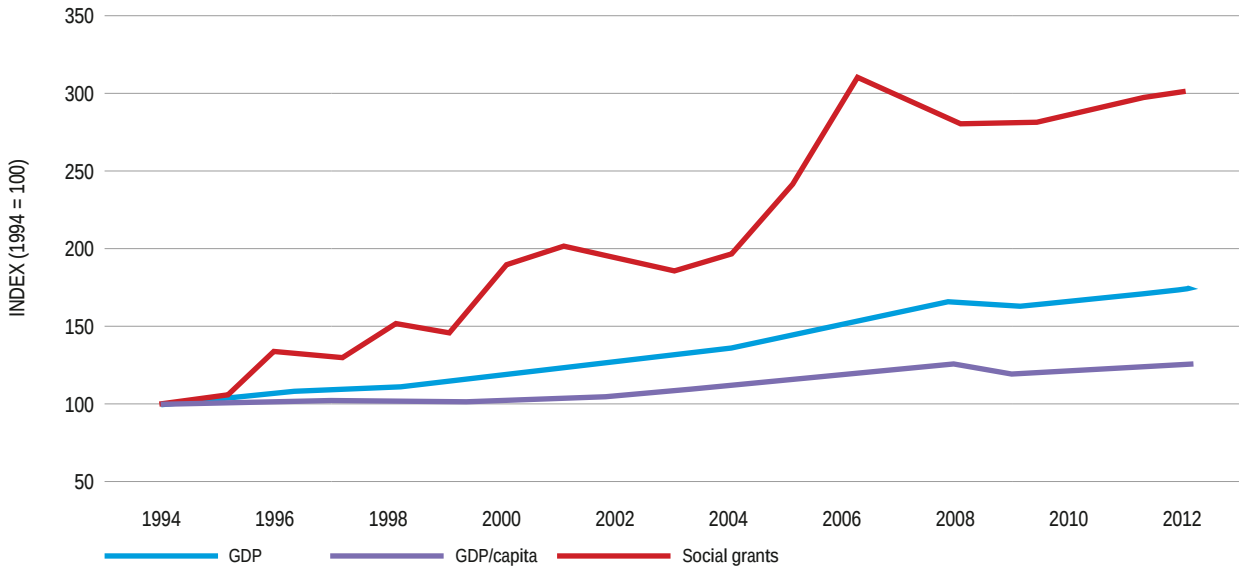


Figure 1. South Africa's GDP and social grants (1994 to 2012)

1 It is noted that all economic data have been extracted from the World Development Index database in constant US$ 2005 and then indexed to 1994 (=100) unless otherwise indicated.

> "Since 1994 South Africa has made great progress in reducing absolute poverty by rolling out social grants for pensioners, the disabled and children. Access to education, housing, water, electricity and other services has been greatly broadened. As a result, well-being has increased substantially. A sound macroeconomic framework with a stable fiscal position, inflation targeting, a floating exchange rate and largely unimpeded international capital flows underpinned this progress and has earned South Africa the confidence of financial markets.
>
> Nevertheless … inactivity is widespread, settlement structures are too remote from economic centres and severe infrastructure bottlenecks prevent economic activity from delivering the benefits of globalisation to all."

Alongside economic growth, high unemployment as a proportion of the total labour force is a persistent and ongoing challenge for government and the unemployed. Although employment has risen by 6.1 million since 1994, the total available labour force has increased by 9.6 million with the result that the number of unemployed based on the expanded definition has increased by 3.4 million (see Table 1). In other words, employment levels have remained static as a proportion of the total available labour force (Statistics SA, 2015).

Table 1. Unemployment data in South Africa (1994 and 2014)

	1994	2014	CHANGE
STRICT (1,000S)			
Employed	8,896	15,055	69%
Unemployed	2,489	5,067	104%
Unemployment Rate	21.9%	25.2%	15.2%
EXPANDED (1,000S)			
Unemployed	4,707	8,157	73%
Available Labour Force	13,603	23,212	71%
Unemployment Rate	34.6%	35.1%	1.6%

Source: Statistics SA (2015)

The problems of unemployment and income inequality are noted by several studies. Seekings and Nattrass (2015) highlight the deficiencies in the South African labour market as the key factor in the two issues, with the market being characterised by a decline in low-wage formal employment opportunities and higher earnings/better working conditions for white- and blue-collar workers as a result of an enduring skills shortage. The same diagnosis was reached by a separate study undertaken by the Reserve Bank which concluded that the country needed to triple the growth rate of skilled labour, thereby significantly increasing the pool of skilled workers and reducing their cost, as firms can expand their skills base without bidding-up wages (Faulkner et al., 2013). Based on an economic model, this study predicts that relieving the skills constraint will raise potential growth to 6.7% by 2025, but that this result will require long-term reform across the education and training spectrum.

The divergence between labour market conditions for unskilled vs skilled labour is an enduring feature of apartheid policies which specifically sought to establish and preserve high wages and protected incomes for a minority (Seekings, 2015). Policies such as trade liberalisation and the promotion of a high-productivity growth path have favoured capital-intensive over labour intensive firms, resulting in rising real wages for the employed in 2014 compared to 1994 (Nattrass and Seekings, 2015; Seekings, 2015) (see Figure 2). As a result, the benefits of the economic growth since 1994 have largely been experienced by the lower and upper middle classes, with the poor and unemployed being excluded.

Better paid (in real terms) but static employment (as a proportion of the total labour force) has been accompanied by increasing capital intensity and labour productivity, as also shown in Figure 2. The rapid increase in both capital and

productivity is part of a global trend and reflects general increases in output as a consequence of technology. Studies on the source of economic growth and labour productivity in South Africa were undertaken in the early 2000s, as reported by the OECD (2007). The work used the standard approach of growth accounting and considered the relative contributions of capital, labour and total factor productivity, where the latter represents increases in productivity as a consequence of changes in technology (and other efficiency factors). It was concluded that over the decade 1995 to 2004, total factor productivity was the most import driver of economic growth, exceeding the contributions of labour and capital, and reflecting increases in efficiency as a consequence of more open international trade and imported technology (Du Plessis and Smit, 2006).

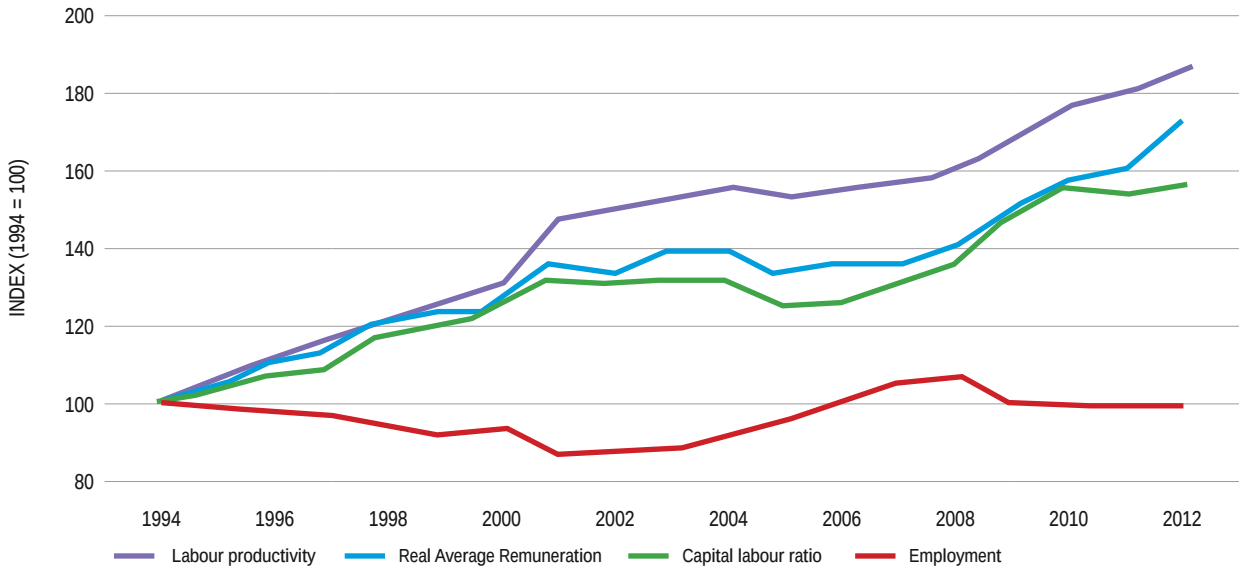


Figure 2. Trends in labour productivity, capital ratio and employment; 1994 to 2012

Although it could be argued that the main outcome of the post-1994 economic policies (rising wages, static employment and increasing capital intensity) is a result of poor policy choices (such as trade liberalisation), the problem could also be interpreted as a consequence of the failure in the economy to realise the targets of the strategy. In other words, the strategy itself may have been appropriate, but its implementation has been widely deficient. Indeed the latter argument is partly supported by the data from the performance of the economy in respect of diversification and high technology manufacturing; this data is now covered in more detail.

Any review of past performance needs to be explicit about methodology. In the first part of this section, the performance of the South African economy has been reviewed using time series data with some reference to growth accounting. In the next part we use a cross-country, longitudinal approach, which compares the South African economy vs the performance of the Brazilian economy over the same period. Brazil is a useful comparator for a number of reasons; it is a BRICS country, it has a similarly sized manufacturing sector in proportion to the total economy and had an equivalent GDP per capita in 2002 (see Figure 3).

Since 2002, the GDP per capita of Brazil has nearly doubled that of South Africa. The difference between the two countries does not seem to lie in manufacturing, since the growth in both manufacturing value added and manufacturing exports (total and high technology) has been equivalent for the two countries (see Table 2). However a significant difference between the two countries exists in respect of innovation performance, as measured by patent registration at the United States Patent Office and royalty/licence receipts, with the Brazilian innovation system performing on average two to three times better than South Africa.

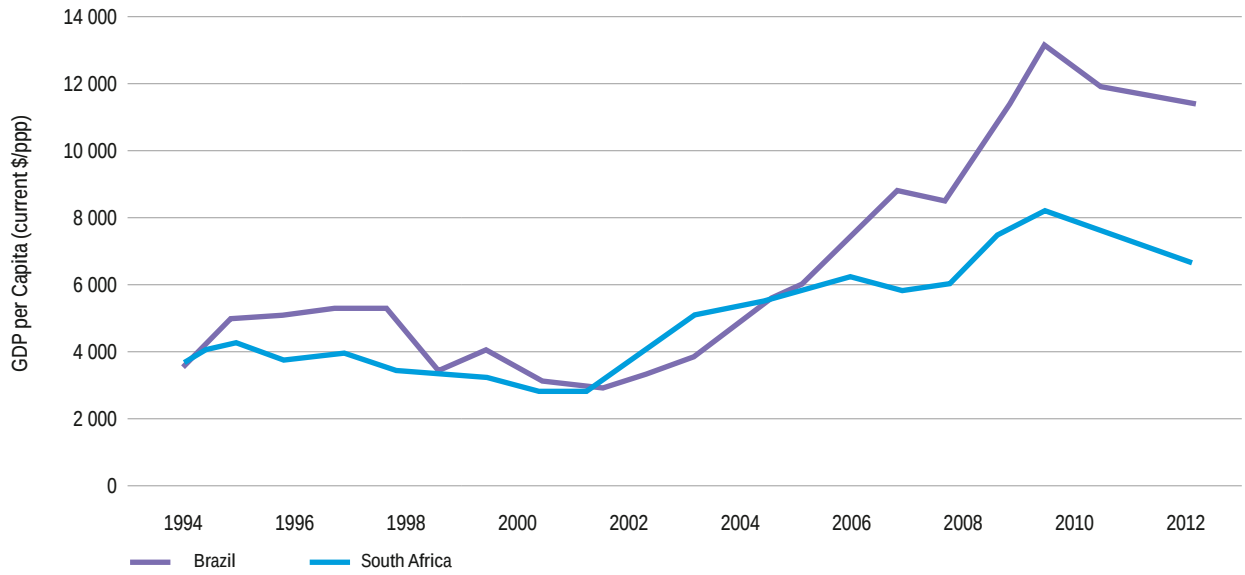


Figure 3. GDP per capita for Brazil and South Africa

Furthermore, Brazil significantly outperforms South Africa in respect of entrepreneurship, with a highly favourable culture, a positive attitude towards self-employment, a perception of significant opportunity and a widespread confidence in having the necessary skills to become an entrepreneur. According to the Global Entrepreneurship Monitor, Brazil exceeds South Africa in all aspects relating to entrepreneurs, and is more than three times higher on the key indicator of total early-stage entrepreneurial activity (see Table 2) (Herrington et al., 2014). The problem of limited formation of new firms is also highlighted by the OECD's economic survey of South Africa which notes that "SMEs face high regulatory burdens, and the pattern of social housing hinders business opportunities" (OECD, 2015). The report recommends that employment opportunities should be improved by building new, denser settlements closer to the economic hubs, regulatory burdens for SMEs should be reduced and the powers of regulators should be increased to allow entry of third-party providers in protected markets.

Table 2. Comparative economic performance; Brazil and South Africa

METRIC	UNITS	BRAZIL	SOUTH AFRICA
Growth in Manufacturing Value Added (2000 to 2010)	%	27.5%	26%
Growth in Manufacturing Exports (2000 to 2010)	%	227%	234%
Growth in High Technology Exports (2000 to 2009)	%	145%	144%
Number of researchers (2010)	No/million population	710	364
Growth in researchers per million population (2000 to 2010)	%	168%	121%
Growth in Royalty and Licence Receipts (2000 to 2010)	%	318%	120%
Number of patents at United States Patent Office (2010)	Number	219	142
Growth in patents at United States Patent Office	%	194%	114%
Total Early-stage Entrepreneurial Activity	%	17%	7%

Although this data does not indicate any direct causation between innovation and GDP growth, it does confirm the previous perspective, namely that the labour market conditions in South Africa continue to reflect the apartheid legacy of protected employment for skilled and semi-skilled workers. For instance, although R&D expenditures have risen over the period 2000 to 2014, this increase in expenditure has not translated into increases in innovation output. R&D employment levels have risen only marginally in this period and patent/royalty outputs have been almost static. Key indicators such as the technology balance of payments and the proportion of high technology exports vs imports have been largely unaffected. As argued in Section 2.2.1 of the Situational Analysis, a significant increase in the latter is the primary means by which innovation-led growth will be realised. Although the strategy may remain valid, its implementation has been largely hindered by adverse labour market conditions, low levels of entrepreneurship and the slow response of the educational system to deliver human resources for a high technology economy.

In summary, path dependence remains a key determinant in the economy with relatively little change in several aspects. The post-apartheid state acquired a system of actors, institutions and policies which had historically paid little attention to the needs of the poor (Mariotti and Fourie, 2014). Although the new state has performed well in several respects, including the management of knowledge, the ability to collect taxes, and the operation of a substantial welfare state, it has been deficient in development planning and implementation and, as a result, largely ineffective as a developmental state. Key actors such as the economic elite have retained a powerful influence over policy to the extent that little change to the distributional patterns of income have been possible. Moreover the potential of innovation-led growth has been under-realised by static performance of the innovation system.

2.2.2 Policy Challenges

In terms of policy, it appears that South Africa walks on a tightrope between opposing constituencies. For instance, since 1994 South Africa's industrial policy has been based on opening its markets to international competition and using supply side measures to raise the competitiveness of its manufacturing sector. Demand-led growth was never a possibility considering the inherited high levels of debt and the dominance of neo-liberal policies of the period (Nattrass and Seekings, 2015). As a result, the government policy followed a more constrained path in terms of investment in public infrastructure (including transport, education, housing, energy and security) than would otherwise have been possible. On the other hand, the consequences of its supply-side emphasis were extensive de-industrialisation of various labour-intensive sectors including clothing, footwear and leather bags.

The tension between longer term policies/expenditure and shorter term welfare state measures to reduce poverty has been particularly evident in innovation policy, a factor which was identified in 2007 by the OECD review of the country's innovation system (OECD, 2007). The latter report noted that, in addition to supporting the skills and innovation needs of the first economy, it would be imperative for STI to provide tangible benefits to the majority of the population, particularly the second economy, in order to secure sustained political support for STI. The report recommended a dual strategy with efforts to stimulate both the supply side (principally human resources) and the demand side (markets for pro-poor goods and services) of the second economy.

This duality of policy has been evident in a number of sectors with some analysts describing South Africa as an uncomfortable and unproductive mix between social and liberal democratic policies, as well as between labour-intensive and technology-intensive growth strategies. It is evident from the previous section that social democratic policies have done little for the unemployed; while the focus on innovation and competitiveness has increased the demand for, and the relative income of highly skilled workers, it has done little for the unskilled or the unemployed.

The key tensions between the various interest groups, as identified by the OECD review, remain evident with the principal challenges being to create employment without undermining the rights of existing workers to a living wage; to

provide welfare without reducing public investment in education, infrastructure and knowledge; to support innovation within the confines of international agreements; and legislation on intellectual property, the environment and finance. Furthermore these tensions must be managed within the context of static or even declining government revenues, as shown in Figure 4.

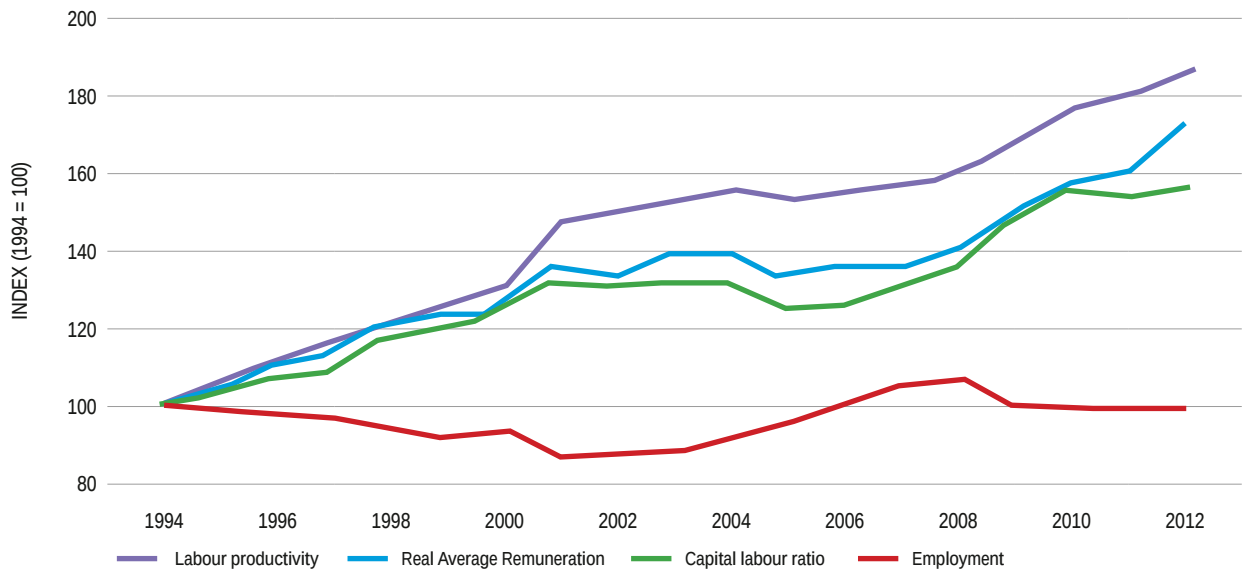


Figure 4. Government revenue in real terms; 1994 to 2014

In the subsequent sections, issues relating to tensions surrounding innovation policy within an environment of fiscal constraint are further elaborated; in particular Chapter 9 characterises South Africa's innovation policy mix with the objective of firstly providing a rationale for the choice of the innovation systems approach, and secondly identifying the present gaps and weaknesses which should be addressed in any revision thereof.

2.2.3 Business Research and Development

The 2007 OECD review of the NSI described the high level of business enterprise performance of R&D (BERD) as a proportion of total R&D performance as a "virtue which reflected industry's ability to build on existing strengths, especially in resource-intensive sectors" (OECD, 2007). Since this review, BERD has declined alarmingly since 2008 and is now about 60% of its peak value. This change is ascribed to a number of factors including the partial demise of several large companies which were responsible for the bulk of BERD (e.g. Anglo American and Eskom), the movement of local R&D to other countries (De Beers and others), the closure of the Pebble Bed Modular Reactor, a decrease in public funding for experimental development (see Figure 5), and a steep decline in the business confidence index.

The DST has adopted a broad set of instruments to deal with this problem, including the introduction of the R&D tax incentive, the establishment of the Technology Innovation Agency and the direct funding BERD in certain sectors such as energy, biotechnology and pharmaceuticals. More details on these interventions and how they could be further improved are given in Section 5.4.

2.2.4 Institutions and Governance

The 2007 OECD report made a number of highly specific recommendations as to how the governance of the NSI could be improved in order to support innovation. In particular, the review called for the strengthening of the networks between the universities and industry, a more prominent role of the public research institutions in supporting innovation in private firms (not just for firms), ongoing support for the universities as centres of learning, scholarship and world class research, and the establishment of a "forum at the highest level of government that plays a strong integrative role across the whole of government, not least in balancing the various policies and instruments that in practice combine to make up innovation and research policy".

All of these issues are discussed in more detail within this report. The governance in general is covered in Section 2.2.4, governance of the science councils is discussed in Section 6.1, resource allocation to the universities is reviewed in Section 5.3, and the promotion of linkages between actors discussed in Section 6.3.

2.3 REQUIREMENTS OF THE WHITE PAPER

2.3.1 Promoting Competitiveness and Employment

The White Paper is explicit on the questions of employment creation and competitiveness, noting that post-1994 South African businesses faced highly competitive international markets and would require incentives and support from government to meet the new challenges. It was proposed that this support should include sustaining SMMEs, redistributing public funds from government facilities to R&D executed in the private sector, building effective technology transfer mechanisms and developing entrepreneurship.

The Innovation Fund (IF) was proposed as one of the primary instruments to support technology transfer and commercialisation. The impact and evolution of this fund is covered in Section 5.2. In this section, progress towards the establishment of competitive industries based on technological innovation is discussed more broadly.

As noted in Section 2.2, the system has not moved forward in most of the key aspects relating to the requirements for competitiveness, employment creation and diversification into higher value added products. The reasons for the poor outcomes appear to be twofold; firstly the system is still overly S&T focussed and secondly the commercialisation agencies have failed to meet the need for the support of experimental development.

This perspective is supported by two sets of data. Although the total funds for R&D have increased, little of the additional funding has been allocated to experimental development, with the result that the latter has fallen as a proportion of total R&D (see Figure 5). Furthermore the proportion of government funding for R&D (referred to as Government budget appropriations or outlays on R&D or GBOARD) used to support business R&D performance has fallen from its highest levels of 25% in 2008 to about 5% in 2012/13, where the latter year is the last year for which data is available (see Figure 6).

These trends are the opposite of the redistribution as proposed by the White Paper and contradict the perspective that public funding of R&D should be more balanced with less funding of basic and applied research. Much of the additional public funding for R&D has instead been allocated to the universities, which are rapidly approaching the same level of R&D performance as business enterprises.

The problem of large-scale funding for development work (such as large prototypes, agricultural biotech, pharmaceuticals and energy generation) has been a systemic failure over a long period. For instance, the problem was identified in the development of the National R&D Strategy (Department of Science and Technology, 2002) and was one of the reasons for the formation of Triumph Venture Capital and Bioventures, both of which were backed by state funding (DST and IDC).

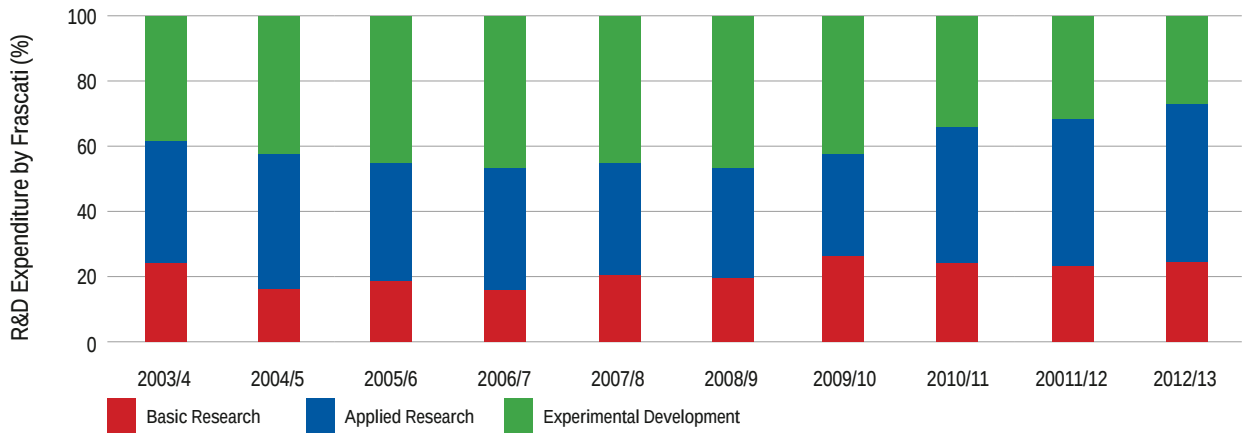


Figure 5. R&D performance and expenditure based on Frascati category

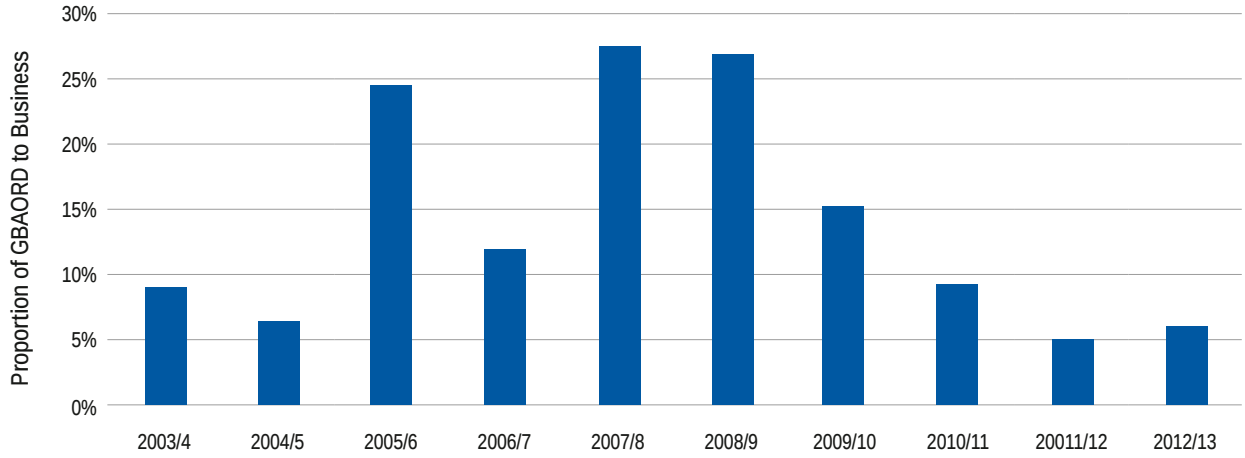


Figure 6. Funding of BERD by government (% of GBAORD)

However both funds were found to be not sustainable. The risks of early stage development are too high and the success rates too low to sustain a venture capital model, regardless of who provides the funding. In the classic model, the state has to intervene in this area and provide the funding/shoulder the risk (Mazzucato, 2013). In this way, the state can facilitate improvements in the competitiveness of existing industries and the creation of employment through the establishment of new industries.

Unfortunately the track record of the last twenty years is one of competitiveness vs. employment rather than competitiveness and employment. As noted in Section 2.2.1, productivity (and by implication) competitiveness has increased, accompanied by greater capital and reduced labour intensity. In other words, industries have become more competitive at the expense of employment and with the assistance of technology. This result is the opposite of the White Paper intentions and a number of reasons for this discrepancy have already been proposed including the issues of path dependence, human resources and the powerful influence of labour on government industrial policy.

2.3.2 Developing Human Resources

See Chapter 7.

2.3.3 Working towards Environmental Sustainability

See Section 4.2.

