ERAWATCH COUNTRY REPORTS 2012: South Africa

ERAWATCH Network – Institute for Economic Research on Innovation (IERI)

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Acknowledgements and further information:

This analytical country report is one of a series of annual ERAWATCH reports which cover the EU Member States, Countries Associated to the EU Seventh Research Framework Programme (FP7) and, since 2011, selected third countries (ERAWATCH International).

ERAWATCH is a joint initiative of the European Commission's Directorate General for Research and Innovation and Joint Research Centre - Institute for Prospective Technological Studies (JRC-IPTS). The reports are produced, under contract, by the ERAWATCH Network.

The analytical framework and the structure of the reports have been developed by the Institute for Prospective Technological Studies of the Joint Research Centre (JRC-IPTS) with contributions from Directorate General for Research and Innovation and the ERAWATCH Network.

The authors would also like to acknowledge Michael Kahn for his valuable comments and contributions to the preceding version of this report.

The report is only published in electronic format and is available on the ERAWATCH website (http://erawatch.jrc.ec.europa.eu/). Comments on this report are welcome and should be addressed to jrc-ipts-erawatch-helpdesk@ec.europa.eu.

Executive Summary

South Africa has the largest economy in Africa. With just over 50 million inhabitants, it accounts for only 5% of the total population of the continent but generates about one quarter of the African GDP. Despite its large representation in the African continent, the country is small among the five BRICS countries, accounting for 3% of this group's GDP and less than 2% of its population (World Bank, 2012).

South Africa is a middle-income country with a relatively established national research and innovation system. In 2009/10 (FY2010) GERD reached €1.79b (20.96b Rands), the equivalent to 0.87% of the GDP and a nominal increase of €46m. However, in Rand terms GERD declined by R86m from the R21.0b recorded for 2008/9 (FY2009). This indicates the third consecutive year that research funding as a percentage of GDP has dropped – with ratios in 2007-08 (FY2008) of 0.93%, and 09.2% in FY2009. Such decreasing trend does not only move away from the target of 1% of GDP that was sought for 2008, but is even further from the ambitious 2% GDP of R&D spending expected by 2018. The Government is the largest single funder of R&D (funding 44.4% of the GERD), followed by the domestic private sector with 42.5% even though most of the R&D is performed by the private sector (performing almost 53.2% of the total R&D expenditures). Concerted efforts to promote science and technology (S&T) cooperation with the EU, have led South Africa to be one of the most active Third Country participants of the Framework Programmes. With nearly 250 participations in FP7 and a direct EC investment of nearly €35m, South Africa ranks only behind the USA, Russia, India and China.

The end of apartheid in 1994 marked a new era for South Africa's S&T policies, which were redefined within a NSI approach. The system is currently populated by a growing number of public institutions, advisory bodies and funding agencies, guided by multiple strategies and policies that steer R&D and innovation activities. Current policies build on the initial White Paper on Science and Technology (1996) and the subsequent NRDS (2002). The NRDS gave priority to a few technology platforms in key sectors (such as biotechnology, information and communication technology (ICT), advanced manufacturing, and astronomy) as well as poverty alleviation. Current national strategies, such as the Ten-Year Innovation Plan normatively aim at the small hi-tech sector (accounting for 3% of manufactured exports), while other sectors with larger socio-economic impact and larger job-generating potential are getting relatively less attention and research funding. These include the low-tech and medium-tech sectors to support manufacturing, construction and the services sector.

South Africa's socio-economic landscape, historically shaped by exclusion and inequality, continues to prove to be resilient to policy efforts at redressing it. Exclusion and inequality has race, class, gender, economic and geographic dimensions. Policy and institutional choices over the past fifteen years concerning the research and innovation system appear to have a limited positive impact on the livelihoods of the lower income segments of the economy and society.

Knowledge Triangle

In relation to the policy mix, a number of policies and programmes are in place to enhance the development of the research system, with innovation receiving growing attention both institutionally and in policy. Given the country's past exclusionary policies, education policy aimed at tackling the severe deficit of human resources with the highest priority. Achieving the 'grand challenges' or targets as established in the Ten-Year Innovation Plan will require a significant expansion in the provision of high-level skills. South Africa's severe shortage of research skills in key areas is likely to jeopardise achievement of the ambitious plans set out to 