2.3.3.1 Promoting an Information Society

The White Paper states unequivocally that the development in South Africa of an information society is urgently required, where the latter refers to the creation of an equitable information order characterised by the appropriate balance between personal and public access, support for education, public services, social development and a structure which empowers ICT innovation.

Although South Africa has comparable levels of internet usage to many middle income countries (see Figure 7), this usage is driven mainly by mobile platforms (see Figure 8) and not fixed-line broadband (see Figure 9). Furthermore mobile broadband is based on personal subscriptions and South Africa is rated as one of the most expensive countries amongst the 17 African countries included in the African Broadband Price Index (Calandro et al., 2014). As a result South Africa continues to lag behind other middle-income countries in critical areas such as e-government, and its efforts towards affordable public access need to be urgently re-invigorated in order to ensure that open innovation and other benefits of the information society are realised.

As noted in Table 6, the adoption of the broadband policy document "South Africa Connect: Creating Opportunity, Ensuring Inclusion" is an important step but the Department of Communications appears to be moving in the opposite direction with little being done to implement this strategy. Experts in this area consider that the issue of congestion and cost, particularly in the rapidly growing sector of mobile broadband, can be resolved by the conclusion of the long-awaited policy directive on the assignment of Long-Term Evolution, also known as the 4G or LTE, spectrum (Calandro et al., 2014). In addition, the department needs to develop specific plans to realise the goals of SA Connect, which include:

- give every South African access to a broadband connection at a cost of 2.5% or less of the average monthly income
- offer 90% of South Africans a minimum speed of 5 megabits per second (Mbps)
- provide at least 50% of the population access to 100Mbps broadband by 2020.

2.3.4 Knowledge Generation

See Section 5.3, Chapter 7 and Section 8.4.

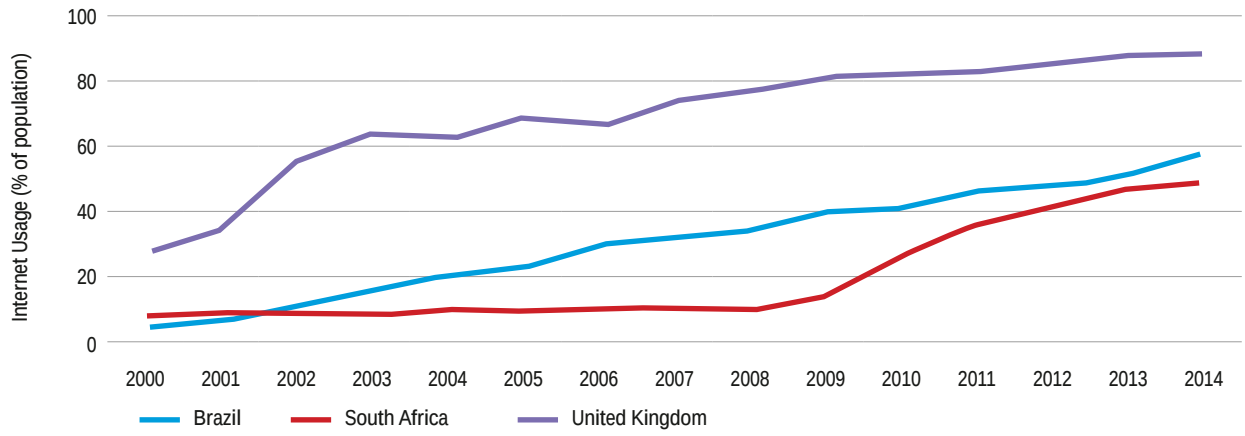


Figure 7. Growth in internet usage; South Africa vs Brazil and United Kingdom

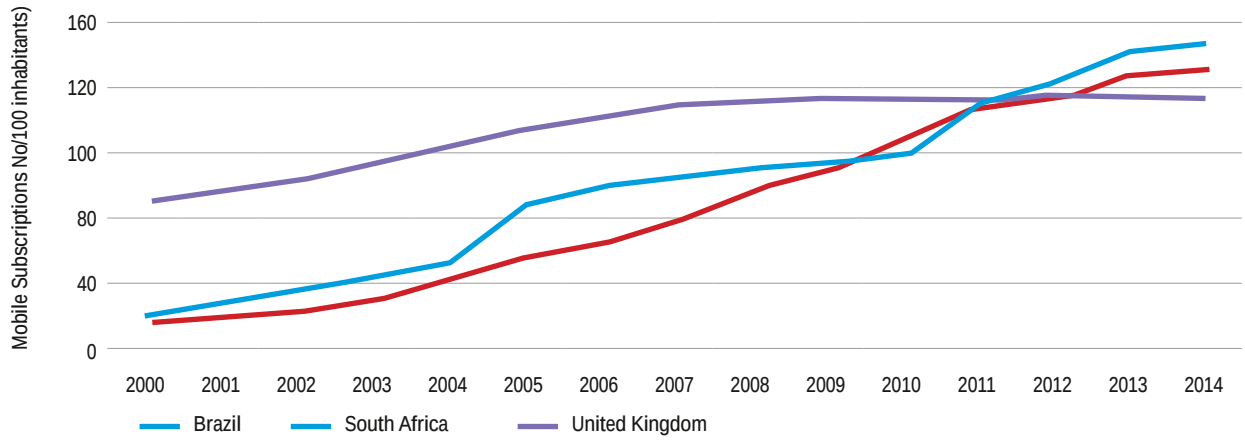


Figure 8. Growth in mobile subscriptions; South Africa vs Brazil and United

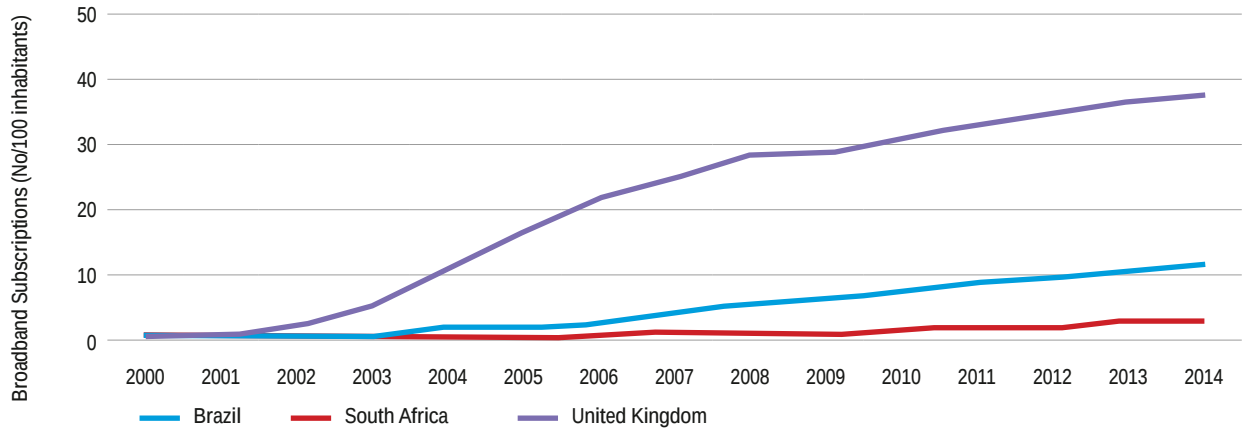


Figure 9. Growth in broadband subscribers; South Africa vs Brazil and United Kingdom

Chapter 3

Policy Formulation and Resource Allocation

The key terms of innovation and systems of innovation have already been defined (see the introduction to Chapter 1). These definitions refer to the constituents of systems of innovation as being the sum of the components plus the relations between the components. Furthermore the main components of the NSI are a set of organisations and the institutions where the former are the formal structures with an explicit purpose and are also referred to as the players or actors (Edquist, 2010). Furthermore it is assumed that the NSI has a function (to pursue innovation and its processes) and an associated set of activities (the determinants of the function including development, diffusion and use of innovation).

However there is some ambiguity or even confusion over the use of the term institution. The NSI literature defines this term as 'the set of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organisations' (Edquist, 2010). The White Paper itself adopts a different definition, referring to institutions as those organisations which form part of Government's set of organisations that guide and regulate the NSI, including for instance the National Advisory Council on Innovation, and the Department of Science and Technology.

In this review, the latter definition will be adopted; the 'rules of the game' will instead be referred to as the regulatory framework, which implies a much narrower use of the term but avoids any ambiguity in respect of the distinction between organisations and institutions.

3.1 INSTITUTIONAL MECHANISMS

3.1.1 Proposals of the White Paper

Well-funded, well-functioning and well-coordinated institutional mechanisms are essential to the productive operation of the NSI, an issue which has been highlighted in all sections of the literature and all reviews of the NSI. It is therefore not surprising that the subject of institutional mechanisms should be the starting point of the White Paper.

Reflecting on the institutional arrangements in respect of government initiatives relating to the stimulation of South Africa's national system of innovation as "(these arrangements) are spread throughout the structures of government in ways which are poorly co-ordinated and frequently overlooked in policy debates - a heritage of the past", the White Paper made a number of proposals including the strengthening of existing institutions. For instance, it noted that "to ensure concern for promoting the national system of innovation remains prominent among the list of governmental priorities", the government had already established:

- a national ministry responsible for science and technology, namely the Ministry of Arts, Culture, Science and Technology
- a Ministers Committee for Science and Technology (MCST), a committee composed of all Ministers whose portfolios encompass a significant Science and Technology component and is the principal policy coordinating and information disseminating body for science and technology matters across government

- a Department of Arts, Culture, Science and Technology (DACST) to support the Minister (subsequently split to the Department of Science and Technology and the Department of Arts and Culture), whose terms of reference were defined by the White Paper as follows:
    - promote coherence and consistency in the government's approach to stimulating South Africa's national system of innovation in general, and in its commitment to the support of science, engineering and technology development in particular
    - promote and co-ordinate interdepartmental and government-wide initiatives relating to the support of innovation and technology diffusion
    - direct the preparation of a government-wide Science Budget, in order to permit ministers to assess relative spending priorities, on a multi-year basis, across the full spectrum of government's activities in support of innovation
    - design and present to Ministers a comprehensive system for the management of government science, engineering and technology institutions
    - ensure that the management system referred to above includes adequate arrangements for evaluation of performance against international best practice, and that output measures are in place to indicate the nature of the contribution being made by government Science, Engineering and Technology Institutions (SETIs) to South Africa's development
    - manage the process of evaluation and review created within the management system described above and to recommend to Ministers any actions necessary as a result of assessments carried out
    - represent the government in formal international and intergovernmental negotiations dealing with science, engineering and technology, as well as with the promotion of innovation
    - provide a link between government and the activities of the National Advisory Council on Innovation
    - commission or conduct any policy research necessary to the fulfilment of the responsibilities set out above.

The White Paper then proposed that the following bodies be established:

- National Advisory Council on Innovation (NACI)
- National Research Foundation (NRF), which will be responsible for support to research and research capacity building.
- Innovation Fund (IF)
- National Facilities for Research.

3.1.2 Progress in Implementation

Progress in respect of all the actions in this section is shown in Table 4 and Table 5. It is apparent from these tables that the specific initiatives have either been completed or are ongoing, the one notable exception being the Ministerial Council on Science and Technology which was disbanded in 1999 along with other inter-ministerial councils.

It is also apparent that the White Paper remains central to the vision, mission and objectives of the Department of Science and Technology (DST), with the Director General recently re-affirming in his presentation to Parliament on the department's 2015 strategy that "the DST derives its mandate from the 1996 White Paper on Science and Technology, which introduced the concept of a National System of Innovation" (Department of Science and Technology, 2015; Mjwara, 2015). The key goals of the department can be mapped against the White Paper's original goals as shown in Table 3.

Table 3. Comparison of White Paper and DST goals

WHITE PAPER GOAL	DST GOAL
Establishment of an efficient, well co-ordinated and integrated system of technological and social innovation	A responsive, coordinated and efficient NSI
The importance of knowledge generation	Increased knowledge generation
Developing human resources	Human capital development
Promoting competitiveness and employment creation	Using knowledge for economic development
Stakeholders, especially those who were formerly marginalised, are part of a more inclusive and consultative approach to policy decision-making and resource allocation for science and technology	Knowledge utilisation for inclusive development.

Notwithstanding the centrality of the White Paper goals to the DST's strategic plan, the attainment of one of the more fundamental goals, namely the coordination of the NSI, is unrealised to a meaningful extent. Moreover other departments seemed to have paid little attention to the important issues of research and innovation, as revealed by a word count of these terms in their respective annual reports (see Figure 10; the data has been generated using the frequency of each word relative to the total words and then normalised for the frequency count of the National Development Plan for the same word).

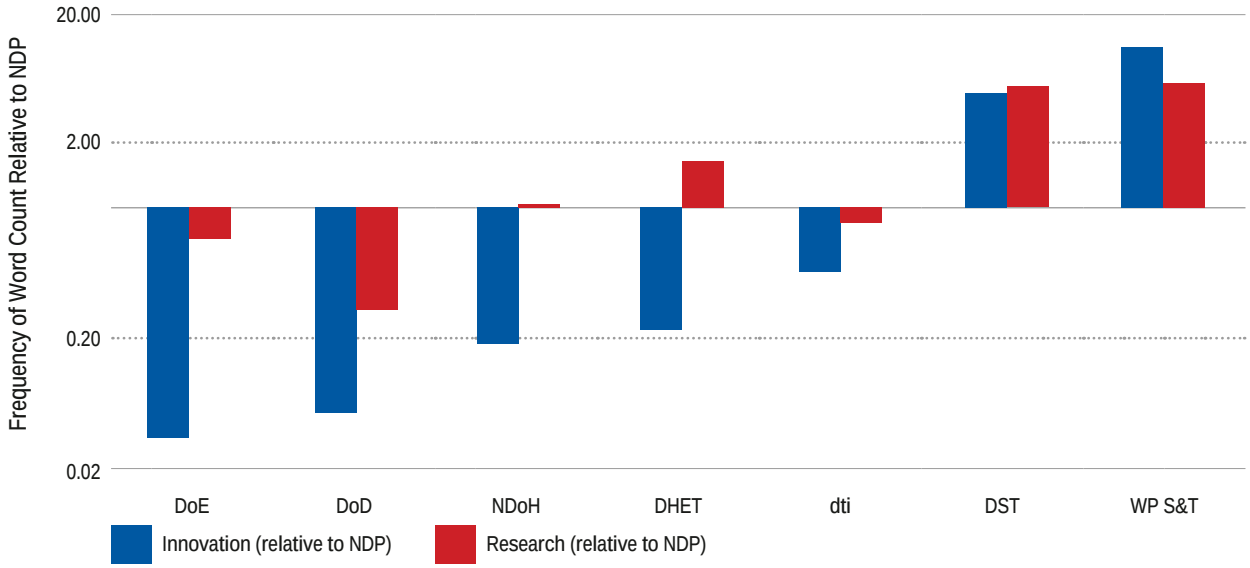


Figure 10. Word frequency (research and innovation) in departmental annual reports

This issue has been raised in previous reviews and reflects the complexity of achieving overall integration of a culture and concept which cuts across multiple government departments. However the abandonment of the MCST indicates a lack of commitment to realising the potential of innovation. Alternative means of raising the profile of S&T within the Executive need to be developed and implemented.

Table 4. Implementation of institutional mechanisms

ACTION	PROGRESS	COMMENT
Establish National Advisory Council on Innovation	Established in 1997	The organisation was established in 1997 in accordance with the recommendations of the White Paper. Although playing a clear role in providing advice to the Minister of Science and Technology on key issues, its impact has been criticised and it has been the subject of several reviews, including those undertaken in 2003, 2007 (as part of the OECD review), 2008, and 2012 (Department of Science and Technology, 2012a). One of the issues is that, from a policy perspective, it is required to have a wider influence across the NSI, but this role is 'hamstrung' by the fact that it is administered within the DST and reports to the MST (OECD, 2007). The Ministerial Review even proposed the scrapping of NACI, and its replacement with a new statutory Office for Research and Innovation Policy (ORIP), which would have a broader mandate and report indirectly to the Deputy President (through a National Council on Research and Innovation). The reports have also made other recommendations including a strengthening of its role, greater autonomy from the DST, the inclusion of the private sector in its membership and work, and greater emphasis on creating coherence on innovation-related activities and policies across government.
Establish the National Research Foundation (NRF)	Established in 1998	The NRF was established through the National Research Foundation Act (Act No 23 of 1998). The new entity incorporated the functions of the research funding agencies that were previously servicing various sections of the research community, namely the former Centre for Science Development (CSD) of the Human Sciences Research Council (HSRC) and the former Foundation for Research Development (FRD), the latter including several National Research Facilities.
Establish the Innovation Fund	Established in 2000	The Innovation Fund was established in 2000 with the objectives of promoting technological innovation within the research community; facilitating a reallocation of funds from the historical patterns of government science towards the key issues of competitiveness, quality of life, environmental sustainability and harnessing information technology; increasing the extent to which funds for the activities of government SETIs are obtained via competitive processes; and promoting cross-sectoral collaboration within South Africa's NSI. The fund was latter absorbed into the Technology Innovation Agency (www.tia.org.za) which has a similar mandate.
Establish the National Facilities for Research	Established with the NRF in 1998	The national research facilities now form part of the NRF (see http://www.nrf.ac.za/research-platforms/national-facilities) and are administered within the structure and budget of this funding agency.
Ongoing operation of the MCST	Abandoned in 1999	The MCST was disbanded in 1999 due to the proliferation of Ministerial Committees under the Mandela presidency (19 altogether). These committees suffered from poor attendance and delegation to increasingly junior officials. President Mbeki made the decision to disband the Ministerial Committees and increase the number of Cabinet Committees from 3 to 6; the meetings of the latter were well attended and minutes were taken. Under the Zuma Presidency the number of Ministerial Committees has again expanded but implementation of the respective portfolios appears to have weakened.
Terms of reference for the DST	Ongoing	See Table 5

Table 5. Fulfilment of DST terms of reference

OBJECTIVE	PROGRESS
Promote coherence and consistency in the government's approach to stimulating South Africa's national system of innovation in general, and in its commitment to the support of science, engineering and technology development in particular. AND Promote and co-ordinate interdepartmental and government-wide initiatives relating to the support of innovation and technology diffusion.	These two objectives are perhaps the most contested aspects of the DST's terms of reference, with recent reviews arguing that the department has not been successful in co-ordinating interdepartmental initiatives. For instance, the recent Ministerial Review (Department of Science and Technology, 2012a) stated that: "Apart from the apparently short-lived inter-ministerial MCST and the intrinsically 'hamstrung' design of NACI, the most critical structural issue in the NSI created by the White Paper was the setting up of a separate Ministry and Department of Science and Technology to achieve ambitious systemic national goals, mostly in other ministers' or departments' 'backyards'. This was likely to lead to frustration at the level of the Ministry and Department of S&T as it sought to lead NSI development mostly by energetic advocacy at the highest level (Cabinet and Ministerial cluster), or by default within its own circumscribed domain. It is true to say that no other line department of government (except perhaps the Department of Trade and Industry) has shown much visible interest in the NSI as a 'mental model' crucial to its own strategies and preoccupations – that has been left to the DST." However the mandate is well understood and consistently articulated. For instance in a recent presentation to the Portfolio Committee on Science and Technology, the Director General was clear about the role of the DST stating that "the DST, as the custodial coordinator for the development of the NSI, influences this system through key strategies such as the National Research and Development Strategy and the Ten-Year Innovation Plan. The latter, particularly, seeks to contribute to the transformation of the South African economy from a resource-based economy into a knowledge-based economy, in which the production and dissemination of knowledge will lead to economic benefits and enrich all fields of human endeavour. In this regard, the measure of success will be the level to which science, technology and innovation play a driving role in enhancing productivity, economic growth and socio-economic development." (Mjwara, 2015)
Direct the preparation of a government-wide Science Budget, in order to permit ministers to assess relative spending priorities, on a multi-year basis, across the full spectrum of government's activities in support of innovation.	See Section 5.1
Design and present to Ministers a comprehensive system for the management of government science, engineering and technology institutions, in order to ensure that their roles within the national system of **innovation are clearly defined, that they have clearly defined and understood objectives,** and that they undertake their mandate with **efficiency, economy and effectiveness**	See Section 6.1
Ensure that the management system referred to above includes adequate arrangements for evaluation of performance against international best practice, and that output measures are in place to indicate the nature of the contribution being made by government SETIs to South Africa's development	See Section 6.2

OBJECTIVE	PROGRESS
Manage the process of evaluation and review created within the management system described above and to recommend to Ministers any actions necessary as a result of assessments carried out	See Section 6.1
Represent the government in formal international and intergovernmental negotiations dealing with science, engineering and technology and with the promotion of innovation	This role has become one of the core functions of the DST although it accounts for a small proportion (1.6%) of the total budget (Department of Science and Technology, 2015; Mjwara, 2015). Further details are provided in Section 6.4.
Provide a link between government and the activities of the National Advisory Council on Innovation	This action is complete; NACI reports directly to the DST. Indeed this is one of the concerns of the Ministerial Review which recommended that NACI be replaced by the new statutory Office for Research and Innovation Policy at arms-length from the DST and be responsible for compiling evidence across the system to inform policy planning by the DST and other bodies (Department of Science and Technology, 2012a).
Commission or conduct any policy **research necessary to the fulfilment of the** responsibilities set out above	This work is ongoing; examples of recent research include the recent Ministerial review of the science and technology landscape, and the annual R&D surveys. However there is an important aspect to this work which appears to have been neglected. The White Paper refers to two important surveys as a means of generating background data to inform the development of strategy and policy, namely the Research and Technology Audit, and the Research and Technology Foresight. Although both studies were completed, the use of foresight studies to inform the allocation of public R&D on an ongoing basis has not been continued. As a result, it could be argued that the DST has been haphazard in its approach to the matching of technology trends with market need and, as a consequence, missed a number of key opportunities (see also Table 6).

3.2 INPUTS TO POLICY MAKING

3.2.1 Proposals of the White Paper

The White Paper defined a number of areas in which it considered Government could be more proactive in respect of sourcing data to inform policy making including the following:

- information society
- results of the research and technology audit
- research and technology foresight.

The connection to S&T policy is clear; evidence-based policy development is essential for the sustained impact and potential benefits to be derived from the latter. The following key actions were identified by the WP:

- Information Society
  - facilitating the more intense and widespread use of information technologies (IT) by all those participating in the development process, particularly government and communities
  - using the opportunities presented by IT in improving government operations and the growth/competitiveness of all South African business.

- Science and Technology Audit
  - conducting a comprehensive Research and Technology Audit including an innovation survey, assessment of existing government interventions and completion of an inventory
- Research and Technology Foresight
  - conducting the foresight exercise with particular attention to the associated benefits of communication; concentration; co-ordination; consensus; comprehension and commitment

3.2.2 Progress in Implementation

All of the actions in the section above have been completed or addressed to some extent; details are given in Table 6.

However it is noted that, with reference to the section on the information society, it is firstly not clear why this section is included under 'inputs to policy making' and secondly it is noted that the recommendations are at a very general level, making it difficult to undertake a formal evaluation. It is apparent in South Africa that information technology has been widely applied across all sectors of society and is being used as initially proposed by the White Paper. However, given the progress made by other countries in providing access to broadband, e-government and more broadly the use of the information technology infrastructure, it is apparent that the realisation of an information society in South Africa is not at the desired level.

Table 6. Progress on inputs to policy making

ITEM	PROGRESS AND DATE	COMMENT
Information Society	Several initiatives	A number of initiatives have been completed or are ongoing, including the development of the Information and Communication Technology Research, Development and Innovation (ICT RDI) Roadmap, which produces an annual update (see http://www.dst.gov.za/images/Attachments%20/ ICT_RDI_Annual_Update_2013_2.pdf) The most important general document in this area is the policy document "South Africa Connect: Creating opportunity, ensuring inclusion in South Africa's Broadband Policy". The document sets a number of well-defined targets for broadband access including that 90% of the population should have access to broadband at speeds of at least 5 Mbps (Department of Communications, 2013) .
R&D Survey	Annual survey	R&D surveys have been undertaken on an annual basis since 2001, including information on funding, performance, number of researchers and Frascati category. There have also been a number of articles on the results of the survey (Mustapha et al., 2015; Kahn, 2013; Kaplan, 2008; Kaplan, 2004)
Innovation Survey	Two surveys completed	Two innovation surveys have been conducted (Moses et al., 2012; Oerlemans et al., 2001). However the longer term attention to the measurement of innovation, and hence the design of appropriate policy instruments to address weaknesses in the system, remain a challenge, not just in South Africa.
S&T Audit	Single audit completed	The science and technology audit was published in 1998 and covered the five areas of Scientific and Technological Infrastructure; Human Resources in Science, Engineering and Technology; Scholarship, Research and Development; Technology Base of the South African Business Sector; and Research and Training Equipment in South Africa. Further information is provided in Section 8.5

ITEM	PROGRESS AND DATE	COMMENT
Research and Technology Foresight	Single foresight study completed	The White Paper noted that 'technological advance derives increasingly from the matching of technical insight with identified needs' and identified the needs for a foresight exercise to inform R&D investments by the public and private sectors. One such study was completed covering a broad range of different sectors including energy, agriculture, environment and manufacturing. Although an objective of the study was to identify priorities for publicly funded research, there is little evidence that this result, or any of the other intended outputs, were realised. Indeed, the identification of funding priorities by the Department of Science and Technology, and more broadly by Government, seems to have followed a rather inconsistent approach (see Section 5.1 and Walwyn and Sithole (2010))

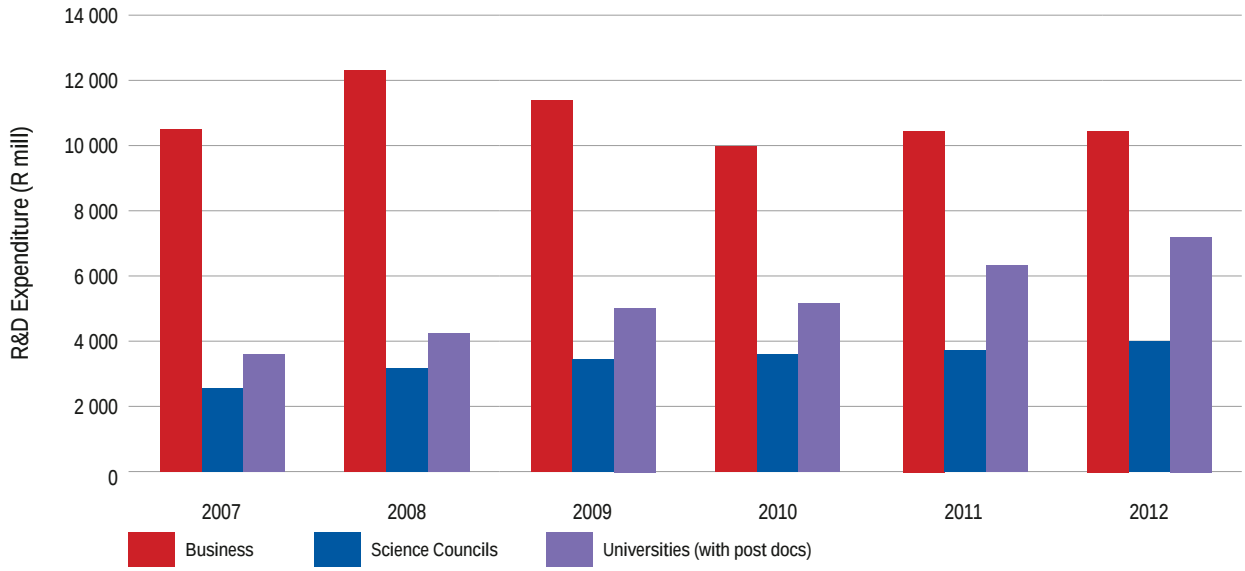


Figure 11. Nominal R&D expenditure in South Africa; 2007 to 2012

3.3 INTERACTION WITH OTHER POLICIES

3.3.1 Other Major Policy Influences

Under this section of the review, the relationship of the White Paper to other main government policies is described. The White Paper states that the policy "…is specifically designed to reinforce the pillars of the Growth and Development Strategy" where the latter was government's overall policy document at the time. This was later replaced by the National Development Plan (NDP), which is still in place and defines government's strategic direction until 2030.

Other relevant prevailing policies are the National Industrial Policy Framework (NIPF) and the Industrial Policy Action Plan (IPAP). The latter seeks to advance economic growth and employment, particularly in the manufacturing sector. This section reviews the interaction between S&T policy and these two strategy documents.

3.3.1.1 The National Industrial Policy Framework and Industrial Policy Action Plan

Relevance to S&T Policy

Industrial Policy is at the centre of the government's strategy for overall growth and development. Enhancing the competitive capacities of existing firms has a strong technological dimension as does the emergence and growth of new firms, many of which seek to compete on the basis of innovation, whether in the products or the process workplace. The growth of existing firms and the growth of new technology-based firms, in turn, serve to enhance technological capacities and the spread or diffusion of these enhanced capacities more broadly. Industrial policy and innovation and policies to enhance S&T are therefore deeply intertwined.

Progress in Implementation

Under the heading of Innovation and Technology, the NIPF outlines a differentiation in the respective roles of the DST and the Department of Trade and Industry (dti):

> "The DST's National Research and Development Strategy sets the overarching framework for technological interventions, particularly on the research side of R&D. The focus of the dti's efforts will be weighted heavily towards the development side of R&D." (Department of Trade and Industry, 2007b)

The NIPF recognises the need for closer collaboration with DST:

> "There is a need for greater coherence and collaboration between the dti and DST in developing such process and product innovation and commercialisation of technologies support measures." (Department of Trade and Industry, 2007b)

The first IPAP reproduces the NIPF section on Innovation and Technology (Department of Trade and Industry, 2007a). However, subsequent IPAPs up until 2012 did not place innovation as a central feature and IPAP 2010/11 – 2012/13 bracketed skills and innovation only in relation to sector support strategies. Innovation was not identified as central to industrial policy and no specific actions were advanced in respect of innovation.

IPAP 2011/12 – 2013/14 was the first IPAP to deal specifically with innovation and technology and to identify them as one of the "seven sets of policies (that) are critical to achieving a scaled-up industrial policy." A number of departments and agencies were identified as critical to effecting and implementing policy. The lead departments/agencies were identified jointly as DST and the dti. Subsequent IPAPs have, in regard to Innovation, identified the dti as the lead department and DST as supporting department together with a number of agencies. The latest IPAP has listed the supporting departments/agencies as the DST, Industrial Development Corporation (IDC), CSIR, Technology Innovation Agency (TIA), NRF and the universities (Department of Trade and Industry, 2014)

Comment

The importance of innovation and technology to industrial development was not fully recognised in the past and is arguably still not fully appreciated. A new analysis of the role that innovation and technology can play in industrial policy and development could serve to strengthen both industrial development and changes in technological innovation. While it is generally agreed that there is a need for strong collaboration between DST and the dti, this has not always been effective. The need for greater coherence and collaboration is explicitly recognised.

In broad terms, the dividing line is said to be that the DST is concerned with the research part and the dti with the development part of R&D. However, since R&D is closely linked and there are feedback loops, this division is not always clear.

We were unable to find any documents that sought to clarify this division and delineate the precise role of DST and the dti. Moreover, the practice belies this distinction. Most critically, TIA receives its finances from DST and has a board appointed by the Minister of S&T. The dti exercises no control or even influence on the goals and/or the functioning of TIA, yet TIA's main task is commercialisation and application, very much the development part of R&D. It may be worth noting that in many countries, the equivalent of TIA falls within the equivalent of dti.

As an alternative arrangement, the accompanying report to this review proposes that a separation of mandates between the two departments could be structured using the two distinct modes of learning within innovation systems, namely learning through 'S&T for innovation', and learning through 'doing, using and interacting', with the DST assuming responsibility for the former and the dti for the latter.

3.3.1.2 The National Development Plan

Relevance to S&T Policy

The NDP characterises South Africa as caught in a development trap. As with many other middle income countries, South Africa is unable to compete at the "bottom end" with low income countries whose costs of labour are far lower, but is simultaneously unable to break into and compete in new higher-value added products currently dominated by high income countries (National Planning Commission, 2011).

The NDP argues that what differentiates successful middle income countries are skill, innovation and technology development or "how much the country invests in human capital, product development and technology", a view which draws from the accepted literature on this issue. According to Felipe et al. (2012), "we view today's development problem as one of how to accumulate productive capabilities and to be able to express them in (i) a more diversified export basket and (ii) in products that require more capabilities (i.e., more complex). We conclude that countries in the middle-income trap have to make efforts to acquire revealed comparative advantage in sophisticated and well-connected products".

It is precisely these areas in which South Africa is currently deficient and should be made the focus of policy attention. S&T, innovation and skill and capabilities are accordingly central to the NDP's objectives for economic growth and exports. The NDP envisages GDP growth rates of 5.4% per annum and of 6% in exports, 2010 - 2030. The NDP aims for growth in employment of 11 million jobs by 2030 with employment growth highly conditional on the rate of economic growth (NDP: 121). Employment growth, in turn, is critical, indeed a *sine qua non*, for reducing inequality, alleviating poverty and addressing a range of social problems.

The NDP accords a far higher status to S&T and innovation and the development of skills and capabilities than previous government strategy documents. It would be no exaggeration to say that success in S&T and innovation is imperative for the success of the NDP.

Comment

There is broad consensus that unemployment is the key problem in South Africa. Accordingly job creation is seen as the key performance indicator for many government policies. However, it is important to understand how S&T and innovation can make a contribution to job creation.

The NDP sees by far the largest share of jobs as being located in the services sector. "In the short to medium term, most jobs are likely to be created in small, often service-oriented businesses aimed at a market of larger firms and households with income. Significantly, these firms are often intensive in mid- and low-skilled employment". And again "A large percentage of the jobs will be created in domestic-oriented activities and in the services sector. Some 90 per

cent of jobs will be created in small and expanding firms.. By 2030, the share of small and medium sized firms in output will grow substantially".

The NDP later identifies more precisely what sectors are likely to experience employment growth. "Most new employment will arise in domestically oriented activities, where global competition is less intense and there is a high labour component. It may be functionally possible to trade in these activities, but in essence, they must take place where the demand exists. Examples include housing, construction, retail, personal services such as hairdressing or cleaning, and business services such as office cleaning or repair."

Small service oriented firms in general are not dependent on and therefore do not undertake S&T or innovation. Housing construction, retail, personal services such as cleaning or repair are the least R&D intensive sectors and activities. According to the NDP, jobs are overwhelmingly likely to be located in firms (small scale), in activities (such as cleaning and repair) and in sectors (such as construction and personal services) where S&T and innovation have very little, if any, direct relevance.

Such small scale service activities directed at the local market are essentially non-traded activities i.e. they do not earn exports nor do they compete with imports. Such activities will have some import content; house construction for example will utilise some imported inputs. Those earning remuneration from such activities will consume some imports.

In brief, the activities in which the NDP suggests employment will grow are consumers of imports while not adding to exports (or reducing imports). The extent to which these activities can expand and hence create employment will therefore depend critically on other traded activities which are export-earning (and hence ensure a favourable balance of payments). S&T and skills/capabilities will be critical to the expansion of the traded sectors. This is particularly valid for manufacturing, which is mostly technology and skill intensive, and for manufactured exports destined for global markets where the competition is intense.

A key objective of policies for STI and skills/capability building is accordingly the enhancement of South Africa's capacity to compete in more sophisticated higher value products, particularly in global markets. This would accord with the central thrust of the NDP.

To firmly align with the NDP, South Africa's S&T system overall and many of its individual policies should be assessed and evaluated accordingly. The Key Performance Indicators (KPIs) for S&T and innovation would relate therefore to assessing this contribution and at a system level might include, for example, the following:

- share of high and medium technology products in SA exports
- the unit value of SA exports
- increase in new non-traditional exports
- increases in New Technology-based Firms
- share of high and medium technology products in GDP.

Utilising such KPIS as comparing South Africa's performance with other comparator countries will provide a key test of the efficacy of S&T policies. The example below shows how South Africa's share of high technology exports has actually declined post 2004 and while South Africa's share was (marginally) greater than Brazil in 1994, it is now less than 40% of that of Brazil.

Table 7. High technology exports in South Africa and Brazil; 1994 to 2010

	HIGH TECHNOLOGY EXPORTS (% OF MANUFACTURED EXPORTS)				
	1994	1998	2002	2006	2010
Brazil	4.60	9.41	16.52	12.08	11.21
South Africa	4.88	8.75	5.16	6.46	4.28

Source: World Bank, 2014.

At a programme level, similar KPIs could be introduced for the bio-economy strategy. For example, success would be measured by the growth in bio-economy exports. All of the KPIS could be assessed against similar measures of performance for comparator countries.

STI has multiple objectives and performs multiple functions, and there exists a wide range of KPIs reflecting this diversity. However, there is a strong case for aligning S&T and innovation with the NDP by particularly emphasising and indeed prioritising these KPIs. While job creation is clearly a top priority for the NDP, the contribution of S&T and innovation should not be assessed by its direct impact on employment. DST struggles to show positive direct contributions of its spending and activities on employment growth. It should redirect attention to the indirect effect that STI has on employment via its impact on growth and exports.

3.3.2 Getting SET on the Agenda of Other Policies and Legislation

The White Paper identifies that a key challenge for S&T is "…in devising means to ensure that government actions across all fields – in trade, education, labour laws and environmental protection, to name but a few – be taken with due consideration of how these actions would affect the climate for innovation…"

Governments everywhere face a major challenge in getting government departments to ensure that their actions and policies are assessed and evaluated for their impact on innovation. There is a further challenge – namely how to get government departments, particularly the large "service" departments such as health, education and transport, to adopt practices themselves that spur innovation (some proposals in this regard are made in the Situational Analysis report).

The White Paper assigns these challenges to DACST in two ways; firstly to promote coherence and consistency in government's approach to the NSI in general and government's support for science, engineering and technology in particular. Secondly to promote and coordinate government-wide initiatives to support innovation and technology diffusion.

One mechanism for securing coordination in government is the governmental clusters which bring together different departments. The DST is a member of the clusters for Economic Sectors, Employment and Infrastructure Development and Social Protection, Community and Human Development.

In addition there are the regular bilateral engagements with other departments. One important engagement has been with the Department of Higher Education and Training (DHET). According to DST "…cooperation with the DHET has led to several important interventions. We have clarified where the DST responsibility for the national research network ends, and where that of the HE sector starts; we have aligned DST/NRF funding priorities with the DHET's New Generation of Academics Programme, a major DHET intervention to recapitalise the HR base of the universities; we are jointly and in collaboration developing relevant policy responses to the very low levels of retention and progression of postgrad students; - to name just a few." (Communication with Thomas Auf der Heyde. 04/09/2015)

The Parliamentary Portfolio Committee (at the time of the White Paper, the Portfolio Committee for Arts, Culture, Science and Technology) has responsibility to place S&T within the national debate and to deal with public concerns in respect of S&T. DACST has a responsibility to keep the Portfolio Committee well informed.

3.4 RESOURCE ALLOCATION

3.4.1 Proposals of the White Paper

The White Paper argued for an overall Science Budget covering the science and technology expenditure across the whole of government as opposed to just the spending by DST, citing the advantages as being the balancing of allocations across different priorities and providing Parliament with a better overview of the range of government SET allocations. The specific concerns included:

- the need for better co-ordination (primarily of public resources) in order to encourage innovation in the private sector;
- developing frameworks that "promote linkages between universities, science, engineering and technology institutions (SETIs) and the private sector" mainly in respect of resources and risks
- improved management of "big science, fundamental research and service-oriented science and their relationship with technology development, infrastructure, basic needs provision and human resource development"
- "comprehensive measurement of the inputs and outputs of S&T research and development, and its impact on the goals of national policy objectives, both in S&T and other fields."

A number of recommendations were made for DST/DACST action including:

- review of government expenditure on S&T
- DACST and the Department of State Expenditure (now National Treasury) reaching agreement on the definitions of activities to be covered by the Science Budget and on the necessary questionnaire to be used to collect the data from departments during the budget preparation process.
- an annual Science Budget document (to be available in its first iteration in the 1998-99 fiscal year) constructed using data drawn from departmental budgets, which displays all governmental S&T expenditures including specifically:
    - o science councils and national facilities
    - o departmental intramural expenditures and transfer payments on S&T
    - o transfers in the Defence Sector for S&T
    - o other departmental transfers for S&T, including, in particular, the support offered by the Department of Education to institutions in the higher education sector
- adoption of the Department of Finance's (now National Treasury) proposed multi-year fiscal framework (MTEF) for general government budget expenditures and applied to the Science Budget
- "significant reallocations" to be introduced in the 1998/99 with respect to specific policy objectives; core and non-core activities as determined by the review; R&D compared to investments in other related scientific activities such as the provision of infrastructure services; and the balance of government support among government in-house activities and support to activities in the private and higher education sectors

It was emphasised that the "purpose of the Science Budget is to inform departments of the S&T portfolio across government; the rights of individual departments to decide on their own budgets will be unaffected". Furthermore the White Paper stated that "the Science Budget will be an important tool for Ministers to use as they allocate resources to competing priorities", whilst simultaneously providing Parliament with a better overview of the range of government allocations in support of SET activities and maximising the benefits from departmental budgetary allocations.

3.4.2 Progress in Implementation

This recommendation on a Science Budget was never implemented. However the DST did produce a review of government's expenditure on science and technology activities, as noted in Section 5.1 (Department of Science and Technology, 2014a).

The intent of the Science Budget was to incorporate expenditure on DACST, the eight science councils, three national facilities, all government departmental intramural expenditures and transfer payments on S&T, transfers in the Defence Sector on S&T, and other department transfers for S&T, especially support offered by DHET to institutions in the higher education sector. Progress in respect of all the actions in this section is shown in Table 8.

Table 6. Progress on inputs to policy making

ACTION	PROGRESS	COMMENT
Agreement on the definitions of activities to be covered by the Science Budget	Partial 2008/09	While the DST introduced an annual survey of all public funding for scientific and technological activities in 2008/09, to date no formal agreement with the National Treasury on the definitions of activities envisaged to be covered in the "Science Budget." The DST annual survey of public funded STA is based on a survey of national government departments (25 in the most recent iteration) and a standardised set of definitions established by the DST. The degree to which other departments understand or agree with these definitions is not clear. In respect of the Basic Accounting System (BAS) and the charter of government accounts (which are set out by the Accountant General) there is no standardised approach to expenditure and funding classification or agreement on key definitions with respect to STA. The upshot of the above (as noted further below) is that even in the absence of a "Science Budget" it is at present not possible to draw a comprehensive report on actual funding commitments and expenditures for STA from government accounts.
Annual Science Budget document	None	To date no "Science Budget" document has been developed. While the White Paper has a number of caveats that suggest that this budget would be more of a guiding document than a binding budgetary commitment framework, other White Paper comments suggest that what was envisaged is in effect a single Science Vote. In line with the introduction of the Public Finance Management Act (PFMA) in 1999, the newly established DST was required to produce a multi-year budget in 2005/6?(see more below) – this is classified in respect of the Estimates of National Expenditure and the National Division of Revenue Act as the Science & Technology Vote (currently Vote 30). However this Vote only covers the funding to the DST and its entities (see Figure 12). The concerns are as follows: • The Science & Technology Vote only represents funding to the DST and its entities. There is very significant funding that occurs in respect of STA and broader innovation activities in a number of other key national departments – notably Higher Education, Health and the Department of Trade and Industry. The DST in its annual STA review indicates that in respect of public sector STA expenditure the dti currently only accounts for 17%. • The current budget framework implemented by the National Treasury involves an extensive consultative process that is undertaken annually to determine the budget allocation to DST. However, at present the Budget Group only comprises DST and the Department of Environmental Affairs. A previous attempt to include other Economic Cluster Departments such as the dti proved to be too unwieldy. Treasury has indicated that an informal consultative process has been initiated as of 2015 to get key departments involved in innovation and STA to share information – however this still falls far short of a single budget.

ACTION	PROGRESS	COMMENT
		• It is unlikely that within the current public finance management framework a single Science Vote is achievable. There are also concerns as to whether it is practical, and there appears to be little evidence of similar approaches elsewhere in the world (although Australia is cited as a possible example). However it is clear that a better level of information sharing and coordination would go some way to addressing the objectives of the White Paper. The ongoing need for a Science Budget was also identified by the Ministerial Review which recommended that a "unitary Research and Innovation Vote should be established, designed to extend beyond the original version that operated until 2005, to function as a macro-coordinating mechanism" (Department of Science and Technology, 2012a).
Adoption of a multi-year fiscal framework	2005/06 Adopted in line with PFMA (DST Vote)	As noted at the establishment of the DST and the development of its budget, the Department was required to develop a multi-year budget in line with the Medium-term Expenditure Framework (MTEF) as prescribed by the PFMA. To the extent that Vote 30 to the DST (Science & Technology) refers to a segment of STA expenditure in the public sector, the White Paper objectives have been met. The application of the multi-year fiscal framework has also been applied to all other Departments and STIs. However this is not a single science vote.
Budget reallocations	Not clear	Given the absence of a single Science Vote and any sound budgetary process that can engage with all public expenditure on STA and innovation activities, the effective reallocation (outside of the DST vote) appears not to have taken place. Various government reviews (Department of Science and Technology, 2012a) indicate that there is still duplication, lack of clarity with respect to mandates and differing strategic objectives across departments and entities. Better alignment to national priorities and more effective direction of resources has been limited.

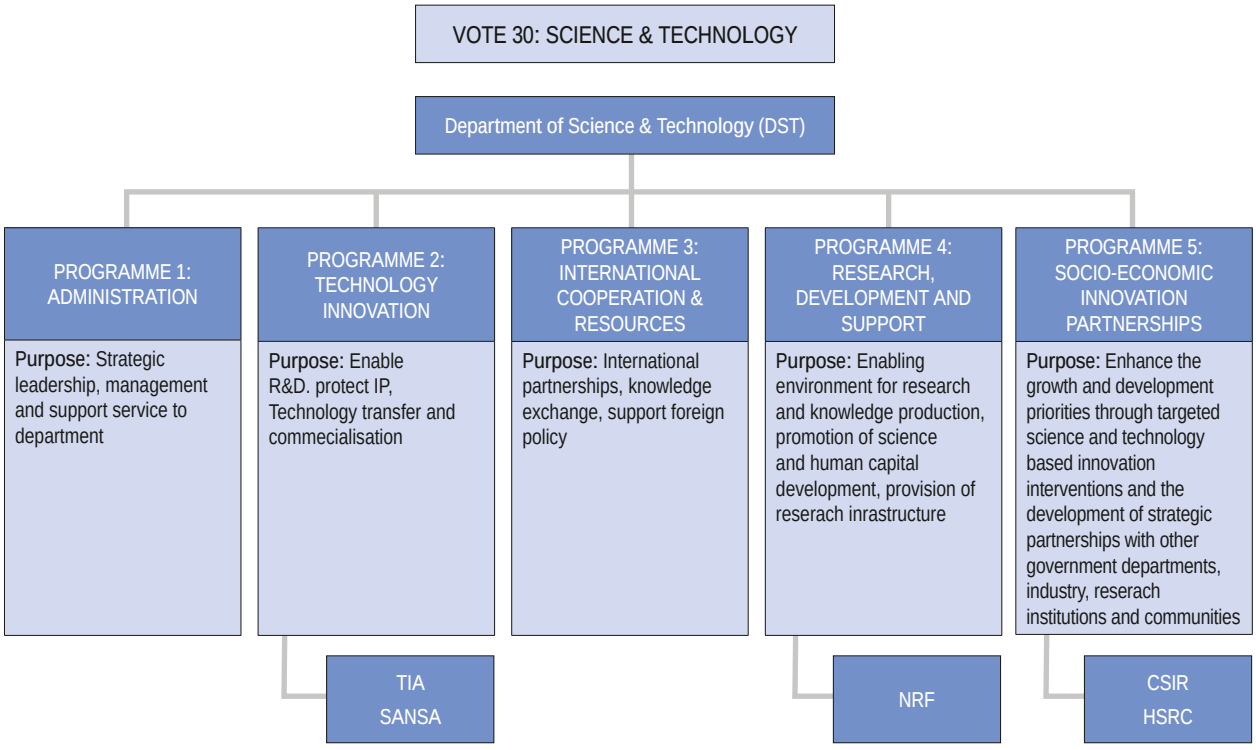


Figure 12. Reporting structure of the DST (for Vote 30)

Chapter 4
Regulatory Policy

As part of its broader function, the White Paper reminds Government of its role in respect of creating and maintaining an environment in which innovation is promoted, including the establishment and maintenance of a system for regulating the recording, awarding and protection of intellectual property. In this respect, there were two particular aspects identified in the White Paper, namely aligning patenting regulations with international norms; and promoting the protection of safety, health and the environment. This section assesses the progress that has been made in the two areas in terms of both policy formulation and implementation.

4.1 ALIGNING PATENTING REGULATIONS WITH INTERNATIONAL NORMS

4.1.1 Proposals of the White Paper

According to the White Paper, one means of promoting innovation is to create an environment that will enable innovators to profit from the success of their creative ideas in the marketplace through the protection of their intellectual property. This assumption, which aligns with the concept of the appropriability or exclusivity of private knowledge, refers to the capacity of the regulatory system to ensure that innovative companies are able to prevent the use of their knowledge by their competitors through patenting. In other words, the registration of patents, trademarks and copyrights, covering new or improved goods, services or production processes developed through the investment of private funds, curtails unauthorised imitation and ensures that the innovative companies can enjoy the exclusive benefits from their innovative ideas, at least for a minimum period of time. Given the environment of globalisation, the challenge is not only to establish intellectual protection laws within a country but to also to harmonise these with international norms and agreements.

It is noted that this claim (that the protection of intellectual property rights promotes innovation) is not necessarily supported by empirical evidence. Research studies on the value of intellectual property protection to innovation promotion, in developing countries, show a wide range of results (Lall, 2003). Some studies indicate that intellectual property supports stronger innovation (Kanwar and Evenson, 2003). In other studies, the results are conditional to a range of factors, including the size of the innovation (Pajak, 2010), the type of industry (Harabi, 1995; Mansfield, 1986) and whether the innovations are new-to-the-world (Hanel, 2008). Furthermore other work has found evidence for an outright rejection of the claim that strong intellectual property regimes spur innovation (Boldrin and Levine, 2008).

4.1.2 Progress in Implementation

Intellectual Property Rights from Publicly Financed Research and Development

A major regulatory policy development with respect to intellectual property since the publication of the White Paper, has been the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008, whose purpose is to ensure the more effective identification, protection, utilisation and commercialisation of intellectual property emanating from publicly financed research and development. The Act was promulgated on 22 December 2008, it took effect on 2 August 2010 and it applies to intellectual property derived from publicly funded research and development after the commencement date.

The Act brings about certainty in a number of areas that relate to publicly funded intellectual property that may not have been previously articulated. It requires public institutions to assess, record and report on the benefit to society of publicly funded R&D, thereby providing a stronger motivation to seek commercialisation opportunities. These organisations are required to protect the intellectual property arising from such work from appropriation whilst ensuring it is available to the State to use in ways which promote the interests of society. The Act emphasises the need to recognise and reward the creators of intellectual property, and outlines how this could be done. Furthermore, it gives priority to South Africans to benefit from publicly funded intellectual property, with commercialisation opportunities extended to preferably small enterprises and black empowerment entities.

The Act requires of publicly funded research and development institutions, such as universities and science councils, to disclose and acquire intellectual property that flows from this work. If an institution prefers not to own or protect the intellectual property, it is required to defer the rights first to the National Intellectual Property Management Office (NIPMO) or, in the event that this office decides not to take up the offer, to the creator of the intellectual property. The Act also outlines the various considerations and procedures to be taken into account in this process, including a number of management and disclosure duties on entities that produce intellectual property out of publicly funded research and development.

The National Intellectual Property Management Office

A major consequence of the Act was the establishment in 2011 of NIPMO to operationalise the Act and ensure the achievement of its key objective, namely that the public derives the greatest benefit possible from publicly funded research and development. The functions of NIPMO are outlined in the Act as follows: to

- promote the objectives of this Act, which include the statutory protection, management and commercialisation of the intellectual property referred to it;
- ensure that it has the capacity to consider any intellectual property referred to it and to deal with it in accordance with the Act;
- liaise with the relevant institutions to determine the viability of obtaining statutory protection for the intellectual property referred to it;
- conclude any intellectual property transactions or commercialisation of such intellectual property;
- manage information in respect of intellectual property contemplated in the Act, including data concerning the recipients;
- provide incentives to reward proactive securing and protection of intellectual property and commercialisation and, generally, for promoting innovation;
- provide assistance to institutions with the establishment of offices of technology transfer and related capacity-building;
- provide appropriate standards and best practices;
- develop guidelines for intellectual property transactions involving non-South African entities and persons, and manage the implementation of such guidelines; and
- monitor, evaluate and review the obligations of recipients of public funds for research and development in terms of this Act.

Technology Transfer Offices

A further product of the Act is the establishment of Technology Transfer Offices at research and development institutions that are publicly funded. These institutions include public universities and the science councils. The Act stipulates that the Offices of Technology Transfer must be properly capacitated by appropriately qualified personnel who have interdisciplinary knowledge, qualifications and expertise in the identification, protection, management and commercialisation of intellectual property and in intellectual property transactions.

In terms of the Act, the Technology Transfer Offices are required to:

- develop and implement, on behalf of the institution or region, policies for disclosure, identification, protection, development, commercialisation and benefit-sharing arrangements;
- receive disclosures of potential intellectual property emanating from publicly financed research and development;
- analyse the disclosures for any commercial potential, the likely success of such commercialisation, the existence and form of the intellectual property rights, the stage of development thereof and the appropriate form for protecting those rights;
- attend to all aspects of statutory protection of the intellectual property;
- refer disclosures to NIPMO on behalf of an institution;
- attend to all aspects of intellectual property transactions and the commercialisation of the intellectual property;
- conduct evaluations on the scope of statutory protection of the intellectual property in all geographic territories subject to commercialisation potential of the intellectual property; and
- liaise with NIPMO as provided for in this Act.

The promulgation and enactment of the Act addresses some of the issues that were identified as hindering intellectual property management in South African publicly financed institution (Sibanda, 2009). For instance, there is improved clarity and certainty on the management of intellectual property and the Act reaches an appropriate balance between benefits to society from publicly financed intellectual property and reward for the inventors. Furthermore NIPMO is operational and technology transfer offices have been established in most universities.

However the ultimate test of the Act is the extent to which it has increased the number of products and services that reach the marketplace and its contribution to promoting innovation in the country. A more detailed analysis will be required than is covered in this review.

The National Patenting System

While government policy and the regulatory environment for publicly-funded R&D has advanced, the national patenting system has changed little since 1996, with the exception of a limited set of amendments to the Patents Act in 2005. The South African Patent Act (Act No 57 of 1978) and the Companies and Intellectual Property Registry Office (CIPRO) are the key local institutions for intellectual property protection. CIPRO is a non-examining authority which means that the local system is open to abuse and the granting of exclusivity, whether this may be either warranted or legal. In a recent study of CIPRO's role in South Africa's intellectual property regime, the following issues came to light (Pouris and Pouris, 2011):

- given that CIPRO does not investigate the claims to novelty of the inventions in the disclosures, frivolous patents may be granted thus conferring unmerited market power
- the vast majority of patents granted by CIPRO would not have been awarded under a different regime
- CIPRO does not have online search facilities which limits public access to the know-how embedded in the patents

- the non-examining status of CIPRO means that the cost of registration is cheaper compared to other countries and the speed of registration is faster (Department of Science and Technology, 2012a); it could be argued that this system favours foreign inventors in that they protect prospective intellectual property at low cost in South Africa, resulting in abuse of the system.

The implications of the above are important for innovation in South Africa. The intellectual protection regulatory regime appears to work against the goal of promoting local innovation and unwittingly confers advantages to foreign inventors. Local inventors may use valuable resources on a system that is detrimental to public good (Pouris and Pouris, 2011), although there are no easy answers to this problem.

Policy Responses to International Protocols

It is not clear whether the call by the White Paper to align national patenting regulations with international norms was a response to the requirements of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) which was negotiated at the end of the Uruguay Round of the General Agreement on Tariffs and Trade in 1994. South Africa was one of the first members to accede to the World Trade Organisation (WTO) on 1 January 1995 and the ratification of TRIPS was a compulsory requirement for membership of the WTO. TRIPS required countries to align their domestic laws with the WTO in order to enjoy the benefits of membership such as market access.

Right from the outset, TRIPS has come under criticism, particularly for its effects on developing nations, including the agreement's failure to promote technological development (Gana, 1996), possible protection of biopiracy by developing countries (Kerr et al., 1999) and the dilemmas faced by countries such as South Africa over acquiring the medication for addressing pandemics such as HIV/AIDS (Harrelson, 2001).

The debate concerning the rights of communities in relation to indigenous knowledge deserves more analysis because of South Africa's status as one of the world's richest biodiversity countries.

Prior to 1992, the lack of legislation for bioprospecting allowed foreign companies almost unrestricted access to the country's bio-resources in order to conduct R&D and develop drugs for financial gain (Crouch et al., 2008). South Africa and the traditional communities in particular, as custodians of traditional knowledge, did not receive any benefits during this period despite significant benefits to other countries. For instance, sales of the South African species *Freesias* generated profits of R300 million annually for the Netherlands (Ivey, 1993), and sales of *Pelargonium* cultivars reached revenues of approximately R7,000 million annually for New Zealand, Germany and Belgium (Crouch et al., 2008).

South Africa's signature of the Convention on Biological Diversity (CBD) in 1992 lent impetus to developing a more equitable regulatory framework for the sharing of benefits that accrue from the utilisation of genetic resources. The CBD has three main objectives, namely the conservation of biological biodiversity, their sustainable use and the fair and equitable sharing of the benefits arising from the utilisation of genetic resources. The convention was followed by the adoption in 1997 of the White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity, which outlined the need for legislation and institutional mechanisms to control access to South Africa's indigenous genetic resources; the National Environmental Management of Biodiversity Act (Act 10 of 2004), which legislated for a fair and equitable sharing of benefits arising from bioprospecting involving indigenous biological resources; and finally the Patents Amendments Act (Act No 20 of 2005) and the Intellectual Property Laws Amendment Act (Act 28 of 2013) which provide for the protection and equitable compensation for local indigenous knowledge (see Table 9 for a listing of the key dates and legislation).

Table 9. Key dates in the development of rights to benefit sharing

1992	SA becomes signatory to CBD
1995	SA accedes to TRIPS
1996	White Paper on Science and Technology
1996	Intellectual Property Laws Rationalisation Act
1997	White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity
2004	National Environmental Biodiversity Act
2005	Patents Amendments Act
2013	Intellectual Property Laws Amendment Act

A number of issues continue to bedevil efforts to protect and grant equitable dues to holders of traditional knowledge in relation to biological resources. Ownership is not always easily established, the nature of rights to be protected is not clear-cut and it is not straightforward to achieve a balance between protecting and facilitating R&D based on indigenous knowledge (Crouch et al., 2008).

It is concluded that the unresolved question of local examination is a weakness in the system and in this respect the South African intellectual property protection regulatory framework falls short of the expressed goals of the White Paper.

4.2 PROMOTING THE PROTECTION OF SAFETY, HEALTH AND THE ENVIRONMENT

4.2.1 Proposals of the White Paper

The White Paper put the health and wellbeing of people at the centre of all innovation activities and emphasised the requirement for science and technology to act as important contributors to improving the quality of life of all South Africans. It is within this perspective that one of the White Paper priorities covers the protection of safety, health and the environment (SHE).

In order to properly review this component of the White Paper, it is important to take into account the context in which it was written. At the time of the transition of South Africa from an apartheid dispensation to democracy, there was a need to promote technological change as a contributor, rather than a threat, to human wellbeing. Under apartheid, technology-based development and industrialisation was fraught with controversy. The country's energy, mining and manufacturing firms were notorious for air, water and land pollution (Adler et al., 2007). Technological advances supported the apartheid state through spectacular innovations in armaments industries, including developing nuclear capabilities. The health of entire communities had been compromised by a large number of industrial activities (Cock, 2004). It was therefore important that post-1994 science and technology policy laid a foundation for a new dispensation in which science and technology were seen to be contributing to the overall wellbeing of ordinary people.

4.2.2 Progress in Implementation

The White Paper sought to contribute to safety, health and the environment (SHE) legislation that was comprehensive, efficient and streamlined with adequate penalties. The paper did not outline specific actions except to indicate that the department would initiate discussions with the Departments of Labour, Environmental Affairs and Tourism, Health, as well as Mineral and Energy Affairs in order to establish its contribution.

However there is no record to show that these interdepartmental discussions ever took place. Furthermore it appears that this section of the White Paper was added without any real thought as to how the DST could facilitate the three principles of comprehensiveness, efficiency and adequate penalties. In part, this absence of clear activities reflects

the limited scope for DST to influence the national agenda on SHE and the broad scope of sustainable development and physical wellbeing, which together extend beyond compliance regulations relating to SHE in the workplace and the environmental impact assessments. However the White Paper does indicate a lack of foresight and imagination on this important issue, with no mention of important areas and policies such as labour intensive technological industries, renewable energy research, climate change and technology transfer, and technology-based entrepreneurship.

The rise in prominence, nationally and internationally, of environmental sustainability adds another dimension to the importance of environmental safety and protection. It has been demonstrated that human activity has resulted in climate change, global warming and other environmental challenges that have far-reaching consequences to the wellbeing of future generations (Houghton, 2009). Assessments and models of the potential impact of climate change indicate that the developing countries will be particularly badly affected (Mendelsohn et al., 2000). As a result the regulatory framework that governs innovation policy has to move beyond the narrow compliance objectives of SHE and the Environmental Impact Assessment (EIA) requirements, and needs to take into account environmental sustainability, with new focus areas including the promotion of technological innovation to address the impact of climate change on the wellbeing of current and future generations of South Africans.

One of the high-level requirements of the White Paper was 'working towards Environmental Sustainability', which called for the growth of the country's economy to be reconciled with human wellbeing, including environmental health. Research on the environment, including innovations based on environmental technologies, was to receive priority. The lack of detail in the White Paper as to how this could be achieved is a weakness in the policy but not an issue for this review, which deals with the implementation of the stated specific initiatives. The analysis, however, does serve as an example of a more general principle, namely that while many of the specific initiatives were implemented as per the White Paper, the attainment of the higher level requirement and goals has not been achieved and needs sustained attention within the strategy and policy document of Government.

Chapter 5
Financing (at the Performance Level)

5.1 FINANCING AND INNOVATION

5.1.1 Proposals of the White Paper

The White Paper does not define any clear targets in respect of financing of innovation but does reflect on some general principles as follows:

- resources should be allocated not only to R&D and the technological factors of innovation but also the social, institutional and market factors such as adoption, diffusion and transfer
- government, in its efforts to provide infrastructure and health care, and to guide sustainable development and environmental management, must promote new approaches to technology management, including the use of market intelligence and product development in small, flexible, multi-disciplinary teams.

5.1.2 Implementation

Our analysis of the funding for innovation has revealed some interesting insights in respect of government spending, as follows:

- *dti:* previous reviews of the NSI have ignored the massive support for innovation from the dti, including funding of the agencies responsible for intellectual property, standards, and small business development, and a wide range of incentive schemes supporting activities such as R&D, upgrading of capital equipment and sector-specific subsidies. The extent of the funding has grown in real terms since 2004 (see Figure 13).

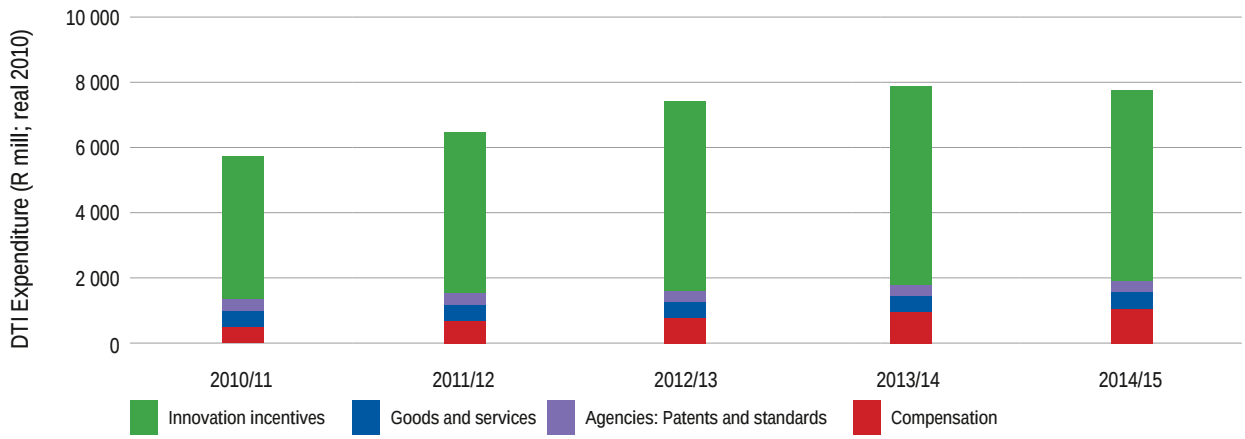


Figure 13. Real dti expenditure on support for innovation (agencies and incentives)

The total dti expenditure in 2014/15 amounted to nearly R10 billion in real terms of which close to R7.5 billion was spent on innovation incentives and R750 million on agencies supporting innovation (see Table 10). The expenditure in some areas raises questions about its efficacy and impact on the NSI and suggests that a review of each instrument would be useful. For instance, SME support totals about R750 million, special economic or development zones about R1 billion and sectoral support (automotive, film and clothing) about R2.1 billion.

Table 10. dti expenditure on innovation incentives and agencies (2014/15)

ITEM	EXPENDITURE (R MILL: 2014/15)
INCENTIVES	
Manufacturing Competitiveness Enhancement Programme	2,281,244
Enterprise Investment Programme	976,400
IDC: Clothing and Textile Production	906,777
Special Economic Zones	762,460
Automotive Production and Development Programme	672,029
Film and Production Incentives	518,305
Business Process Service Incentive	377,980
Export Market and Investment Assistance	413,068
Black Business Supplier Development Programme	361,442
Small Enterprise Development Agency: Technology Programme	126,368
Industrial Development Zones	124,847
AGENCIES	
South African Bureau of Standards	345,452
National Regulator for Compulsory Specifications	109,734
National Research Foundation: Technology and Human Resources for Industry Programme	165,573
Small Enterprise Development Agency	502,282
National Metrology Institute of South Africa	111,000

As noted in Section 3.4, the White Paper envisaged a single science vote or at least better oversight and coordination of all public sector investment in S&T, with the idea being to better understand S&T expenditure specifically and innovation more broadly. The DST does produce an annual report on 'Government Funding for Science & Technology Activities', but this report is based on DST expenditure and a survey of other government departments, and has both methodology and conceptual issues, with the report covering S&T activities more broadly and with less applicability to either R&D or STI activities. The development of a single report on innovation rather than S&T activities would be more useful. Nevertheless it is clear that the dti funding meets the White Paper objective on funding for the 'institutional and market factors such as adoption, diffusion and transfer'.

One area of concern is the recent dti decision to close the Technology for Human Resources in Industry Programme. This funding stream has played an important role in encouraging university/firm collaborations and has been extremely cost effective in respect of the research outputs (Walwyn, 2015). At this stage it is not clear whether a replacement instrument will be launched but such an incentive is required by the system, and the gap following the demise of the programme will need to be filled.

- *DST:* as for the dti, funding for the DST has increased considerably in real terms over the last ten years, with nominal expenditure rising from R400 million in 2005/6 to R6.2 billion in 2013/4, an increase of over 900% in real terms (see Figure 14; note these figures are in real terms).

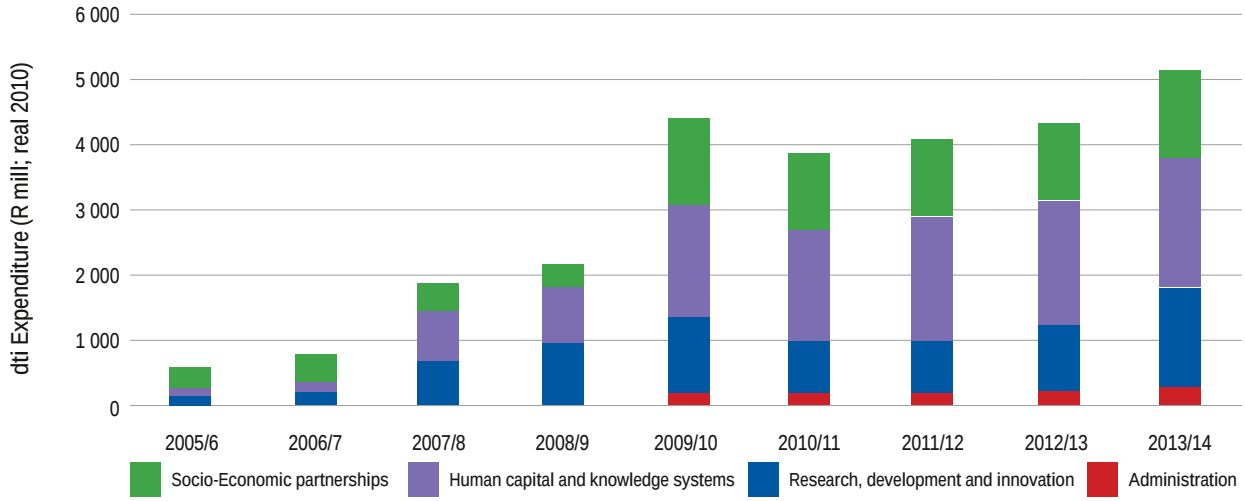


Figure 14. Real DST expenditure by programme (2005 to 2013; 2010 R million)

This increase in funding has been felt right across the system with more resources for R&D, particularly within the universities but including the science councils (see Figure 11). In this respect, the White Paper has been extraordinarily successful in capturing a higher share of the national expenditure for public-funded S&T, including R&D and HRD activities.

- *DHET:* similar to the funding of DST and dti, funding from the DHET to the universities has risen in real terms by 50% since 2004 (see Figure 15), although the increases for the research component of this funding, where the latter is a specific component of the block grant and is allocated based on research outputs (see Section 5.3), have been more modest. Much of the increased funding has been directed through the 'earmarked grants' covering the National Student Financial Aid Scheme and infrastructure funding for new/existing universities. The funding for research through the DHET is now about 10% of its total budget for the universities and in nominal terms is about R2.7 billion per year, or about 20% of the total public sector financing of R&D. This income is highly significant for the higher education sector since it comprises about 27% of their total R&D budget. Increasingly, however, the DST is playing a more important role in supporting R&D within the universities through instruments such as the Centres of Excellence programme and generally through the National Research Foundation.

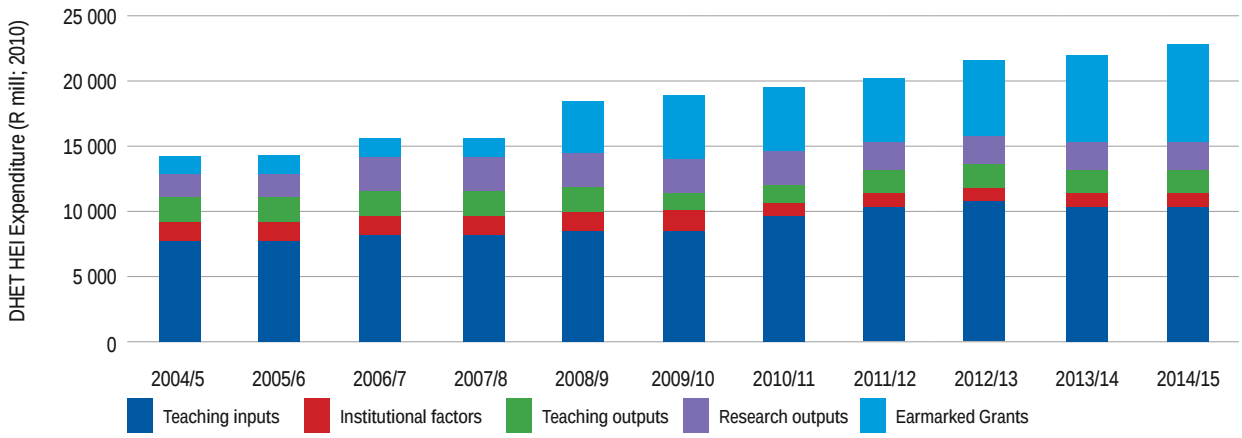


Figure 15. Real DHET funding for the universities; 2004 to 2014

Although DHET funding has increased in real terms since 2004, due to the rising student numbers funding per student has been static, as shown in Figure 16 (data for student enrolments post 2011/12 is unfortunately not yet available).

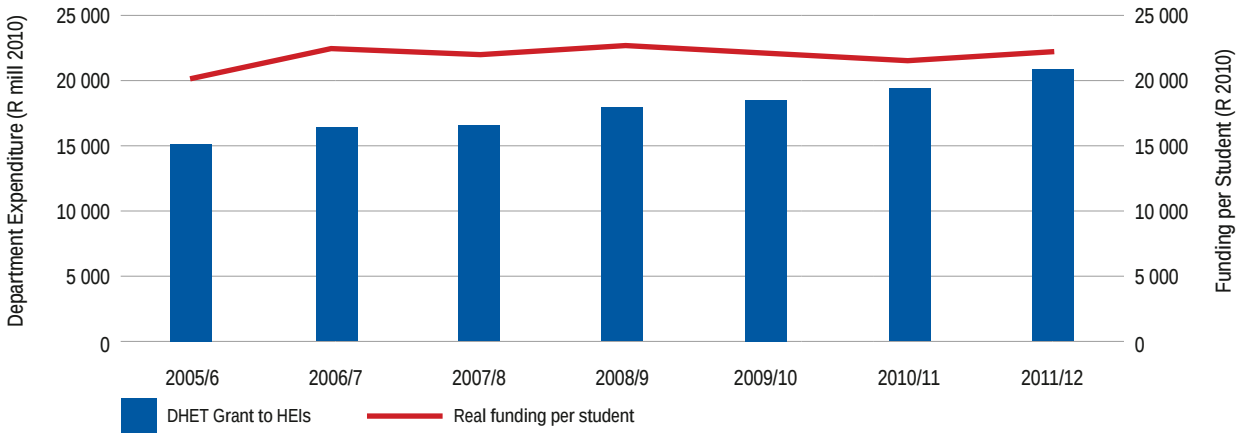


Figure 16. Real DHET funding per student; 2005 to 2011

In terms of the specific objective in the White Paper for government to promote 'new approaches to technology management, including the use of market intelligence and product development in small, flexible, multi-disciplinary teams', such approaches have been pursued within the Innovation Fund (see Section 5.2) and in the new management models for the public research institutes (see Section 6.1).

Finally in this section it is noted that, apart from the introduction of the Innovation Fund, the White Paper is surprisingly passive on the topic of innovation incentives, although it did note that non-technical costs may account for 'as much as 60% of the cost of innovation' and also the need for a R&D tax incentive. Despite this gap in policy, many such schemes have subsequently been introduced by the Department of Trade and Industry (dti) and the DST, including support for technology transfer, upgrading of capital equipment, and the tax incentive, as discussed in this section. The full profile of departmental funding on STI is shown in Figure 17 (figures are shown in constant 2010 ZAR).

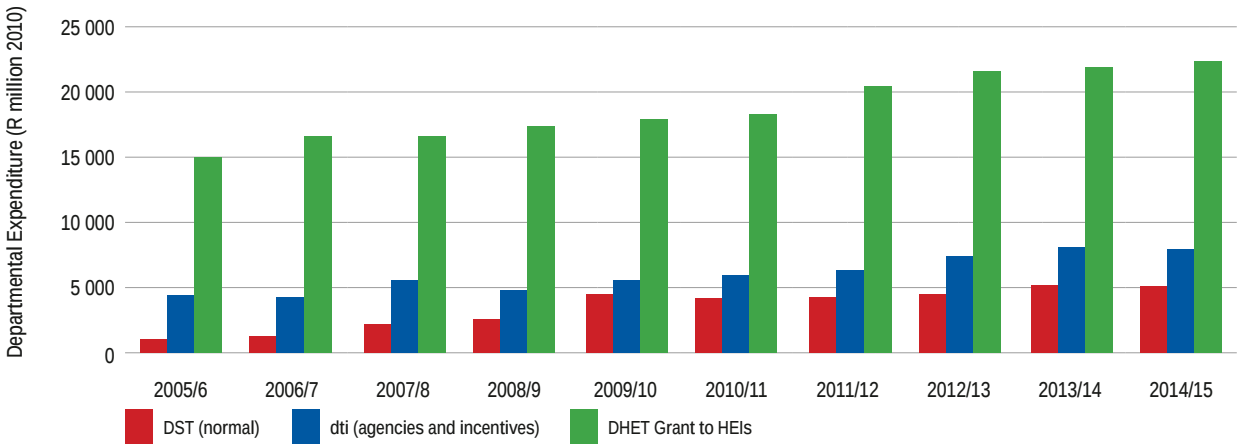


Figure 15. Real DHET funding for the universities; 2004 to 2014

5.2 THE INNOVATION FUND

5.2.1 Proposals of the White Paper

The White Paper, noting that indirect support for innovation was precluded by the Katz Commission at the time, saw direct subsidy as "…the only realistic option if incentives for private sector innovation are to be increased." Direct support for innovation is widely applied in developed and many developing countries on the basis that there is clear market failure with underfunding of R&D by the private sector (innovation projects are associated with long time periods, significant investment and uncertain outcomes leading to unacceptable levels of risk).

5.2.2 Implementation

The White Paper made two major proposals in respect of the Innovation Fund. First, the total money available for direct subsidisation of R&D would be increased. Following the WP, government's direct support for S&T did indeed increase (see Section 5.1). Second, an inter-departmental committee composed of DACST and the dti would be established to align the objectives of the Support Programme for Industrial Innovation (SPII) and the Innovation Fund. The White Paper envisaged a close relationship between DACST and the dti, whereby resources would be combined to support innovation. The White Paper stated that DACST and the dti had agreed to work together to manage these two programmes (the Innovation Fund and SPII) optimally.

As far as we are aware, no such interdepartmental committee was established. There does not appear to have been any formal and consistent working relations between DACST and dti so as to manage the SPII and Innovation Fund optimally. The Innovation Fund was managed by DACST (later DST) and SPII was managed by the dti, through the IDC. There was no pooling of resources on common projects.

In the mid-2000s, the IF developed a relationship with the Industrial Development Corporation (IDC), who managed SPII. The IDC had a Venture Capital business unit, and the IF sought to attract their co-investment into start-ups that the IF had invested in through its Seed Fund. The IF sought relationships with the full set of early stage VC investors at the time, including Argil VC and HBD, to attempt to attract these players to take on earlier stage investments through the IF co-investing with them. The IF co-invested directly with these players, and specifically in the case of the IDC VC unit, it co-invested in businesses like Robonica and Optimal Energy.

The linkage to SPII was less direct than the VC unit, but it was one of the instruments of funding to which the IF would direct entrepreneurs/businesses as part of encouraging them to seek the most efficient, low cost sources of funding support. The IF also always ensured that there was no duplication of receipt of income from two or more sources

between instruments as part of its due diligence on the companies. Part of the reason for the weak linkage with SPII was that the latter was not well suited to high tech start-up companies developing and commercialisation completely new technologies, often into new markets; this market was the mandate of the IF.

The question of mandates emerged again in two respects following the 2013 review of TIA (IF's successor). The latter was formed in 2008 with the promulgation of the TIA Act (Act No. 26 of 2008) and the amalgamation of the IF with several other funding agencies including the Biotechnology Regional Innovation Centres and the Technology Stations Programme. In the first instance there was a disagreement between the DST and TIA's stakeholders on the organisation's mandate (Review Panel, 2013). The Act states its object as "to support the State in stimulating and intensifying technological innovation in order to improve economic growth and the quality of life of all South Africans by developing and exploiting technological innovations". All stakeholders consulted considered this object enabling and appropriate. Nevertheless, the DST's officials insisted that TIA's mandate was intended to be narrowly focused as per the business case, with its primary emphasis expected to be on supporting innovative ideas emanating from publicly funded higher education institutions and science councils, a view that was not shared by any of the stakeholders engaged in the review process, who saw it as reflecting an inappropriate understanding of the requirements for a successful NSI (Review Panel, 2013).

Secondly, the review noted that the technology stations, which are hosted at universities of technology with the purpose of assisting SMMEs to access the resources and expertise at the universities of technology, expressed considerable uneasiness about being under TIA. Given that support for technology transfer and absorption is primarily a dti function, it is not surprising that this feeling of marginalisation had arisen. The transfer of the technology stations to the CSIR or another agency, as recommended by the review, seems to be appropriate action in response to this clear mandate conflict.

Other points relating to the establishment of the IF (and its successor, TIA) and the extent of implementation are reviewed in Table 11. Although only established in 2008 and fully functional in 2010, TIA has already been the subject of review and controversy. The review of 2013, appointed by the Minister of Science and Technology, concluded with 12 recommendations to improve the functioning of the organisation, including the clarification of its mandate as already noted. The panel's report also noted that "sound working relationships have not been consolidated, particularly with universities and that TIA was not meeting the expectations of its stakeholders". Some of the shortcomings identified by stakeholders included "poor response times for enquiries and applications, application processes that are unwieldy and not sufficiently differentiated or responsive to the needs of stakeholders, and poor communication, including an unhelpful website".

Another key recommendation from the review which has appeared frequently in this report was the weakness of cross-departmental oversight and coordination. In response to this situation, the panel recommended that the Minister "endeavour to create a high-level interdepartmental forum to coordinate innovation across the NSI, preferably at ministerial level, but at least at director-general level".

Following this review the organisation has been restructured and streamlined in order to improve its funding efficiency and focus.

Table 11. Implementation of the White Paper actions for the Innovation Fund

ACTION	IMPLEMENTATION
The White Paper saw the Innovation Fund as offering "a new lead in encouraging and enabling longer-term large innovation projects in the higher education sector (HES), government, SETIs, civil society or the private sector".	The Innovation Fund did initiate and support such projects in all of the above. Engagement of civil society appears to have been very limited. By contrast, the IF funded a large number of projects of the science councils.
The Innovation Fund was to serve to reallocate resources from historical patterns of government science to issues of competitiveness, quality of life, environmental sustainability and harnessing information technology.	Projects in all of these areas were, in fact, funded.
Funds were to be allocated via a competitive process	This was done.
The Innovation Fund was to promote increased networking and cross-sectoral collaboration.	It is difficult to assess the degree to which this, in fact, occurred but there were projects where there was cross-collaboration.
Initially, at least 50% of the funding would be allocated to projects directly dealing with the needs of disadvantaged populations	This was not done. Throughout the life of the IF, there were very few projects that dealt specifically with the needs of disadvantaged populations.
Preference would be given to larger and long-term projects	This was done
Priority to be given to applications where there is a close relationship between those conducting the research and eventual users	This does not appear to have been implemented
The Innovation Fund would not finance the salaries of principal researchers	In fact, at least in the period 2006-2010, the IF did pay the salaries of principal researchers
The applicant was requested to suggest potential technical evaluators. Often the IF would use one suggested by the applicant and one located independently.	The IF maintained a database of technical evaluators who were paid for their contribution.
The IF would make use of qualified external reviewers. The IF should draw on the experience of SPII, the Water Research Commission, the Safety in Mines Research Advisory Committee, the Energy Policy Projects and the Directorate of Technology Development of the South African National Defence Force.	For each application for R&D funding, the IF would source 2 or 3 external independent technical evaluators, who were asked to complete a standard evaluation template focused on the technical issues of the proposal. The external reviewers were also invited to attend the site visits (pre-project, middle and final).
There would be a mechanism for developing and updating thematic priorities on a biennial basis. This process should be supplemented and updated by a technology foresight exercise. NACI would also advise on the setting of these priorities.	Foresight and other exercises were carried out and focal areas for support were identified. The Innovation Fund did issue calls for particular sector focal areas. However, the fund accepted applications for any technology domain. The IF was of the view that defining narrow focal areas would potentially miss innovations that had reasonable prospects to succeed (personal correspondence). Once IF (together with the Biotechnology Innovation Centres and the Advanced manufacturing Technology Strategy) had been migrated into TIA, TIA developed sector focal areas. However this Investment Framework Policy did not limit the scope of TIA investments to only certain sectors. The intention there was again to retain some level of openness to innovation opportunities that did not necessarily fit a particular sector or thematic area.

5.3 PRINCIPLES FOR FUNDING R&D IN THE HIGHER EDUCATION SECTOR

5.3.1 Proposals of the White Paper

The White Paper made extensive proposals to reform funding of S&T within the higher education and public research institutions. The overall approach was designed to address the fragmentation of funding and introduce a more coordinated system, based on the following principles:

- broadening of the scope of funding to cover basic research, applied research and experimental development, with greater overall emphasis on directed R&D to national priorities including redress of 'human and institutional imbalances', health, manufacturing, environment, and poverty
- separation of the performing and funding (granting) functions within all public sector agencies or actors in order to avoid conflicts of interest within such actors
- increasing support for interdisciplinary and multi-disciplinary R&D
- adoption of peer review for all proposals and funding instruments including the use of international experts where necessary
- reduction in overheads due to the consolidation of funding agencies
- regular evaluation of all instruments
- regular communication with all stakeholders in the sector on issues relating to the research support and capacity building.

The main recommendation of this section was the creation of the NRF whose primary function would be the support of R&D and R&D capacity building within the higher education sector based on the above principles. It proposed the creation of four divisions within the NRF covering natural sciences and engineering, social sciences and humanities, health sciences, and agricultural and environmental sciences. It was also proposed that the NRF take responsibility for the national facilities (such as the National Accelerator Centre) and be subject to same principles of peer review but with the particular emphasis on ensuring that the facilities become truly national in character (i.e. available to all researchers).

This section of the White Paper also made a number of recommendations about the governance and structure of the NRF including the appointment of a chief executive officer, a board of directors, advisory panels for each division and senior managers with the necessary experience. It allowed for the addition of further divisions as required by the Minister of Science of Technology, and it stipulated that the NRF should 'replace and augment' the current granting mechanisms in the Foundation for Research and Development, the Human Sciences Research Council and the Medical Research Council. However it noted that the NRF should not interfere with the operations of the domain-specific agencies such as the Water Research Commission.

The White Paper also recognised the ongoing role of the Department of Higher Education (and Training) as being an important source of funding for R&D and recommended that DST should engage in regular discussions with the department (DHET) on its formula for the funding of R&D in the higher education sector with specific input on the ongoing revisions to the funding for peer review publications.

5.3.2 Progress in Implementation

Progress in respect of implementation of all the proposals as listed in the previous section has been exemplary (see Table 12), with the one exception of the separation of the performing and funding functions of the Medical Research Council. This reform was resisted by the Department of Health and has never been implemented.

Table 12. Implementation of White Paper reforms for funding in Higher Education

SPECIFIC INITIATIVE	IMPLEMENTATION
Establishment of the NRF	Completed; for details see Section 3.1
Broadening of the scope of funding to cover basic research, applied research and experimental development, with greater overall emphasis on directed R&D to national priorities including redress of 'human and institutional imbalances', health, manufacturing, environment, and poverty	All 3 types of R&D (based on the Frascati definitions) are funded, although the increasing trend towards basic research is a concern (see Figure 20). However the Frascati profile of expenditure has not changed much over the period 2002 to 2012 as shown in Figure 20 (data sourced from the R&D surveys). A bibliometric study reveals that the profile of publications authored by South Africa researchers has indeed shifted over the period 2003 to 2013, with an increasing emphasis on areas such as infectious diseases and occupational health (see Figure 19 and attached discussion).
Separation of the performing and funding (granting) functions within all public sector agencies or actors in order to avoid conflicts of interest within such actors	Completed with the exception of the Medical Research Council
Increasing support for interdisciplinary and multi-disciplinary R&D	Ongoing; progress has been made in this area with an increasing level of multi-disciplinary publications (see Figure 19)
Adoption of peer review for all proposals and funding instruments including the use of international experts where necessary	Fully implemented; the majority of proposals through the NRF are peer reviewed following a competitive application process.
Reduction in overheads due to the consolidation of funding agencies	The NRF has maintained an acceptable overhead level since its establishment. However it is noted that in this study no historical comparison (pre- and post-NRF) has been possible.
Regular evaluation of all instruments	Fully implemented; the NRF and its programmes are evaluated on a regular basis.
Regular communication with all stakeholders in the sector on issues relating to the research support and capacity building	Fully implemented; the NRF engages with its stakeholders on a regular basis.
Assume responsibility for the National Research Facilities	Implemented; see Section 8.4
Establish structure and governance of the NRF	Implemented; the organisation has made all the necessary appointments as per the recommendations of the White Paper
Engage with the DHET on its funding formula	Implemented, although operational and strategic issues remain for the universities with the DHET funding formula (Walwyn, 2008). In 2004, the Ministry of Education published a new funding framework. The higher education budget, in line with this framework, is divided into the following key components on a three-year cycle (figures for 2014/15): Earmarked Grants (28%) and Block Grants, the latter comprising of Teaching Input Grants (48%); Teaching Output Grants (10%); Research Output Grants (10%) and Institutional Factor Grants (4%).
Promotion of R&D in HEIs	Overall the level of funding for R&D in higher education has increased (see Figure 18).

Total funding for R&D in the higher education sector has increased in real terms as shown in Figure 18, unlike the trend in business enterprises (falling in real terms) and in the science councils (static). This trend reflects a growing importance of R&D in this sector, reflecting an international change in terms of R&D performance (OECD, 2011).

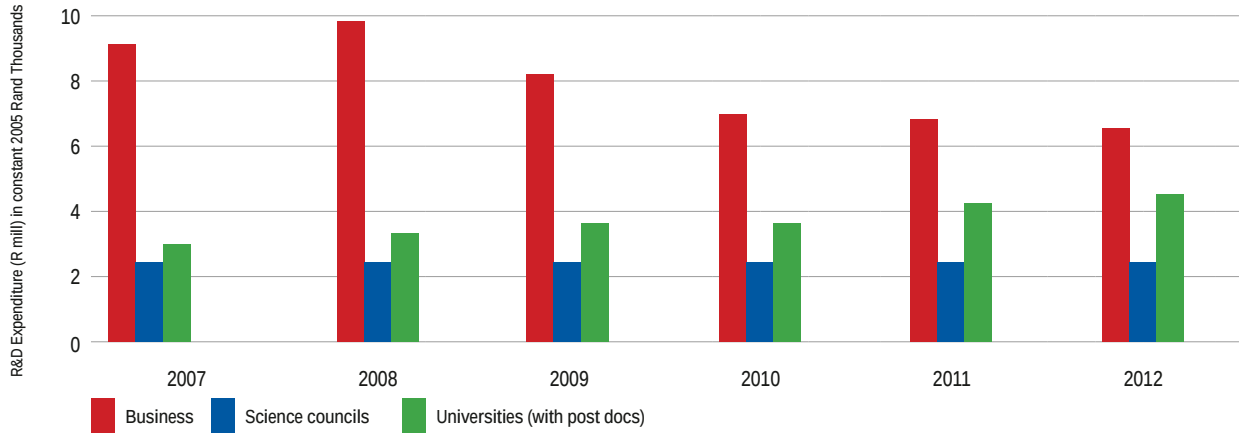
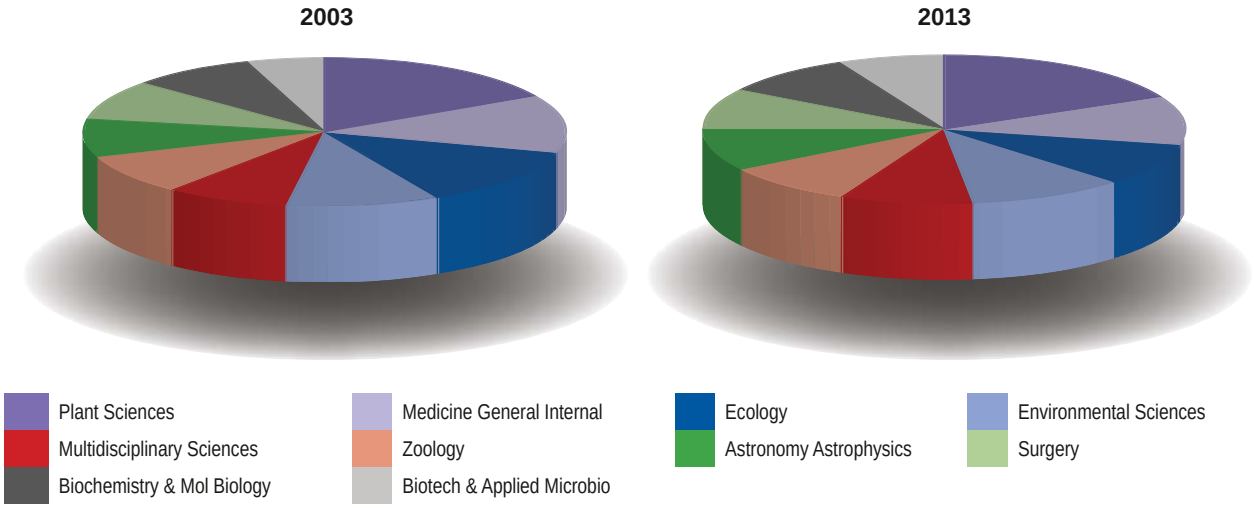


Figure 18. Real expenditure on R&D in South Africa; 2007 to 2012

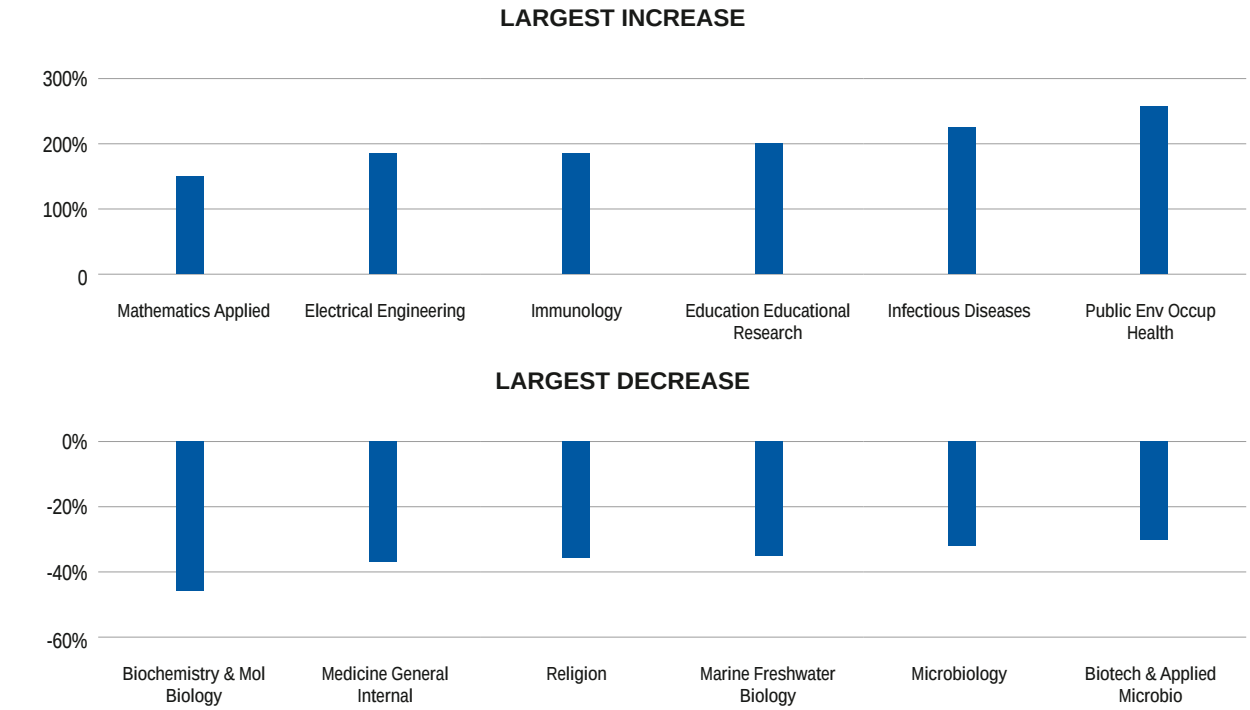
In terms of the application of these funds, a subject area based analysis of South Africa's research publications over the period 2003 to 2013 reveals a shift in research focus areas (see Figure 19). For instance, publications on infectious diseases increased from 106 in 2003 to 462 in 2013, a growth of more than 400%; similarly research articles on poverty or community development have increased from 750 in 2003 to 2,336 in 2013. In the same period, publications in broad science disciplines such as zoology, biochemistry and microbiology have declined from 7.8% of total publications to 5.2%. The largest absolute increases have been in the areas of occupational health and infectious diseases; the largest decreases in biochemistry/molecular biology and general internal medicine (see Figure 20).

Similarly data from the 2011/12 South African R&D Survey shows that expenditure on TB, HIV and malaria increased from R1.1 billion in 2007/8 to 2.0 billion and medical/health sciences research now accounts for 17% of the gross expenditure on R&D (GERD) (Department of Science and Technology, 2014c).



Source: ISI Web of Science

Figure 19. Profile of South African publications by knowledge area; 2003 and 2013



Source: ISI Web of Science

Figure 20. Largest decreases/increases by knowledge area; 2003 to 2013

However the Frascati profile of expenditure has not changed much over the period 2002 to 2012 as shown in Figure 21 (data sourced from the R&D surveys).

Based on this evidence, it is concluded that research in the higher education sector is not necessarily more applied but is certainly more specific to South Africa's social and economic challenges. Similar conclusions have been noted in a previous study, with increased activity in economics and business, immunology (HIV) and social sciences (Pouris, 2012a). Unfortunately it appears that some of the gains have been made at the expense of other areas such as engineering sciences and information, as well as computer and communication technologies, which together declined by more than 8% relative to the 2009 values.

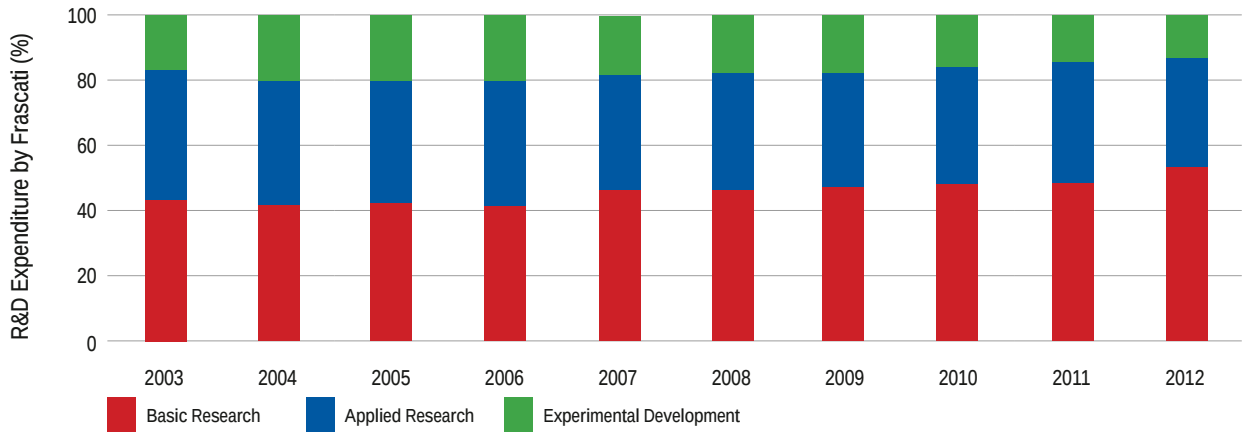


Figure 21: Frascati profiles for HEI R&D; 2003/4 to 2012/13

5.4 PRIVATE SECTOR FUNDING

5.4.1 Procurement Policy

5.4.1.1 Introduction

The White Paper notes that procurement on the part of the public sector is an important policy instrument to promote technology and industrial development. However, it concludes that the policy has, up to that point in time, been ineffective and in some ways even counterproductive, limiting and distorting product development.

The White Paper notes that the Ministry of Finance was engaged in reviewing procedures on government procurement and that the dti was engaged in examining the impact of price preferences, monitoring the participation of small medium and micro enterprises (SMMEs), studying trends and developing guidelines and directives for contracts with firms to develop new products.

In the light of the engagement of the Ministry of Finance and the dti, the White Paper declined "…to formulate any additional guidelines or policy initiatives with regard to government procurement."

5.4.1.2 Implementation

Government's major infrastructure programme provides potential support for local producers. Public procurement is regarded as one of the key instruments to enhance industrial development (Department of Trade and Industry, 2014). At the end of 2011, regulations under the Preferential Procurement Policy Framework Act (Act No 5 of 2000) were strengthened to allow the Minister of Trade and Industry to designate industries, sectors and sub-sectors for local procurement at specified levels of local content.

A wide variety of sectors have been designated for local production with minimum local content thresholds, including rail rolling stock, power pylons, bus bodies, canned/processed vegetables, certain pharmaceutical products, furniture products, and the textile, clothing, leather and footwear sector.

Public procurement is designed to enhance local production, particularly of manufactured products by requiring government and State Owned Enterprises to purchase such designated local products.

Procurement policy, as currently practiced, is therefore not designed to specifically enhance innovation. The extent and degree of innovation entailed is not assessed in determining designation. Many of the products designated have very limited local innovative activity. Technological support is, in some cases, provided to local firms to upgrade products but public procurement itself is not seen as a key mechanism to drive innovation.

A number of countries actively employ public procurement specifically to drive innovation. From 2006, The People's Republic of China produced a catalogue of products that embodied considerable local innovation and granted preferences to such products in government procurement. However, foreign companies and governments complained that this designation was a discriminatory practice, illegal under the WTO and inconsistent with international best practices. In 2011, on a trip to the United States, President Hu Jintao announced that this policy would be discontinued.

These developments have resulted in some changes to the role of public procurement in enhancing innovation, other than local product designation and preference. More creative ways which are non-discriminatory have recently been introduced including the following two examples or pre-commercial instruments drawn from the UK (EU, Sweden and the US have similar policies):

- government departments are encouraged to develop an Innovation Procurement Plan, showing how the department plans to harness innovation in its procurement. The very act of thinking by departmental officials as to how they

might access and utilise innovative solutions in addressing their challenges is important. It changes mind sets and practices away from a repeated ritualised activity to one which is far more dynamic. The Innovation Procurement Plan will also give potential providers information as to departmental plans and opportunities (Office of Government Commerce, 2009).

- departments could run competitions for new technologies to identify a problem that the Department needs to solve and then open it up for competitive bids from small businesses as to how to resolve them. The UK Small Business Research Initiative competition for new technologies is an example. The Department of Health needed to find new ways of tackling Methicillin-resistant *Staphylococcus aureus* and *Colostrium difficile*. It drew up a brief of what it wanted and ran a competition. 13 companies were selected and given initial contracts to develop their new technology. A second stage funding would be provided if any of the innovative ideas were assessed to have real prospects of success (The Department for Innovation Universities and Skills, 2009).

Public procurement policy is currently focused on local production. However, there are many creative ways in which public procurement can be used to enhance innovation and to bring innovative solutions into the activities of government. This is an area where much new thinking and policy is being enacted. These developments and their potential application to South Africa are deserving of significant attention in planning future policy for S&T.

5.4.2 The Innovation Fund and SPII

See Section 5.2.

5.4.3 Tax Incentives

5.4.3.1 Introduction

The White Paper described the tax regime in relation to R&D that applied at the time. The White Paper noted that a growing number of countries were instituting fiscal incentives in support of R&D in private firms. These measures were effective but required extensive resources to implement. The White Paper then noted that the Katz Commission was strongly opposed to any indirect taxes and that the recommendations of the Katz Commission had been accepted by government.

In a rather rueful tone the White Paper expressed its acceptance of this view. “Despite the obvious advantage of indirect incentives, which is that it is able to reach a larger number of firms, the White Paper accepts that government is better equipped to administer direct subsidies …”

However, almost decade later, in 2005, an R&D tax incentive was introduced. This followed the National Research and Development Strategy (2002) which highlighted the importance of private sector R&D and a number of studies of the likely efficacy of an R&D Tax Incentive (Pouris, 2003; Kaplan, 2001).

5.4.3.2 Implementation

The incentives offered are considerable; indeed DST claims that following enhancements in November 2006, “…the South African incentive for R&D is one of the most generous offered by a government.” (Department of Science and Technology, 2012b).

Nevertheless, the uptake has been somewhat limited. Between 2006 and 2014, the total number of companies that accessed the incentive was 810 (Department of Science and Technology, 2013). Approximately 45% of the companies

were companies with annual turnover of below R40 million, defined as SMMEs in the National Small Business Act, Act No 102 of 1996. More than 80% of applicants are from two sectors, namely manufacturing and financial intermediation, real estate and business services (Department of Science and Technology, 2013).

There have been concerns about delays and the complexity of accessing the incentives, and various changes have been made to speed up processes and make them more efficient. A number of improvements were effected in 2012 including a new approval process and other measures to enhance the impact of the incentive. These changes were published in the Tax Laws Amendment Act, 2011 (Act No. 24 of 2011). Prior to 1st October 2012, forms were submitted retrospectively and after this date R&D activities were subject to preapproval. In 2013/14, it was reported that there was a significant backlog and measures had been put in place to clear this backlog (Department of Science and Technology, 2013). The DST target is to provide decisions on preapprovals within 90 days of receiving applications (Department of Science and Technology, 2013).

However, there is still a very considerable backlog. The most recent National Treasury Budget Review (National Treasury, 2015) reported:

> "…. the backlog in the approval process is creating difficulties, especially for smaller businesses, which have to wait months for approval. Measures will be considered to ensure that taxpayers are not disadvantaged by undue delays by the adjudication committee. The issue of third-party funding for R&D activities will also be considered."

5.4.3.3 Comment

At this stage, it is difficult to judge the efficacy of the R&D tax incentive. Based on a survey undertaken in 2012, 75% of companies indicated that the incentive had led to the introduction of new products and improved market position, and 50% indicated that it had led to improvements in their manufacturing process. However, less positively only 42% indicated that the incentive helped expand the scale of initially planned R&D projects and 42% indicated that the incentive helped accelerate the pace of R&D projects. Since a major objective of the R&D tax incentive is to "crowd in" (increase?)additional R&D expenditures on the part of companies, the findings above are of concern.

Furthermore only 20% indicated that the incentive influenced collaboration with science councils and 17% indicated that the incentive influenced collaboration with universities. Since one of the declared purposes of the R&D tax incentive is to stimulate collaboration between companies and science councils and universities, the findings above are of concern. This serves as another example of a National System of Innovation in which the collaboration and linkages between the different institutions, in this case the private sector and science councils/universities, is still limited.

The DST report to parliament covering the period between November 2006 and February 2012, stated that the tax revenue foregone due to the R&D tax incentive was estimated to be R2 billion for the period 2005/06 to 2009/10 (Department of Science and Technology, 2012b). Moreover, the R&D expenditure supported was R12 billion of which R10 billion was eligible for the tax incentive. The tax relief offered therefore is very extensive (R2 billion on allowable expenditures of R10 billion).

A key metric of performance is the additional R&D investment that resulted from the tax incentive as compared with the cost of the incentive, where the latter is measured as tax foregone. Treasury provides information on the latter, viz. R2 billion for the period 2005/06 to 2009/10. However, there is no clear estimate of the additional R&D investment occurring as a result of the incentive. Only 23.1% of the companies participating in the R&D tax incentive responded to the question of how much they had increased their R&D expenditure. These responding firms reported "an estimate of R374 million (2.9%) as the additional R&D investment that has been made as a result of the incentive" (Department of Science and Technology, 2012b). This, admittedly very partial data, may indicate that the increased R&D resulting from the tax incentives are limited relative to the tax foregone, and this issue requires further investigation.

The R&D tax incentive consumes considerable resources and is a major instrument designed to enhance R&D on the part of the private sector and to promote collaboration between companies and other R&D performers. Now that a decade has elapsed since the introduction of the incentive, a substantive review assessing this impact should be undertaken. This review will be an important input both for restructuring and improving the incentive itself, but also for determining overall policy on the part of the DST, designed to enhance R&D in the private sector and to enhance linkages between the private sector and other R&D performers.

5.4.4 An Imperative for the Private Sector

The White Paper noted that "government can play an enabling role in the encouragement of innovation culture within the private sector." It also noted that the private sector underinvests in innovation activities and it accordingly proposed that "organised business develop a policy for building innovation capacity and supporting innovation within the country's enterprises" (DACST, 1996).

However the White Paper gave no indication of what such policy might entail or how it might be implemented, nor did it provide any examples of such a policy being adopted by organised business in any other country. As a result, no such policy has been adopted or even attempted by organised business in South Africa, and the authors of this report are not aware of any other country where organised business has developed such a policy.

However it must be emphasised that business enterprises have not been slow to use government support for R&D and their innovation activities. In a recent survey of South African manufacturing companies, 47% of the respondents indicated that they participate in government technology support programmes. The respondents also urged improvements in these programmes (i.e. more funding), especially in areas including R&D funding, capital equipment funding, support for post graduate studies, enhanced skills development and less bureaucracy (Pouris, 2012b).

Chapter 6

Performance

6.1 MANAGEMENT AND FINANCING OF GOVERNMENT SET INSTITUTIONS

6.1.1 Introduction

The goals of the White Paper in respect of the management of government science, engineering and technology institutions (SETIs) were to establish a new management system for SETIs; to develop policy principles for funding of government funded SETIs; and to implement a process of institutional review.

Each point is now considered in more detail.

New Management System: the White Paper identified three forms of SETIs, namely state-owned corporations, science councils and department-based institutes, and noted that the new management system will only be applied to the science councils.

The new system was designed with a number of goals including ensuring that the activities of the SCs align with national priorities; ensuring that the administrative structures promote a favourable climate for innovation; developing and applying a system of performance management; implementing improved governance of public finance; improving overall coordination and overcoming historical incrementalism.

The essence of the change was fourfold as follows:

- to move from a formula system for budgeting to a zero-based budget approach
- to allow a system of multi-year budgeting as presently illustrated through the Medium Term Expenditure Framework (MTEF)
- to develop a set of performance criteria which will enable 'the effective deployment of public resources in the performance of core SET functions and promoting innovation'
- to avoid micromanagement by government officials through the application of a system of institutional review.

Policy Principles (actually forms of budgetary support): the White Paper recognised that government had an important duty to address areas of market failure and historical problems such as fragmentation and exclusivity. Accordingly, it defined three forms of budgetary support (see below) which would be used to ensure that government achieves its objectives and meets its obligations. The three forms are:

- budgetary support; also referred to as core support or ring-fenced grant funding or block funding, and delivered through a transfer payment (Type A) (existing and traditional form of funding)
- contract support; covering the purchase of science and technology services where the terms and deliverables are specified by the funder (Type B) (existing but minor form of funding)
- competitive funding support; referring somewhat confusingly to competitive funding open to all R&D performers to be used to support outputs required for the NSI (e.g. the Innovation Fund) (Type C) (new form of funding).

Institutional Review: in several places the White Paper was very explicit about necessary reforms to the performance management of the science councils, which were reported to have become dominated by a culture of science-based, curiosity-driven research, individualism and lack of transparency (Basson, 1996). The policy called for the development of a "dynamic system in which the outputs from and outcomes of SETI activities are assessed within the context of current and projected future national needs and benchmarked according to best-practice criteria".

It also noted that such reviews should cover:

- the contribution of the science council output to the realisation of national goals or international commitments
- the scientific quality of the outputs, to be assessed by a team of appropriate experts and peers
- the quality of the management of the institutions.

6.1.2 Progress in Implementation

Progress in respect of implementation of the White Paper goals is listed in Table 13.

Table 13. Management and financing of government institutions

OBJECTIVE	PROGRESS
A new management system for SETIs	All the four initiatives in this section have been implemented, with the most significant of the changes being the introduction of a performance management system.
Policy principles for funding of government funded SETIs	All the forms of budgetary support have been implemented (for instance see Figure 22); competitive funding constituted 20% of CSIR's total public income in 2012, up from 0% in 2004. The implementation of ring-fenced and competitive funding within the science councils and universities has been one of the more important and fundamental changes to the financing of public research institutions, and is at least partly responsible for the improved performance of this sector.
The process of institutional review	In 1997, DACST instituted a system-wide review of all Science Councils and the first major review was completed in 1998 (see http://www.gov.za/sites/www.gov.za/files/setreview_0.pdf) Some SETIs were reviewed in a subsequent round (2010); see MRC http://www.mrc.ac.za/publications/SetiReview.html#p=1 and CSIR (2009) There appears to have been no reviews since this date.

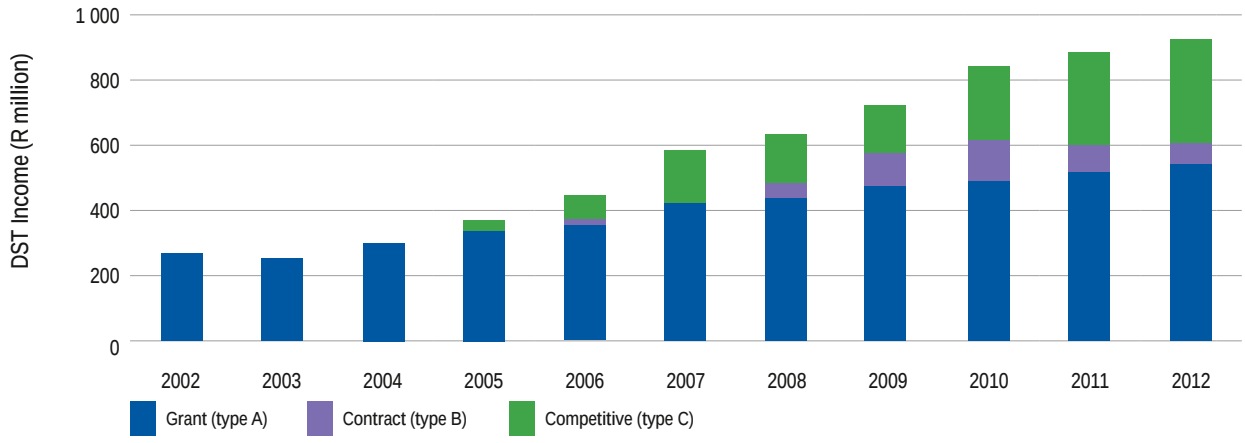


Figure 22. Changes in the CSIR funding profile; 2002 to 2012

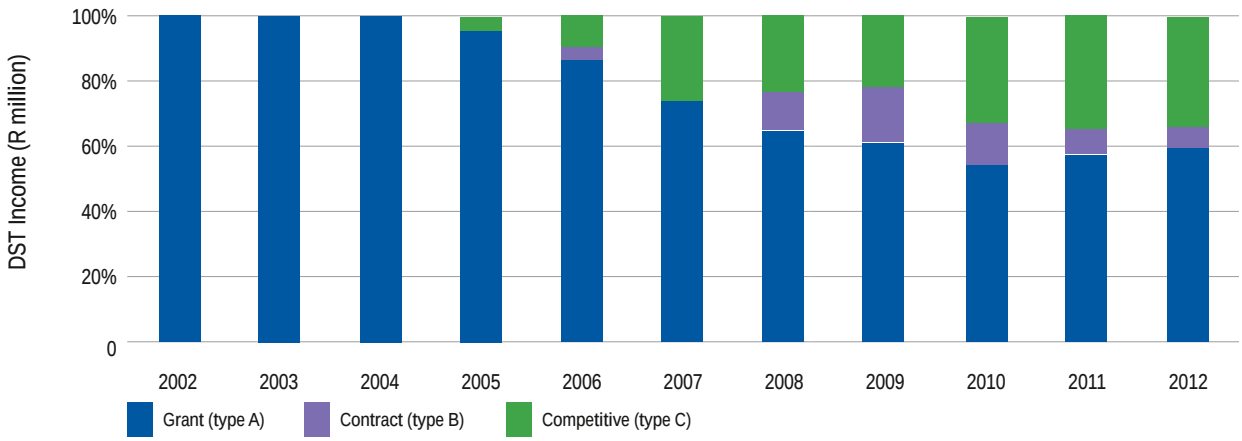


Figure 22. Changes in the CSIR funding profile; 2002 to 2012 (continued)

6.2 OPERATIONAL ISSUES OF GOVERNMENT FUNDED SETIS

6.2.1 Introduction

The goals of the White Paper were as follows:

- The replacement of input criteria with output criteria
- A uniform framework for SETIS
- The role of line departments
- Unfair Competition with the private sector
- Defence research
- The Atomic Energy Corporation
- The linkage of government SETIs to postgraduate education
- Public Finance Management Act (PFMA) and SME ventures

Each point is now considered in more detail.

Replacement of Input with Output Criteria: the White Paper called for the scrapping of the 'system of maximum averages', considered to be outdated and inappropriate for the purpose of ensuring the relevant expenditure of public finances, and the introduction of a set of output monitoring measures, the latter to be identified by the institutional reviews.

Uniform Framework for SETIs: the implementation of the system of Framework Autonomy in 1988 allowed some independence of South Africa's SETIs and specifically facilitated the migration of department-based institutes to science councils, allowing the latter to offer market-related salaries and thereby attract more skilled personnel (Sooryamoorthy, 2015). The White Paper called for the further transformation of department-based institutes to science councils, at the same time noting the need to ensure all data generated with public funds remains in the public domain and that the autonomy should not allow the science councils to move away from their mandates.

The Role of Line Departments: the White Paper supported an ongoing role for line departments in the management of their respective science councils such as the reporting of the Medical Research Council to the Department of Health

and the Council for Geosciences to the Department of Minerals and Energy Affairs (now the Department of Mineral Resources), noting that it is "imperative that there is a well-understood government vision about the relative emphasis of different sectors over time".

Unfair Competition with the Private Sector: it was acknowledged that the dual income system for the science councils could allow for the cross-subsidisation of private sector contract research studies with public grants and hence allegations of unfair competition from private sector companies offering a comparable service. In order to avoid this situation, the White Paper proposed the following key steps:

- strict monitoring of auditable systems for financial management within science councils to ensure that cross-subsidisation for revenue-earning projects does not occur and that grant and budgetary funds are spent with economy, efficiency and effectiveness
- within one year of publication of the WP, all SCs will be required to establish the overhead costs of their activities, and will be required to charge full direct costs plus overheads on all SET contracts, with any exemption from this prescription needing approval by the MCST.
- making a portion of science council funding (determined by the review process) conditional upon partnerships with the private sector

Defence Research: The White Paper recognised the strong technology skills in the defence sector and recommended that these skills be extended or converted to civil use, thereby broadening the industrial skills base. It further proposed that the new strategy of the South African National Defence Force be examined in the context of the NSI since the future of the "defence industry cannot be seen as distinct from that of its civilian manufacturing counterpart; dual use concepts should be understood and applied". It recommended that "the defence industry make special efforts to leverage spin-offs in the civilian sector and to develop relationships with civilian institutions in the NSI to promote spin-ons". The following action points were stated:

- the Department of Defence, DST and the Department of Trade and Industry should co-operate closely to develop a strategy for optimal promotion of the local defence industry
- the Defence Research and Development Committee budget should be displayed in the government SET budget, as well as in the Department of Defence budget.

Atomic Energy Corporation: considering the important role of the SAFARI research reactor at the Atomic Energy Corporation (AEC), the White Paper proposed that the reactor be administered as a National Facility for Research to promote its optimum use by university and technikon researchers and enable vocational training to a much greater extent (with the detailed modalities being agreed upon by the Minister of Mineral and Energy Affairs and the Minister of Arts, Culture, Science and Technology). It also called for an evaluation of the corporation's role according to terms of reference drawn up by the Ministers of Mineral and Energy Affairs, of Arts, Culture, Science and Technology and of Trade and Industry.

Postgraduate Education in SETIs: the White Paper noted that unique facilities existed in the science councils which could be used for training and postgraduate education. It therefore encouraged the involvement of SETI staff or facilities in postgraduate education provided that the following principles (to avoid competition with the universities) were observed:

- SETIs could offer postgraduate education and training only through formal agreements with universities or other tertiary level educational institutions.
- all staff operating costs related to research activities undertaken in the SETIs' own facilities and involving postgraduate students to be borne by the regular budget of the SETI concerned, with the exception of payment of stipends for postgraduate students or salaries for academic faculties who are jointly supervising students (to be paid by the university or the NRF

- tertiary level education institutions involved in such agreements to grant SETI staff involved an adjunct appointment at an appropriate academic level, and such staff should be eligible to receive additional remuneration from the institution involved for any activities (for example lecturing) which are additional to the normal duties of the SETI staff member as a researcher. Similar arrangements in the other direction, involving academic staff taking on additional duties on behalf of the SETI involved, could also be made.

6.2.2 Progress in Implementation

Progress in respect of the above goals is presented in Table 14.

Table 14. Review of specific initiatives covering SETI operational issues

OBJECTIVE	PROGRESS
The replacement of input criteria with output criteria	The science councils report on a quarterly basis against an agreed set of key performance indicators, the latter consisting of a mixture of input and output measures. Further details have been provided in Section 6.1.
A uniform framework for SETIs	This recommendation has not been widely applied
The role of line departments	There was some movement in the reporting of the science councils with the CSIR being shifted from the Department of Trade and Industry to DST and the Human Sciences Research Council from the Department of Education to the DST.
Unfair competition with the private sector	Items 1 and 2 of the necessary steps to avoid unfair competition were implemented and remain in place. Item 3 was not implemented since it was not included in the review process. The issue of unfair competition seems to be a minor issue in the ongoing functioning of the science councils, perhaps as a result of the implementation of full cost accounting and a more detailed governance structure for the Parliamentary Grant.
Defence research	Defence R&D is reported in the National R&D Survey but the actual defence budget is not disclosed. Defence research is about R460 million per annum with total expenditure on science and technology activities being about R500 million (Department of Science and Technology, 2014a). However the envisaged cooperation between the three departments has not been sustained and there is no joint planning at present. This remains an important area for policy.
Atomic Energy Corporation	Neither of the White Paper recommendations were implemented; SAFARI remains part of the AEC and the review did not take place. Nevertheless there is a national facility for nuclear research (iThemba Laboratory). Further details on the national facilities and iThemba can be found at http://www.nrf.ac.za/research-platforms/national-facilities.
The linkage of government SETIs to postgraduate education	The proposed recommendations were implemented and continue to be applied. Joint appointments between the higher education sector and the science councils are now not unusual.

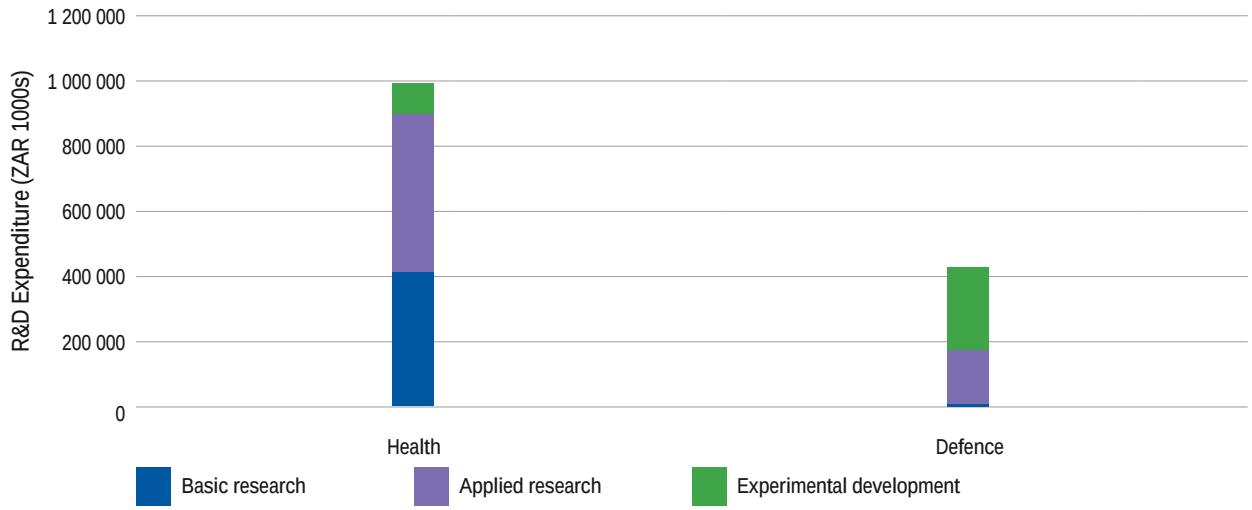


Figure 23. South African government's health and defence R&D expenditure (2011/2)

6.3 PROMOTING LINKAGES BETWEEN SECTORS AND BETWEEN STAKEHOLDERS

6.3.1 Introduction

The White Paper notes that there are few examples of research results being effectively commercialised. There is also the absence of programmes to keep R&D performers in touch with industry. As to linkage between firms, the White Paper notes that the dti is engaged in studies as to how to enhance linkages between firms.

The White Paper states that "the new management system will be administered in such a way as to promote linkages."

The White Paper goes on to state that, while the main thrust is directed at fostering innovation, this must be strongly allied to fostering the diffusion of new technologies. This the White Paper links directly to support for SMMEs. "The time has now arrived to put significantly increased emphasis on addressing the technological needs of SMMEs."

Emphasis should be placed on supporting entrepreneurs in the informal sector. In this regard, the White Paper advocated developing a South African model of manufacturing technology which should reach microenterprises and tap into existing technological expertise.

The White Paper proposed that DASCT would work with the dti on a range of relevant issues related to technology diffusion in SMMEs. Particularly important will be the best means of financing technology development for SMMEs.

6.3.2 Progress in Implementation

It is not clear how the new management system proposed by the White Paper could be administered so as to promote linkages. No significant supports for technological advance in microenterprises were implemented. No South African model of manufacturing technology was developed. The Innovation Fund and SPII, and later TIA, did provide financial support for technology development for SMMEs.

6.3.3 Comment

There are two separate issues being considered in this section of the White Paper and the conflation of the two obscures the importance of each to the overall performance of the NSI. The two issues are the 'promotion of linkages between actors in the system' and 'support for technology absorption within SMMEs'. The latter is broader than the question of linkages since sources of technology and mechanisms of technology transfer, adoption and diffusion go beyond linkages with universities and science councils. Each issue is now discussed separately.

Linkages: Although the White Paper recognised the importance of networks and relationships between actors, and made several suggestions to improve these linkages, such as the establishment of the Innovation Fund and the establishment of a new management system as noted above, it is apparent from the indicators that these networks have remained weak, or have indeed weakened during the implementation period. For instance, the extent of linkages between the science councils and the private sector, as measured by direct business funding of R&D in the science councils has declined from R153 million in 2008/09 to R68 million in 2011/12.

A recent review of the science councils, undertaken for National Treasury, concluded that only Mintek and to some extent the CSIR, are effective in partnering with the private sector (Bertoldi et al., 2014). The study recommended that further work be undertaken to more fully understand the barriers to technology transfer from science councils to the private sector. It is noted that South Africa is not alone in struggling with industry/academia/public research institute linkages. For instance, a recent review of the NSI in Ecuador has identified a similar problem (Byron and Prasanta, 2015).

This issue of limited collaboration between different actors is also manifested in the science council/university relationship, with limited evidence of significant joint R&D. One solution could be to incentivise science councils to partner with the universities for the commercialisation of technologies and particularly technologies which address market failure (where there is little incentive for private companies to invest). This initiative may require the establishment of a dedicated fund within TIA to support university/science council partnerships covering projects which are not funded by the private sector but which have a high public interest or public benefit factor.

The White Paper was heavily focused on fostering innovation. Diffusion of innovation and technology transfer through mechanisms such as foreign direct investment (FDI) and technology licensing received much less attention or was largely neglected. Large multinational corporations have been establishing R&D centres in developing countries such as China and India, but South Africa has not managed to attract such investments.

Technology Absorption by SMMEs: The problem of access to technology seems particularly acute to SMMEs. Although a great deal has been done to support innovation in SMMEs, through the Innovation Fund and more recently TIA, the establishment of technology platforms, incubation programmes and enhancing access to the R&D tax incentive, there are still considerable challenges for such organisations.

6.4 INTERNATIONAL AGREEMENTS

6.4.1 Introduction

The transition into democracy in 1994 allowed South Africa to be fully reintegrated into the international community of nations. The end of the isolation meant that the country could resume diplomatic relations at bilateral and multilateral levels. This created opportunities for cooperation in a range of areas of interest to the country, including science, technology and innovation.

To address this opportunity, the 1996 White Paper envisaged a two-pronged approach. At the regional level, South Africa assumed the role of proactively facilitating innovation through partnerships with its neighbouring countries, which

were not necessarily in its direct interests. Beyond the region, the objective of science and technology diplomacy was to facilitate joint R&D opportunities on the basis of mutual benefit. At the international level, S&T-based international partnerships were positioned to align with the overall foreign policy of the country. It is noted that the White Paper called for a cost-benefit analysis of international partnerships, including the deployment of attaches, in order to ensure that these partnerships resulted in a net benefit for the country.

In the following discussion we assess the extent to which these White Paper initiatives were implemented.

6.4.2 Africa

6.4.2.1 Bilateral Relations

DST has entered into a number of bilateral agreements with countries on the continent in order to achieve specific objectives. According to DST, the motivations for African bilateral agreements are not dissimilar to those that exist in the rest of the world. Joint R&D projects remain the focus of these agreements.

In terms of supporting South Africa's broader foreign policy agenda, S&T agreements are relatively easier to initiate because they are often regarded as a neutral enterprise of clear mutual benefit in comparison to other areas. Therefore, S&T agreements have in some cases been used as a start of a much broader and complex negotiation process of deeper political issues.

6.4.2.2 Multilateral Partnerships

The dominant multilateral bodies on the continent that involve South Africa are the Southern African Development Community (SADC) and the African Union (AU). DST has been involved extensively in the two bodies. In these relationships, South Africa's strategic focus has been to foster the recognition of science, technology and innovation as important areas of activity to drive the development agendas of the two bodies.

From the beginning, South Africa led the process of including science and technology in the agenda of the African Union. The Constitutive Act of the AU recognises the important role of science and technology in development. As a result, institutional mechanisms have been put in place to attend to STI on the continent. The inaugural meeting of the African Ministerial Council for Science and Technology was hosted by DST in South Africa. A number of continental science and technology initiatives, such as in laser technology and biotechnology were subsequently launched. The S&T programmes under the New Partnership for Africa's Development (NEPAD) which South Africa sponsored, were later subsumed into the AU.

Within SADC, South Africa supported various initiatives to increase the profile of science and technology within the region. South Africa spearheaded the signing of the SADC Protocol on S&T. DST also contributed the expertise required for the formulation of the science and technology chapter of SADC's Regional Indicative Strategic Development Plan (RISDP). For several years, DST has seconded an official to serve at the SADC headquarters in Gaborone in order to support regional S&T work.

6.4.3 International Partnerships

6.4.3.1 International Bilaterals

DST has entered into a number of bilateral agreements in S&T with countries in all the regions of the world. The aim of these partnership agreements is to foster R&D bilateral programmes. The programmes are reviewed on a continuous basis so that those that become dormant due to lack of activity, are no longer serviced or renewed. In this way, effort and resources are directed where there is potential for meaningful cooperation.

6.4.3.2 International Multilaterals

DST has been active in several multilateral organisations that have a strong S&T component. The most important of these has been the European Union, which has allowed South Africa to participate successfully in the successive Framework Programmes and the recently launched Horizon 2020. All these have yielded important opportunities for joint R&D programmes, research funding and human resources development. Similarly, DST has valued the opportunities within BRICS, ICSU, TWAS and the OECD.

6.4.4 Attaches

DST has placed attaches in a limited number of countries in order to advance its international relations strategy for S&T, including the following:

- Gaborone: to service S&T matters in the absence of capacity at the SADC headquarters, and to pursue the objective of promoting S&T in the region
- Brussels: to maximise the value that accrues to South Africa from participating in the EU
- Moscow: to leverage opportunities out of the bilateral agreements with Russia and other countries in the region
- Tokyo: to service the bilateral agreement with Japan.

DST is considering placing an attaché in Addis Ababa in order to service the African Union multilateral and the bilateral relations in East Africa.

A summary of DST expenditure over the last two years is presented in Table 15, from which it can be concluded that extensive progress has been made in building international partnerships.

Table 15. Key international cooperation results for 2012/13 to 2013/14

PERFORMANCE INDICATOR	ACHIEVEMENT 2012/2013	ACHIEVEMENT 2013/2014
Foreign STI funds secured for South Africa	R241 million	R436 million
Foreign participants collaborating with South Africans in STI	2,175	4,919
South African post-graduate students participating in international STI programmes	748	896

Source: Department of Science and Technology (2014b)

From the above, it can be concluded that DST has implemented the initiatives of the White Paper in a rational manner, achieving the required balance between obligations in the African continent and leveraging various types of resources elsewhere in order to support local R&D efforts.

Chapter 7

Human Resource Development and Capacity Building

7.1 THE APPROACH OF THE WHITE PAPER

The White Paper's approach to HRD is based on its relationship to S&T policy and innovation, with particular focus on the 'context of problem solving in service of national needs.' In this consistently broad formulation it seeks to give effect to the intentions of government as set out in the Growth and Development Strategy (GDS) due to the perceived central role of S&T in the success of the GDS as it seeks to address the needs of all South Africans. The GDS, it argues, is dependent on the development of the appropriate human resources necessary to give effect to the demands of S&T, referring in particular to the 'race and gender' profile of scientific and technological knowledge and seeking to address what it perceives as a problem in that regard.

In addition, the approach avowed by the GDS in regard to the S&T requirements of the country also raise other important issues about the appropriate types of S&T capability, the qualitative nature of these and the quantity of skills required. It could be argued that these questions precede the development of any strategy around HRD for S&T or at least are coterminous with it. In effect, the development of the appropriate knowledge and capabilities (and its other attributes above) are dependent on how the requirements of the GDS are itself understood as expressing a developmental approach that is both inclusive and comprehensive and not limited to economic questions alone.

In explicating its premises the White Paper refers to the 'Global Context' and its potential impact on development. Here it points to the "globalised" nature of social and economic systems as these are shaped by 'world market forces', the power of ICT and the rapidity of the changes within it requiring responses that are both flexible and innovative. In such a context it avers that the 'major challenge will be to integrate successfully into global systems and communities' explicitly by reference to the context of 'local needs and aspirations of South Africans'.

Itemising the challenges consequent on global developments, it refers to a particular set of factors that are likely to impact on the process of planning and the resource requirements for such plans. Each of these factors is explained in some detail. In referring to these, the White Paper suggests that any analysis of the efficacy of its approach would need to recognise the importance it places on these specific factors affecting planning and resource allocation.

In effect these aspects point to the ubiquity of systems for the rapid dissemination and use of information, global competitiveness based on market led economic systems, the coordination of innovation policies and strategies and problem solving and multidisciplinary partnership approaches to resolve the challenges of growth and development. While the impact of these global realities must be taken into account, that has to be done in the context of the local challenges often repeated in the White Paper, both in regard to addressing the contextual challenges of the post-apartheid society and the means of doing so.

Here too the 'vision of innovation' is informed by the need to serve 'national goals' by focusing 'simultaneously on maintaining cutting edge global competitiveness and on addressing the urgent needs of those of our citizens who are less able to assert themselves in the market' .

Based on these references it is clear that the linkage between innovation strategy and S&T has important implications for an HRD system. In effect how one conceptualises innovation and S&T (as much as of 'development') make a considerable difference in the orientation one adopts towards the strategy for HRD. In the White Paper, HRD is seen in an instrumental role relative to the purposes of S&T and entails an understanding of its role as critical to South Africa on the basis of the conception of development which we have referred to above. In other words S&T is itself an instrument of development and its efficacy is premised on the approach to development (and innovation) envisaged in the White Paper, and encapsulated in the authoritative pronouncements of the Ministers in charge of it. The implication of this is that S&T must itself subscribe to the broad approaches both in regard to the achievement of the ends of freedom and the means for achieving these. Its consequent role is that of a catalyst for the widest conceptualization of the freedoms envisaged in the White Paper through the democratic and participatory means that are set out therein.

7.2 HUMAN RESOURCE DEVELOPMENT TARGETS

Before exploring whether such an approach has been implemented, the specific targets of the White Paper on HRD are discussed. The chapter affirms 'people as South Africa's most basic asset' and defines HRD in relation to capacity building as follows:

> "In its most general usage HRD refers to the process whereby people, either individually or collectively, acquire the knowledge and skills necessary for specific occupational tasks as well as for other social, cultural, intellectual or political roles associated with a vibrant democratic society. It also refers to the ability to access and utilise information resources, to give expression to theoretical concepts and their innovative application."

As one can see from this definition, HRD is defined expansively referring both to its relationship to 'specific occupational tasks' and to a wider range of intellectual purposes consistent with the demands of a democratising society. Even more, it is intended to generate knowledge that is based on strong theoretical foundations and have applicative value. Furthermore,

> "HRD is dependent on a comprehensive strategy outlining coherent and integrated policies in a wide range of related areas, including economic, labour, education and training, and science and technology policy. Central to this approach is the belief that attempts at reforming an element of the system, for example, education and training, in isolation of developments in other policy areas and social institutions will not generate the desired outcomes."

Two things can be remarked upon as important in this formulation of the role of HRD in the White Paper. The first is the relationship it bears with other policies including economic, labour, education and social policies. Secondly, the White Paper regards an integrating approach between policies and practices that concern education and other domains of its responsibilities as 'central to this approach'. This is indeed an important insight and must have a major bearing on how education and training's role towards the development of human resources is understood. This view is further elaborated in the White Paper by reference to its view of the role of institutions (see Section 3.1) and the impact on individuals of HRD through the 'development of high-level skills, competencies, values and attitudes required for S&T development'.

It further avers that S&T development serves both the function of providing content knowledge and skills, acts as a mode of transferring knowledge and skills and speaks to its links with the GDS and HRD's responsibilities in that regard. These emphasise the development of an 'integrated and affordable five-year HRD plan', sectoral investment programmes for the National Training Strategy, 'restructuring education' qualitatively, prioritising 'skills for employment, growth and democracy' social partnerships including with the private sector and a commitment to 'a training investment target of five per cent of the salary bill'.

Very importantly the chapter refers to the 'most significant social element of HRD as its contribution towards the social emancipation of individuals and to the collective upliftment of society' through the acquisition of knowledge and skills enhancing the ability of individuals to 'deal with the day-to-day challenges of society and also through their personal involvement in the social, political and economic spheres of life', while the 'projected economic goal' is similarly enhanced through institutional cooperation and the necessary investment. It pays special attention to the question of 'Equity through Redress' because of the 'pervasive effects' of apartheid and its inequities, and is committed to programmes to 'redress the inequalities which have excluded black women and men from the mainstream of South African society' referring to particular programmes for the purpose.

An effective HRD programme in science, engineering and technology is therefore vital to redress this imbalance, to improve our economic performance and to ensure the proper functioning of the NSI. Such a programme will have to address the consequences of past deliberate policies and practices that promoted racial and gender discrimination in HRD. Apart from the human rights issue, there is also the imperative for South Africa to optimise its productivity and economic performance to succeed in the global marketplace. To achieve this goal, South Africa will have to maximise the utilisation of ideas, creativity, ingenuity and innovation from the entire population.

Further sections of the chapter provide an elaboration of the importance of research capacity, to strengthen the role of HDIs in research through stimulating the development of S&T and by targeting women and black students in these fields of study and through awarding grants based on the ability of programmes to deliver in the immediate term, evidence that programmes promote staff development, incorporation of a strategy for sustainability, specification of expected graduate and research outputs, and gender targets.

This section is followed by the section on HRD and Capacity Building at the National Level making reference to the need for flexibility and the portability of qualifications through the 'establishment of standards, accreditation and certification criteria, credit transfer and the redress of inequities'. Here the White Paper refers to the National Qualifications Framework (NQF) and its regulatory authority, the South African Qualifications Authority (SAQA), which together were intended to integrate learning, improve access, mobility and progress through the system and to ensure that the quality of education and training is enhanced. Thereafter it re-iterates the importance of linkages between institutions so that resources are used optimally. The chapter then focuses on various formative and developmental sectors in the education system, including lifelong learning, which once more emphasises 'a holistic approach towards education and training', and refers to the goal of the White Paper on Education and Training of 1995 as being:

> to enable all individuals to value, to have access to, and succeed in lifelong education and training of good quality. … An integrated curriculum will reflect the norms and values of a non-racial, non-sexist and democratic society. It must ensure that the curricula are relevant to both the needs of the individual as well as to the social and economic demands of society.

The White Paper also notes the importance of Compulsory Mathematics/Science at Pre-tertiary level, based on the 'overwhelming support for maintaining compulsory mathematics and science up to the exit level' and to Adult Basic Education and Training (ABET) because of its importance to 'redress discrimination and inequality imposed under apartheid as well as to redress the exclusive "youth" focus of schooling' and because of its value to the GDS. ABET is aimed at providing adults with education and training programmes equivalent to exit level in the formal school system, with an emphasis on literacy, numeracy and technological skills. It constitutes a fundamental and crucial step in the GDS. The chapter also deals with the importance of technology education as 'central to contemporary society' and refers to its support for the development of this aspect of the education curriculum in assisting the (then) Department of Education.

The final section of this chapter is devoted to the issue of Public Awareness of S&T re-iterating the WPs view about the importance of participation to the process of social transformation in SA and setting out the campaign approach to be adopted by the Department to 'promote awareness and understanding of S&T.' It sets out how it will campaign for a wider appreciation of the role and purposes of S&T through 'public awareness programmes, bringing in a wide network of institutions and organisations for the purpose.

Table 16. Implementation of White Paper Initiatives on HRD

SECTION OF THE WHITE PAPER	SPECIFIC INITIATIVE	PROGRESS IN IMPLEMENTATION
Human Resources as a National Asset	Build institutional and individual capacity to support R&D Strengthen the ability to access and utilise information resources, and to give expression to theoretical concepts and their innovative application.	The White Paper is vague on the targets in this area, other than to state that individual capacity involves the development of high level skills, competencies, values and attitudes required for S&T development. It defines HRD as the process whereby people, either individually or collectively, acquire the knowledge and skills necessary for specific occupational tasks as well as for other social, cultural, intellectual or political roles associated with a vibrant democratic society. As a result, the DST has interpreted the policy in a rather narrow sense with focus on the number of doctorates being produced by the system (see Section 7.3.2).
Links with the Growth and Development Strategy	Support the first pillar of the strategy and specifically bring an S&T perspective to the programmes	The first pillar of the GDS covered the development of a HRD strategy, the development of a training strategy, the restructuring of education, and the establishment of social partnerships in HRD. No evidence exists of the proposed HRD or training strategies as defined in the White Paper, although Government has developed various strategies for HRD without significant outcome on STEM education (see Section 6.3.1).
Equity through Redress	Support programmes to redress the inequity in S&T capability including assistance for students. Network with the Department of Education regarding a Technology 2005 programme	According to the White Paper, DACST was already collaborating with the Department of Education on a Students and Youth into Science, Technology, Engineering and Mathematics Programme, a student recovery programme linked to teacher development. Whilst partnerships including the National Science and Technology Forum and the Department of Basic Education had indeed begun working together on selected schools, no records of a systematic 'Students and Youth into Science, Technology, Engineering and Mathematics (SYSTEM) Programme' that was ostensibly framed as a student recovery programme linked to teacher development is in place. No evidence of a Technology 2005 programme is available.
Research Capacity Development at HDIs	Strengthen R&D at the HDIs including obtaining development assistance as support to establish or strengthen centres of excellence in research in Historically Disadvantaged Institutions	The White Paper sought to improve research capacity at HDIs through obtaining funding to establish or strengthen centres of excellence in research. Subsequent changes in the format of government's relationship with ODA, the restructuring of higher education and training, and further reforms effectively transformed the sector. However the ongoing existence of HDIs as a category makes a pointed acknowledgment of the failure of such an intervention by DST. However, some positive aspects do exist in the Technology Women in Business initiative, albeit mediated by the dti.
HRD and Capacity Building at the National Level	Foundations of an HRD policy Implementing the policy Lifelong Learning and Compulsory Mathematics/Science at pre-tertiary Level	The White Paper recognised that the National Qualifications Framework would be foundational for a comprehensive HRD policy. It argued further that the South African Qualifications Authority (SAQA) would serve as the linkage for HRD, Lifelong Learning, and Compulsory Mathematics and Science at Pre-tertiary Levels of Education and Training.
Adult Basic Education and Training	Make provision for lifelong learning opportunities	DACST was meant, through engagement with SAQA, to contribute to the development of an effective ABET curriculum and policy relating to S&T. Capacity building at national level has indeed been transformed with SAQA driving an elaborate and complex bureaucracy that polices a NQF. As opposed to integrating into a system of lifelong learning which affords mobility and the recognition of prior learning, the South African system has essentially become segregated into distinct silos which separate academic, professional, and vocational streams.

SECTION OF THE WHITE PAPER	SPECIFIC INITIATIVE	PROGRESS IN IMPLEMENTATION
Technology Education	Introduce technology education in school curricula	DACST was meant to have assisted the Department of Education in developing a technology education programme for schools. This remains a national challenge and can still be achieved, especially through the Operation Phakisa in ICT Education launched in October 2015.
Public Awareness of S&T	Introduce a campaign to promote awareness and understanding of S&T	Government was going to institute, via DACST, the delivery of S&T public awareness programmes in collaboration with a consortia of institutions, including societies for the advancement of science, professional associations, academies of science, science museums and libraries, media (printed and electronic), educational institutions and private business. Whilst DACST did indeed advance significant Public Awareness of S&T, especially in the Year of Science and Technology, this task is ongoing and needs to be significantly updated.

7.3 PROGRESS IN IMPLEMENTATION

Progress on all the White Paper areas relating to HRD has been summarised in Table 16; some of the items are now discussed in more detail.

7.3.1 Consequences of the Human Capital Discourse

The central issue that arises from the strong imprimatur of the White Paper's approach to HRD for S&T has to do with the nature of the education and training necessary in the pursuance of its approach. What is clear is that the White Paper interprets HRD's role in the broadest terms that are neither determined by economic ends alone nor by a reductive approach to scientific knowledge. Throughout it enjoins decision makers to adopt approaches to HRD that are inclusive and encompassing, humanising and democratic and based on interpretations of innovation and S&T which are equally so. In affect this approach requires integrative and 'multidisciplinary' knowledge and innovation based on conceptions of knowledge and skills that combine social and technical capability, political awareness and cultural inclusivity. Its definitions, content and purposes of HRD for S&T espouse the achievement of the broadest social, cultural, political and economic purposes for S&T through the development of HRD, requiring that proper attention be paid to the context of the theorisation and application of HRD.

The relationship between S&T for HRD is unavoidably relevant to this day but it is now the subject of very diverse and contradictory interpretations since the passing of the White Paper of 1996. In some of these interpretations a much narrower view of HRD for S&T is favoured and has had disquieting effects. For instance, these narrower interpretations of especially education and training for HRD are in danger of similarly limiting the purview of S&T (and innovation) as essentially an adjunct of a manufacturing (and even more of a military/energy driven economic) system. This interpretation raises questions about how the ideas of the White Paper have been interpreted and their usefulness in relation to its broad and encompassing goals. Such interpretations are circumscribed within the largely productivist approaches to education and training directed at the specific needs of formal labour markets in predominantly industrialized economies.

On the other hand, the broader approaches required by the White Paper in the context of an unevenly developed social and economic system, characterised by very significant (at over 25%) levels of unemployment and poor (or declining) rates of labour absorption, suggest substantively different (to 'productivist') approaches. These contradictory perspectives raise important questions about how the role of education and training in the pursuance of HRD should

be understood and requires us to reflect on the recent developments for their impact on the mandate contained in the White Paper.

Regrettably, especially more recently, leaders in business and in government, unions, institutional leaders, labour market analysts, the media and academics have swamped the discourse of human resource development with the narrower interpretations described above. It is impossible to overstate the seductive lure of the promise of employment and its effects on any conception of human resource development, no matter how tendentious its premises might be, because of the overriding reality of unemployment and its pernicious social and other effects.

The ideas that inform such an approach are based largely on a set of largely economy-based *assumptions* about the role of HRD in society. These assumptions impose a pre-emptive framework that dominates discussions about the role of learning and scientific knowledge acquisition. In particular education and training (and HRD) is often assumed to be the panacea to the resolution of the triadic challenges of poverty, inequality and unemployment without the necessary evidence for this claim. The relationship between education and skills development on the one hand and the socio-economic system on the other is assumed to be best understood through the imperative voice of business's demands. These demands are increasingly framed in relation to 'state failure' on a number of accounts, (variously described as disempowering for the country's competitiveness, productivity, income levels, and the development of a 'knowledge economy') especially when it is alleged that these failures are exacerbated by other factors like inflexibility of labour regimes, poor and inefficient public services, infrastructure (to support private economic activity) and corruption. Nowhere is it acknowledged that business itself is complicit in some of these practices both historically and at this time, nor is its influence in shaping the policies of government in opposition to wider social interests recognised.

The predominantly 'economistic' assumptions require careful consideration because of their impact on how we might interpret and implement the HRD strategy of the WP. They raise a number of pertinent questions. Firstly, is it suggested that under the prevailing economic and social system, there is a readily available supply of jobs if the requisite skills are there; or that, conversely, once there are skills in the market the jobs will follow.

Secondly, how does one understand the conundrum posed by the simultaneous complaint that there are no jobs even for graduates while there are no skills which are appropriate? Is it simply that those who do have unused skills are wrongly educated and trained - too many humanities and biblical studies degrees and too few science and technology? Or is this conundrum really an expression of the contradictory and selective preferences of capitalist labour markets which can refuse particular skills while, simultaneously, complaining about the absence of skills, excluding some workers while employing others based on the narrower requirements of 'efficient' production and 'technological innovation'?

Thirdly, given especially the composition of capital in market driven economies, it is unclear whether the increasing mechanization of work results in increases or decreases in the availability of jobs. What is the presumed relationship between the new forms of technological innovation and employment? What is the record of this relationship over time, and what, similarly, is the role of capital mobility in the sustainability of jobs in any national employment system? What evidence is there about this relationship in the global arena in the face of job losses in formal labour markets?

Fourthly, statements about the relationship between jobs and skills demand are largely silent about the qualitative attributes of work, about the particular attributes of gendered, racialised and alienating work even in developed economic systems. How do these relate to conceptions of citizenship and nation-building and a broader framework of rights in society?

Fifthly, are the assumptions drawn from developed economic systems about job opportunities transferable to economic and social systems based largely on the primary economic sector or for subsistence economies? Can the benefits associated with beneficiation resolve the size of the problem either itself or with other industry policy strategies? And are these assumptions valid even for developed countries given the financial crisis of 2008 and its consequences?

Sixthly, how does - in any economic system and certainly here in South Africa - the extreme concentration of investment capital in a few large multinational corporations affect the possibilities for employment creation, both in the private

sector and in a highly dependent informal economy, and what is the impact of the extreme mobility of investment capital on the possibilities for job creation in any area of work including the formal sector employment? Assuming, however, that the corporate capital sector is not the main area of concentration of job possibility (denied daily in the public media and by the representatives of free-market ideas), and assuming that in fact, it is in the small business, public, informal and care economy, what then are the conditions precedent which would make these areas of economic activity meaningful possibilities?

In short, the relationship between human resource development as the process of developing knowledge and skills cannot be understood as simply the linear cause and effect that it is purported to be, since there are a range of historical and contextual factors which inform the conditions and possibilities affecting that relationship. The notion that in South Africa at this time, education and training will resolve the problems of unemployment because it will build economic capability and simultaneously resolve the problem of unemployment/jobs, is untenable. It arises from the limits of the present practice especially responsive to the imperative voice of business alone which has had profound effects on the thinking and actions of government in the pursuance of its very own policies and its failure to implement the visionary ideas contained in a great deal of legislation (including the White Paper) about how HRD should be conceptualised and dealt with in practice.

7.3.2 Enrolments and Attainment Rates in Higher Education

Enrolments in higher education institutions have increased from 632,719 candidates in 2001 to 938,201 in 2011, representing an increase in participation rates from 14% to 17% over the ten year period (Statistics South Africa, 2013). Although more recent statistics are not available, it seems likely that the national target of 18% participation rates by 2014 has been met. However the gains are substantially uneven; participation rates for women (20%) are higher than men (15%), with African men having the lowest rate at 11% vs. white women at 63% (Higher Education South Africa, 2014). Enrolment at FET colleges for middle level skills such as technical and vocational education reached 400,273 in 2011, well below the targeted figure of 1 million (Statistics South Africa, 2013) and further increases are clearly required.

About 28% of all student enrolments are in the area of science, engineering and technology (Council on Higher Education, 2013), which is high by international standards and on a par with Russia, Finland and Germany (Cornell University et al., 2014). Nevertheless, the number of school leavers with acceptable mathematics and science literacy levels is low and South Africa was placed last out of 144 countries in the Global Competitiveness Index in terms of the quality of mathematics and science education. Clearly this is a major area for improvement; until young South Africans can attain levels of literacy at secondary school level that will equip them with the necessary skills for engaging in the broader economy, youth unemployment will remain at dangerously high levels.

In terms of outputs of doctorates, it is noted that the system only managed to double its doctoral output over the period 2000 to 2015 from 685 to the current doctoral output of 1,421 graduates. The South African National Planning commission expects a threefold increase in doctoral graduates by 2030, and has set a target of 5,000 doctoral graduates per annum for the South African higher education system, a target which seems highly unlikely of being met, having been criticised as unrealistic given the way in doctoral degrees are structured in South Africa, how doctoral students are supported and supervised, the differences between professional and academic doctoral qualifications and how these impact on the potential contribution of doctoral qualifications on the knowledge economy (CHET, 2015).

7.3.3 Links with the Growth and Development Strategy

No evidence exists of a “human resource development investment strategy which would be an integrated and affordable five-year HRD plan” nor a “training strategy which details sectoral investment programmes for the National Training Strategy, with a priority on immediate investment strategies”. Efforts to intervene in basic and general education may have

indeed sought to restructure the sector "through improving the quality of education within the prevailing fiscal constraints with the priority on skills for employment, growth and democracy" but there is again no evidence of a DST "plan for effective backlog provision."

Such an intervention would have contributed to redressing historical and contemporary inequalities which continue to be reproduced under the regime of austerity. Without a clearly articulated plan or institutional format, no evidence exists that DST monitored social "partnerships with the private sector on education, health and training" to ensure that they attain "a training investment target of five per cent of the salary bill". The GDS, has since given way to subsequent versions of national developmental plans that have included an Accelerated and Shared Growth Initiative for South Africa, a New Growth Plan and the current National Development Plan. From the GDS, no evidence exists of the DST directly bringing the perspectives of S&T in HRD into their elaborations. Whilst interdepartmental interactions were indeed affected, there is no public list of documentary responses to any of the national developmental plans of the South African government from DST.

As already noted, there are profound consequences for inappropriate interpretations of the role of human resource development and its relationship to society's needs. Understandings based on de-contextualised concepts and practices obfuscate rather than clarify the relationship. Policies that simply emphasise the enhancement of technical competencies, narrowly conceived, diminish the role of educational knowledge, more broadly conceptualised, and invariably give rise to particular choices in the way that resources are utilised. The effects of the racialised and racist conceptions of HRD, under engineered by apartheid, continue to abide in the forms of differentiation and structural inequalities that persist to this day in South Africa, both in its education and training systems and in many of the attributes of its S&T, largely because the qualitative attributes of S&T have been ignored in the reductive discourses about its development. These have had and will continue to have effects on the possibilities for achieving the stated goals of the White Paper.

7.4 SUMMARY OF WEAKNESSES IN IMPLEMENTATION

In summary, the following conclusions in respect of implementation of the White Paper's HRD objectives are noted:

- The broad vision that is encapsulated in the formulations of the White Paper, including the role of education and training for HRD, has been narrowly interpreted; the vision needs strong and renewed affirmation through concrete practices and strategies, resource allocation and policy choices in order to ensure a more comprehensive implementation.
- HRD for S&T requires strongly multi-disciplinary approaches to the development of the knowledge that is appropriate to the advancement of S&T – especially in relation to knowledge for 'national development', even if such 'national development' is conceptualised critically. In this regard the White Paper enjoins a view of basic science and technological innovation that is complementary. Moreover it abjures the reductive language based on the old and unhelpful division about the 'two cultures' (separating the physical sciences from the humanities and social sciences) that continues to be pervasive in aspects of university culture, making the reconciliation of a wider range of perspectives – social and scientific, natural and humanist, available for the analysis and resolution of social and planetary crises - impossible.
- As the White Paper suggests, finding the right approach to probe the deeper and substantive purposes and content of HRD for S&T requires appropriate and meaningful engagements with the communities most affected by the development of HRD for S&T. Approaches to HRD that are unconcerned about the participation of communities in the definitions, content and delivery of a human resource strategy are likely to fail as the many examples of past failure would attest.
- The present lacuna in the White Paper surrounding the issue of global biosphere, including environmental and ecological aspects, needs to be reconsidered so that an appropriate formulation of this issue is developed for the purposes of the HRD strategy.

Chapter 8

Science and Technology Infrastructure

8.1 ESTABLISHMENT, OPERATION AND MAINTENANCE OF INFORMATION SERVICES

8.1.1 Introduction

The goals of the White Paper in this area were defined as follows:

- Communications and information systems; the White Paper stressed that government should play an active role in communications and information systems, not only as the regulator but also in the provision of infrastructure and information. In the area of telecommunications infrastructure, it recommended that government should provide such services to all sectors of the community, including digital exchanges and transmission networks, broad and narrow band transmission and international connections through either optical fibre or satellite linkages. It noted the possibility that information technology could be used to improve education and health services, thereby addressing issues of development. Finally the White Paper commented that South Africa was in 'dire' need of a management system that would facilitate a sound national information infrastructure.
- Libraries and museums; the White Paper remarked on the broad role that museums and libraries play in terms of providing access to important resources and in fostering public awareness of science and technology. It stressed that the DST should investigate the establishment of a science museum to raise public awareness of science.
- Statistical services, indicators and databases; the White Paper reminded government of its role to gather data for statistical purposes and recommended that the DST should take responsibility for the Research and Technology Audit, now known as the annual R&D Survey.

8.1.2 Progress in Implementation

Communications and information systems: there is clearly significant overlap between the White Paper recommendations for the DST and the role of other government departments and regulatory bodies. Notwithstanding this overlap, it is apparent that government has failed to respond adequately to the overall demand or opportunity in the information and communications technology (ICT) sector and as a consequence South Africa lags behind many other middle income countries in ICT areas (Schwab and Sala-i-Martin, 2014). This remains an area of technological weakness, to the extent that the DST has now adopted a specific ICT Research, Development and Innovation Roadmap in order to focus and strengthen ICT research activities at higher education institutions and R&D institutions, to develop a strong and robust innovation chain and to achieve a marked increase in the advanced ICT skills base to improve the absorptive capacity in ICT. This roadmap is presently being implemented, with the end-goals being increased ICT access for all South Africans, modernisation of the South African economy and government, a vibrant and well-developed ICT industry, and increased e-participation by citizens for government.

Libraries and museums: it is apparent that the level of funding for the maintenance of the country's libraries and museums has not kept pace with the demand and, as a consequence, many of these facilities are in a poor state. The NRF noted recently that South Africa contains 71 zoological collections in South Africa, consisting of over 15 million specimens housed at 22 institutions (National Research Foundation, 2014a). A 2014 audit established that these

collections are rapidly deteriorating due to the retirement of highly skilled personnel and dwindling operational funds, and in order to prevent any loss of material, 5 institutions have been appointed to act as collection points for any natural history collections that may soon collapse (National Research Foundation, 2014a). In the 2013/14 financial year, the NRF spent R4m on museums' infrastructure.

Statistical Services. Indicators and Databases: the R&D Survey has been completed annually since 2003, compiling information on R&D expenditure by performance sector, by funding sector, by Frascati category, by socio-economic objective and other categories as shown in Figure 24 (Department of Science and Technology, 2014c). In addition, two innovation surveys have been completed (Moses et al., 2012; Oerlemans et al., 2001) and one survey of government's science and technology activities (Department of Science and Technology, 2014a). It is considered that this objective of the White Paper has been fully addressed in terms of its initial objectives.

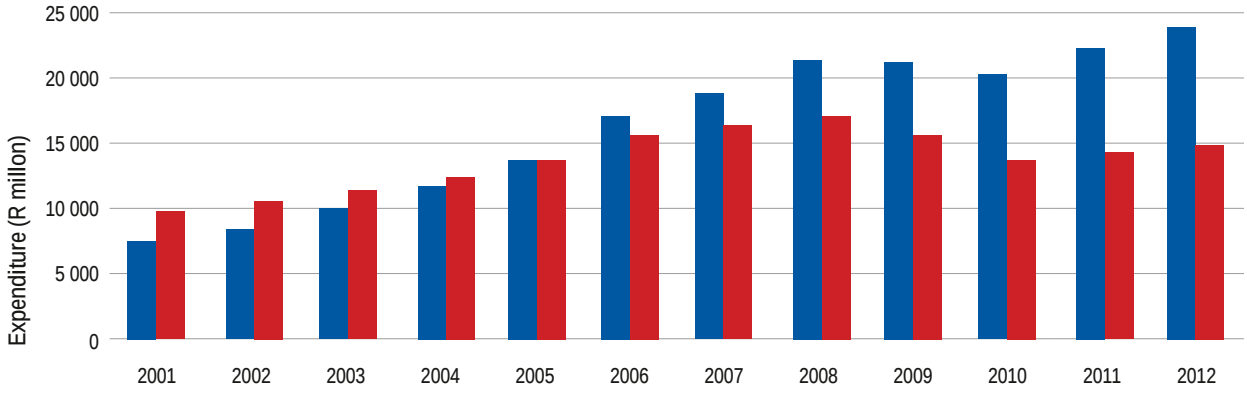


Figure 24. GERD for South Africa from the R&D Survey; 2001 to 2012

8.2 ESTABLISHMENT, OPERATION AND MAINTENANCE OF TECHNICAL SERVICES

8.2.1 Proposals of the White Paper

The White Paper recommended that five types of technical services must be maintained at a national level, namely measurement standards; calibration; product and service standards; quality and environmental management standards; and national accreditation.

It declared that all the government-funded agencies that cover the above technical services should be reviewed under the SETI review system discussed in Section 6.2. Examples given of such organisations were the South African Bureau of Standards, the National Calibration Service (now the South African National Accreditation Service of South Africa) and the National Metrology Laboratory (now the National Metrology Institute of South Africa).

8.2.2 Progress in Implementation

All these services are still in operation and governed by the Department of Trade and Industry. According to its latest annual report, the South African Bureau of Standards (SABS) is one of four specialised entities of the Standardisation, Quality Assurance, Accreditation and Metrology (SQAM) institutions supporting the collective efforts of the Department of Trade and Industry in driving industrialisation and access of South African industries to regional and international markets (South African Bureau of Standards, 2014). The other entities are the National Regulator for Compulsory Specifications Metrology, the South Africa National Metrology Institute of South Africa and the South African National Accreditation System (SANAS).

8.3 OPERATION AND MAINTENANCE OF A SYSTEM OF AWARDING, RECORDING AND PROTECTING INTELLECTUAL PROPERTY

The White Paper specifically recommended that, "whatever regulatory system South Africa adopts for awarding, recording and protecting intellectual property, a modern search and retrieval capability using modern information technology should be implemented to reduce management costs and to promote compliance with international standards"

Progress on this item is covered in Section 4.1.

8.4 ESTABLISHMENT, OPERATION AND MAINTENANCE OF MAJOR NATIONAL FACILITIES FOR RESEARCH AND DEVELOPMENT

8.4.1 Introduction

The White Paper identified the need for National Facilities, where the latter were defined as occupying a unique position in South African science and technology; possessing core technologies, research methods, data pools and collections of an international standard; having a high scientific output, and the potential to develop partnerships with local universities, industry and international collaborators; seeking goals aligned with the overall objectives of the NSI; and presenting opportunities for human resource development with special efforts to involve researchers from previously disadvantaged communities. The NRF was assigned the task of administering the facilities with appropriate budgeting,

At the time of the WP, three National Facilities were identified, namely the National Accelerator Centre, the South African Astronomical Observatory and the Hartebeeshoek Radio Astronomy Observatory. It was also proposed that the following should be considered as National Facilities, once the appropriate feasibility and due diligence studies had been completed:

- the SAFARI research reactor at the Atomic Energy Corporation site at Pelindaba
- science, engineering and technology computing and general network infrastructure, encompassing the existing UNINET.

8.4.2 Progress in Implementation

There are at present 6 National Facilities and one special project (SKA) as shown in Table 17. Neither of the recommendations made by the White Paper with respect to UNINET or SAFARI was implemented but the number and budget of the National Facilities has grown since 2003.

Table 17. List of National Facilities, including emerging facilities and special projects

ORGANISATION	DESCRIPTION
Hartebeeshoek Radio Astronomy Observatory (HartRAO)	HartRAO is a national facility of the NRF. Its radio astronomy research focuses on stellar evolution, pulsars and masers; and its Space Geodesy research uses space-based techniques to study the earth. The facility is also used by university students for carrying out research, while it also undertakes science awareness programmes for schools and the general public
iThemba LABS (formerly the National Accelerator Centre)	The iThemba Laboratory for Accelerator Based Sciences is the continent's largest facility for particle and nuclear research as well as one of only a handful of facilities in the world producing radionuclides for commercial, research and medical applications. In addition, its facilities include a full radiotherapy clinic for the treatment of certain cancers using both proton and neutron therapy.

ORGANISATION	DESCRIPTION
National Zoological Gardens (NZG)	NZG is a rapidly transforming facility reporting to the NRF. It has an impressive animal collection, conservation centres, a Centre for Conservation Science as well as an NZG Academy. The NZG is well placed as an education and awareness platform for visitors comprising of educators, learners, students, special interest groups and the general public.
South African Astronomical Observatory (SAAO)	The SAAO is a national facility of the NRF and the national centre for optical and infrared astronomy in South Africa. Its primary function is to conduct fundamental research into astronomy and astrophysics. SAAO oversees SALT, located at its site near Sutherland, on behalf of an international consortium and promotes astronomy and astrophysics in Southern Africa.
South African Environmental Observation Network (SAEON)	SAEON is a business unit of the NRF and serves as a national platform for detecting, translating and predicting environmental change through scientifically designed observation systems and research. SAEON also captures and makes long-term datasets freely accessible, and runs an education outreach programme. SAEON has six nodes dispersed geographically across the country.
South African Institute for Aquatic Biodiversity (SAIAB)	A national facility of the NRF, SAIAB is famous for its association with the discovery of the enigmatic coelacanth and is internationally recognised for ichthyological research, dynamic research staff and active postgraduate school. SAIAB provides unique skills and infrastructure support in marine, estuarine and freshwater ecosystems research, molecular research, collections and bioinformatics.
Square Kilometre Array (SKA)	SKA, a project of the DST administered by the NRF, will be the world's largest and most sensitive radio telescope.

The scientific output (peer-reviewed journal articles) of the facilities has grown from 181 in 2009/10 to 305 in 2013/14, and the 2013/14 capital investment budget amounted to R256 million of which R234 million was allocated to the SKA (National Research Foundation, 2014a). The facilities and staff are also fulfilling an important role in human resource development including providing facilities for research, supervising post-graduate students, and hosting international conferences. The SKA project is progressing and the first of the 64 antennas that will make up South Africa's new radio telescope, MeerKAT, was delivered at a special launch in March 2014. Already global astronomy teams have signed up to use MeerKAT as soon as the initial 16 of its 64 receptors have been commissioned; the full array is projected to be operational by the end of 2017.

8.5 SCIENTIFIC EQUIPMENT

8.5.1 Introduction

The goals of the White Paper were to make provision for the purchase of expensive scientific equipment.

8.5.2 Progress in Implementation

A national audit was undertaken in 1988 under DACST (Foundation for Research Development, 1998). The audit concluded that the equipment infrastructure for research and technology development was below international standards; of the more than 200 items identified through the audit (with a replacement value of R3.7 billion), only 10% could be regarded as being state-of-the-art. At the time of the survey, the respondents indicated that equipment valued at R512 million would have to be replaced in the next five years (until 2002), with a further R224 million being required to upgrade the equipment infrastructure to meet the research and training needs of institutions.

Following this audit, the NRF prepared, and obtained DST approval for, the National Key Research and Technology Infrastructure Strategy which outlined a number of aims including the following (Department of Science and Technology, 2004):

- prioritise the types of research equipment and the purpose of such equipment
- create a long range planning culture around research equipment
- establish guidelines for economic models required to sustain the research infrastructure
- ensure the optimal use of world-class research equipment in a sustained manner
- assure access to research equipment by providing grant funding for mobility of researchers.

The strategy resulted in the introduction of the National Nanotechnology Equipment Programme and the National Equipment Programme (National Research Foundation, 2014b), whose main objectives are to:

- support the acquisition, upgrade or development of state-of-the-art instrumentation for South African public research institutions to undertake world class research
- promote, through the placement of research equipment, the development of research collaborations
- support and strengthen the objectives of the DST's Ten-Year Innovation Plan, the National Development Plan and the National Key Research and Technology Infrastructure Strategy.

The programmes have provided significant amounts of funding for scientific equipment with a total of R4.6 billion being invested over the period 2009/10 to 2013/14 as shown in Figure 25.

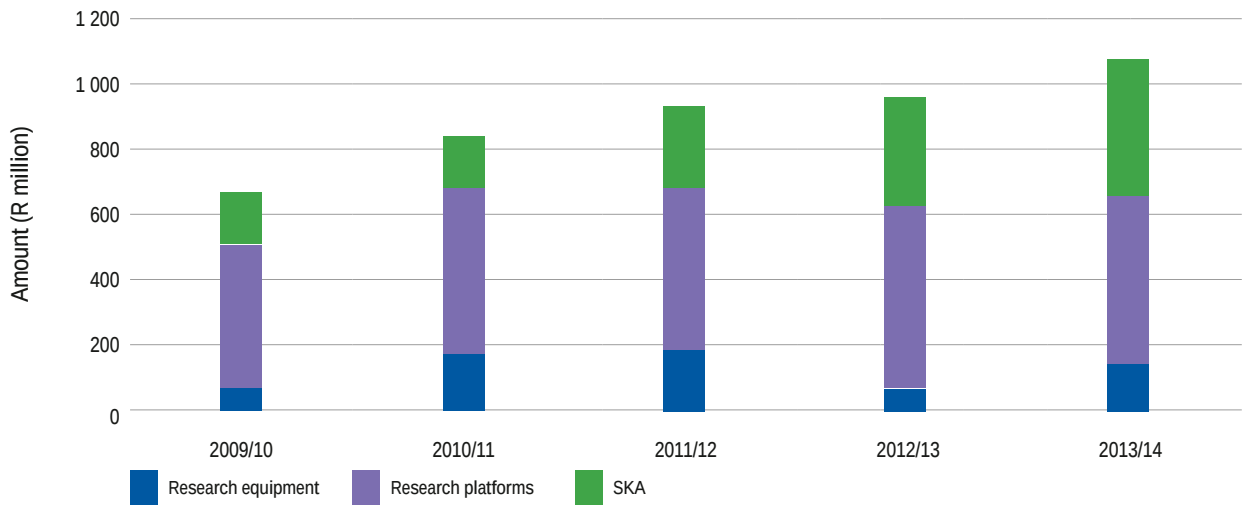


Figure 25. Investment in scientific infrastructure by the NRF

In addition to providing funding, the NRF also maintains an on-line national equipment database (see http://eqdb.nrf.ac.za/) with information on a wide range of scientific equipment available within local institutions including calorimeters, spectrometers, chromatographs and detectors.

The National Key Research and Technology Infrastructure Strategy was also supplemented by a separate study undertaken by the National Advisory Council on Innovation (NACI) which commissioned a study on the required physical infrastructure to attain the vision of the NSI (Botha and Von Gruenewaldt, 2006). The latter identified a number

of necessary investments mostly in the designated science and technology missions (space science, biodiversity, earth science, etc.) and covered the purchase of high technology science equipment including facilities for satellite testing, space optics, fuel cell testing and research vessels. It is not clear how much of the proposed R5.6 billion was ever made available.

As a follow-up to this and other studies, the DST developed a research infrastructure roadmap which defined a number of actions important for the longer term development of research facilities (Wood et al., 2013). The report identified 17 potential key installations and a number of general recommendations including:

- the need for efficient cyber-infrastructure
- the importance of integrating research infrastructure with schools and other institutions within the social and political context
- the need to attract the top researchers in the chosen field
- the requirement of strategic longer term planning and coordination
- a guarantee of good management, financial accountability and risk management to give assurance to government and/or the funders that the research infrastructure is well-run and delivering according to its mandate.

It is understood that the department's implementation of the report's recommendations is in progress, although the principle initiative in this area remains the National Equipment Programme.

Chapter 9

Policy Choice and Mix

Policy mix as an analytical framework has become an important tool for innovation policy research and formulation, and is reviewed in more detailed in Section 5.3.3 of the associated report to this study (Walwyn et al., 2015). The framework can take various forms including the categories developed by Izsák et al. (2013) and the dimensions used by the ? (OECD, 2012). In this section, the rationale for the use of a 'system of innovation' approach for South Africa is covered briefly, followed by a categorisation of the present policy mix in South Africa using the OECD approach.

The NSI theory, as originally defined by Nelson and Rosenberg (1993) and subsequently applied in South Africa, has a number of advantages relative to other approaches, as noted in Section 2.3.1 of the associated report (Walwyn et al., 2015). These advantages include a focus on innovation as opposed to S&T, an acknowledgement of the importance of linkages in addition to actors, a focus on improving output rather than reducing cost as a path to increasing international competitiveness, a shift from a linear to a highly interactive conceptualisation of innovation and finally a new understanding of the evolutionary nature of firm-level behaviour. NSI theory has also shaped the approach to innovation incentives, and particularly achieving the appropriate balance at a national level. Discussion of this issue, known as policy mix, in South Africa now follows.

As already mentioned the OECD structure has been used to analyse the South African policy mix. The advantage of using this framework is that it is less subjective (although with grave limits on its external validity) and has more comparative data. The approach was implemented by analysing the 2014/15 innovation expenditure of the three departments considered as core to the NSI, namely DST, the dti and DoE. Data on total expenditure by each department has already been reported in Section 5.1.2; the disaggregated (programme-level) data was allocated into the separate OECD categories and then collated to give the final values as shown in Figure 26.

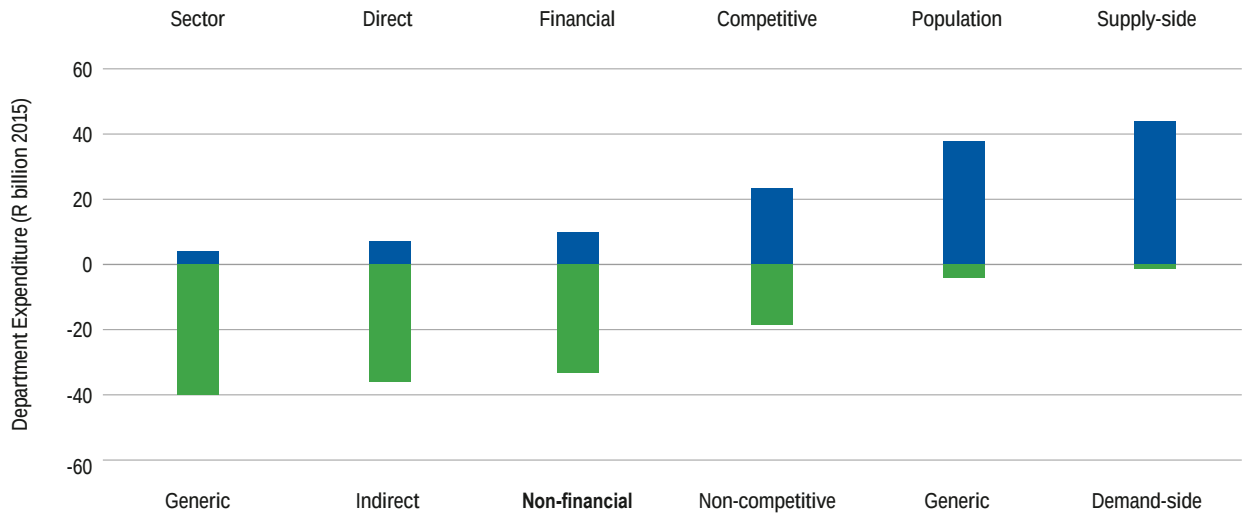


Figure 26. Policy mix of South Africa's public innovation expenditure

In all cases the allocations were made based on the vantage point of a business enterprise or firm; in other words it was assumed that public innovation expenditure is mostly directed at improving firm-level competence and capability. By way of illustration, a generic R&D tax incentive was considered as an indirect, non-competitive, financial, supply-side measure.

The total expenditure for 2014/15 was about R42 billion. Of this amount, about 7% was allocated to specific sectors (such as the film industry, the automotive sector and biotechnology), 15% was direct funding, 19% was financial, 55% was competitive, 87% was population-specific and 99% was supply-side (for definition of each category, see the box). Given that the figures are overwhelmed by the DoE's expenditure on universities, the same exercise was repeated with this department excluded; the results are shown in Figure 27. In this case the total expenditure for 2014/15 was R14.3 billion of which once again about 99% was allocated to supply-side programmes. However the profile is now more direct, more financial and more generic, with the main target population being small firms in the event that the policy is non-generic (see also Table 18).

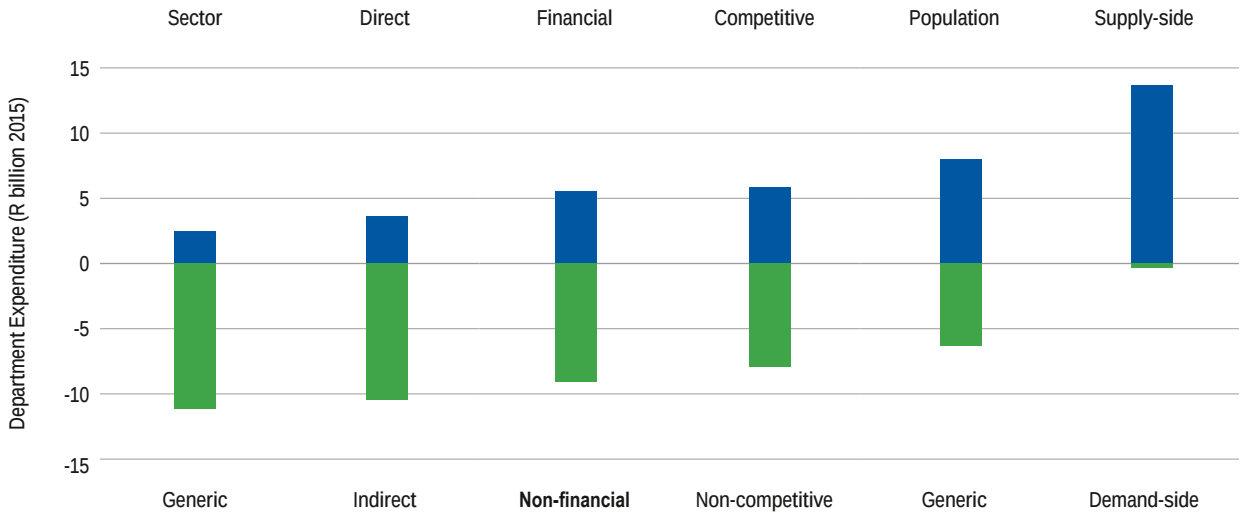


Figure 27. Policy mix of DST and dti innovation expenditure only

It is useful at this point to compare South Africa's policy mix vs. that of other OECD countries. By way of introduction, however, it is noted that there is a difference in methodology between the OECD study and the data as reported in Figure 26 and Figure 27. The OECD data was obtained using a semi-quantitative survey and is based on the sentiment and perception of the respondents, not the actual data. Based on the comparison as shown in Figure 28, it is apparent that South Africa's policy mix has:

- more generic rather than sector-, population- or technology-based instruments
- more non-competitive and non-financial incentives
- more supply-side rather than demand side instruments.

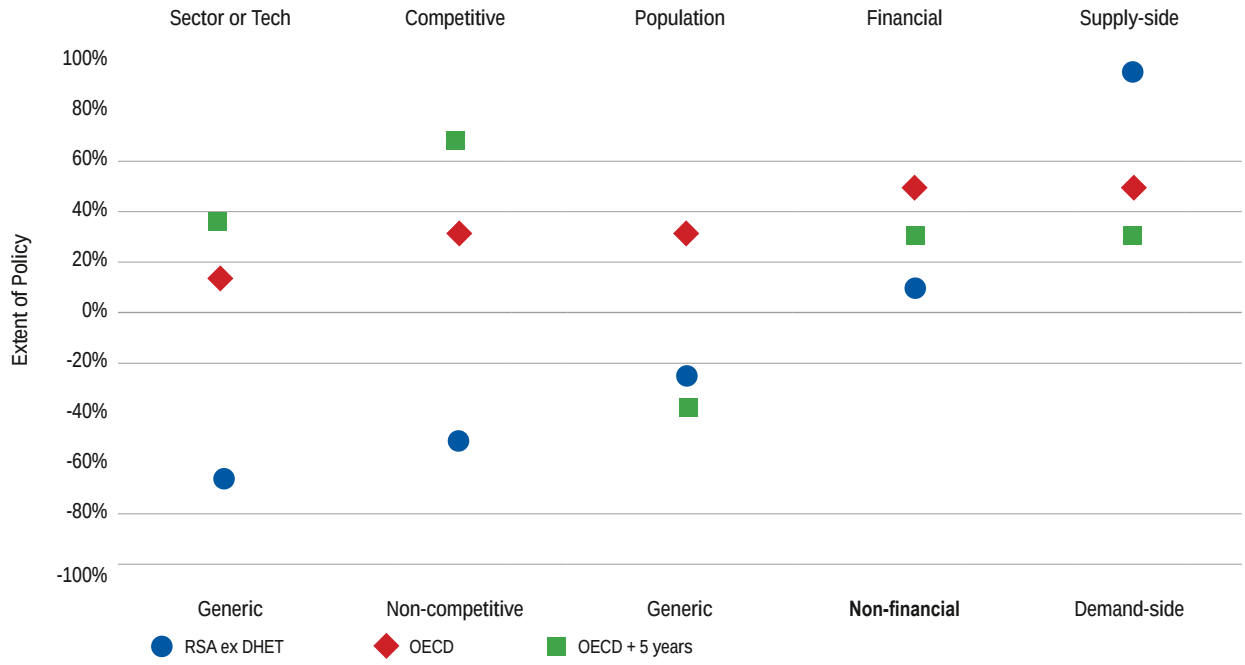


Figure 28. Comparison of South African policy mix vs OECD average

The extensive use of supply-side measures in South Africa relative to the OECD is both unexpected and nonsensical. South Africa has pursued supply-side measures since 1994, prompted at least partly by its subscription to the General Agreement on Tariffs and Trade (GATT) which came into effect in the same year and was heavily influenced by the monetarists and neo-classical economists of the period. Critics of supply-side economics have labelled it as a crank doctrine which is in effect a disguised version of trickle-down economic theory with tax cuts for the wealthy and a diminishing role for the state.

It is noteworthy that at least one major area of economic growth in South Africa over the last decade, namely the renewable energy sector, has in fact been driven by a demand-side intervention. The Renewable Energy Independent Power Producers Procurement Programme, introduced in 2011, has resulted in the installation of more than 2 GW of renewable energy, an investment of R193 billion (of which R53 billion is foreign direct investment), the creation of 19,000 job years, and a local content spend which will reach R65 billion by June 2016 (Department of Energy, 2015), all of which has been achieved at a highly competitive procurement price.

The OECD (2012) report also covered the sentiment of the respondents in terms of the evolution of each country's policy mix, with the general trends being towards increasing use (within 5 years) of sector- or technology-specific instruments, increased competitive bidding for instruments, less use of population-based incentives, and more demand-side/non-financial policies, as shown in Figure 28. These trends and the present nature of South Africa's instruments suggest the following changes to its policy mix:

- more use of demand-side, competitive, sector-specific instruments which include both financial and non-financial measures
- less use of population-based incentives.

The performance of the NSI since 1994 also suggests that whilst the actors have responded well to the need and incentives for science and technology for innovation (ST4I), the reaction to efforts covering doing, using and interacting for innovation (DUI) has been poor and more attention should be focussed in this area. Whilst this weakness may not

be a reflection of a gap in the policy mix, but rather the manifestation of inadequate implementation, it is crucial that all the relevant policies and particularly those presently administered by the dti, should be reviewed and improved where necessary.

OECD POLICY MIX CATEGORIES

The OECD surveys on policy mix adopt a different set of categories for the characterisation of policy instruments, as follows:

- population-targeted versus generic instruments; population-targeted instruments are those targeted towards specific types of firms, especially SMEs or new-technology based firms
- sector- or technology-targeted versus generic instruments; examples of technology-targeted instruments include renewable energy or biotechnology
- financial versus non-financial instruments
- direct versus indirect instruments; direct financing instruments include credit loans and guarantees, repayable advances, competitive grants, technology consulting services and extension programmes, innovation vouchers, equity financing and venture capital investments. Indirect financing instruments include tax incentives on R&D and innovation.
- competitive versus non-competitive instruments; competitive instruments imply ex-ante evaluation of proposals with allocations based on the quality of the application and the available funding
- supply-side versus demand-side instruments.

Table 18. List of dti incentives

TYPE OF INCENTIVE	INCENTIVE SCHEME	DESCRIPTION
	Automotive Investment Scheme (AIS)	The AIS is designed to grow and develop the automotive sector through investment in new and/or replacement models and components that will increase plant production volumes, sustain employment and/or strengthen the automotive value chain.
	Capital Projects Feasibility Programme (CPFP)	The CPFP is a cost-sharing programme that contributes to the cost of feasibility studies likely to lead to projects outside South Africa that will increase local exports and stimulate the market for South African capital goods and services.
	Clothing and Textile Competitiveness Improvement Programme (CTCIP)	The CTCIP aims to build capacity among clothing and textile manufacturers and in other areas of the apparel value chain in South Africa to enable them to effectively supply their customers and compete on a global scale. Such competitiveness encompasses issues of cost, quality, flexibility, reliability, adaptability and the capability to innovate.
	Production Incentive (PI)	A sectoral incentive (clothing, footwear, leather goods and textiles) designed to assist industry in upgrading its processes, products and people
	Critical Infrastructure Programme (CIP)	The CIP aims to enhance investment by supporting critical infrastructure, thus lowering the costs of investment. It is made available to approved eligible enterprises upon the completion of the infrastructure project concerned. Infrastructure for which funds are required is deemed to be 'critical' if the investment would not take place without the said infrastructure or the said investment would not operate optimally.
	Manufacturing Competitiveness Enhancement Programme (MCEP)	The MCEP aims to encourage enterprises to upgrade their production facilities, processes, products and upskill workers and to provide for the upgrading of sectors to maximise output and employment.

TYPE OF INCENTIVE	INCENTIVE SCHEME	DESCRIPTION
	People-Carrier Automotive Incentive Scheme (P-AIS)	The incentive is designed to stimulate a growth path for the people-carrier vehicles industry through investment in new and/or replacement models and components that will result in new employment, retention of current employment and/or strengthen the automotive vehicles value chain.
	Section 12I Tax Allowance Incentive (12I	The 12I Tax Incentive is designed to support Greenfield investments (i.e. new industrial projects that utilise only new and unused manufacturing assets), as well as Brownfield investments (i.e. expansions or upgrades of existing industrial projects). The new incentive offers support for both capital investment and training.
	Support Programme for Industrial Innovation (SPII)	The SPII is designed to promote and assist technology development in South African industry through the provision of financial assistance for projects that develop innovative products and/or processes. The SPII is focussed specifically on the phase that begins at the conclusion of basic research (at the stage of proof of concept) and ends at the point where a pre-production prototype has been produced.
	Aquaculture Development Enhancement Programme (ADEP)	The ADEP is an incentive programme available to South African-registered entities engaged in primary, secondary and ancillary aquaculture activities in both marine and freshwater classified under SIC 132 (fish hatcheries and fish farms) and SIC 301 and 3012 (production, processing and preserving of aquaculture fish). The grant is provided directly to approved applications for new projects or the upgrade or expansion of existing projects.
	Black Business Supplier Development Programme (BBSDP)	The BBSDP is a cost-sharing grant offered to small black-owned enterprises to assist them to improve their competitiveness and sustainability so they are able to become part of the mainstream economy and create employment. The BBSDP provides a grant to a maximum of R1 000 000 (R800 000 maximum for tools, machinery and equipment and R200 000 maximum for eligible enterprises to improve their corporate governance, management, marketing, productivity and use of modern technology).
	Co-operative Incentive Scheme (CIS)	The CIS is a 100% grant for registered primary co-operatives, in the emerging economy to acquire competitive business development services, and the maximum grant that can be offered to one cooperative entity under the scheme is R350 000.
	Technology and Human Resources for Industry Programme (THRIP)	THRIP is a partnership programme funded by the dti. On a cost-sharing basis with industry, THRIP supports science, engineering and technology research collaborations focused on addressing the technology needs of participating firms and encouraging the development and mobility of research personnel and students among participating organisations.
	Incubation Support Programme (ISP)	the dti initiated the ISP as a grant to develop incubators into successful enterprises with the potential to revitalise communities and strengthen local and national economies. The ISP encourages partnerships in which big business assists SMMEs with skills transfer, enterprise development, supplier development and marketing opportunities.
	Small Enterprise Development Agency (Seda)	Seda's mission is to develop, support and promote small enterprises throughout the country, ensuring their growth and sustainability in co–ordination and partnership with various role players, including global partners, who make international best practices available to local entrepreneurs.
	Small Enterprise Development Agency :Technology Programme (Tech Transfer)	Seda Technology Programme (Stp) is a division of Small Enterprise Development Agency focusing on technology business incubation, quality & standards and technology transfer services & support to small enterprises.
	Business Process Services (BPS)	The BPS incentive aims to attract investment and create employment in South Africa through offshoring activities.

TYPE OF INCENTIVE	INCENTIVE SCHEME	DESCRIPTION
	Export Marketing and Investment Assistance (EMIA)	EMIA seeks to provide marketing assistance to develop new export markets and grow existing markets; assist with the identification of new export markets through market research; assist companies to increase their competitiveness by supporting patent registrations, quality marks and product mark; assist with facilitation to grow FDI through missions and research.
	Film and Television Incentive	The South African Government offers a package of incentives to promote its film production and post-production industry, which includes the Foreign Film and Television Production and the Post-Production Incentive, the South African Film and Television Production and Co-Production Incentive, and the South African Emerging Black Filmmakers Incentive
	Sector-Specific Assistance Scheme (SSAS)	The SSAS is a reimbursable 80:20 cost-sharing grant offering financial support to Export Councils and Industry Associations.

Chapter 10

Summary and Conclusion

This review of the White Paper has considered both the high level objectives of the policy and the implementation of its more detailed initiatives.

At the high level, it is important to ask the question about the extent to which Government has succeeded in its vision to create and use the NSI as "a means by which a country seeks to create, acquire, diffuse and put into practice new knowledge that will help that country and its people achieve individual and collective goals". Unfortunately this vision and many of the White Paper's other high level goals and requirements, including the important issues of reducing unemployment, providing safety and security and working towards environmental sustainability, are under-realised. Important indicators across a range of components including life expectancy, employment and standard of education remain at low levels (World Bank, 2015), although progress has been made in access to public infrastructure and social grants (OECD, 2015).

At the more detailed level, it is apparent that implementation of the specific initiatives has been largely achieved with most of the objectives within each category having been achieved. The most important achievements include securing a huge increase in innovation funding over the period of the review, establishing and maintaining the institutional mechanisms (such as DST and NACI), sustaining and growing the National Facilities, and promulgating the necessary legislation to ensure the full benefit of publicly-funded R&D.

Notwithstanding this progress, there remain a number of critical areas where progress has been limited and corrective attention is required. These areas include HRD; effective inter-departmental coordination leading to greater policy cohesion and the achievement of a culture of innovation within Government; the promotion of an information society; and the use of government incentives for innovation. Although this prognosis does not result solely from the present innovation policy or the performance of the DST, it does highlight the need for certain revisions to the policy.

All of the strengths, weakness, opportunities and threats, as identified through this report, have been summarised in Table 19. In an accompanying report (Walwyn et al., 2015), the present context for innovation in South Africa and ways in which the practice of innovation policy has changed in the last twenty years are discussed. The two reports are then combined in a synthesis report which attempts to define a revised policy framework as a guide for the DST in the preparation of its next Decadal Plan.

Table 19. Strengths, weaknesses, threats and opportunities for the NSI

	HELPFUL (ENABLING THE NSI)	HARMFUL (DISABLING THE NSI)
INTERNAL ORIGIN	STRENGTHS • Rising levels of funding for STI in real terms • Innovation-led development at the core of the NDP • Strong major public research institutions and universities (governance and performance) • Growing output of research publications • (efficient system for knowledge creation) • High level of international science collaboration • Strong financial institutions • Diverse policy mix with relatively high levels of indirect financial support • NIPMO and intellectual property regulation	WEAKNESSES • Declining BERD and business confidence • Stagnating GERD relative to GDP (0.76%) • Insufficient government financial support for experimental development and system overly focussed on ST4I rather than DUI • Policy mix too focussed on supply side instruments • Poor patent output relative to expenditure • Low levels of trust between public and private sectors • Low levels of entrepreneurship • Failure of several high profile historical initiatives in specialisation (PBMR, Joule, biotechnology) • Poor primary and secondary education • Low levels of mathematics and scientific literacy • Limited broadband access • Shortage of skilled labour • Limited acceptance within government of the NSI's importance to meeting social needs and poor overall government coordination of the NSI • Low return on investment from funding for innovation, including instruments supported by the DST and the dti • Growing deficit on the technology balance of payments and trade in high and medium technology products
EXTERNAL ORIGIN	OPPORTUNITIES • Square Kilometre Array and Big Data • High demand for medium and high technology products • Strong trade links with the region • Renewable energy and smart grid technologies • Short cycle technologies including software development, fashion and design items, and systems for distributed manufacturing	THREATS • Global economic downturn • Static government revenues • Persistent high levels of unemployment • Declining foreign direct investment • International competition in terms of FDI and human resources

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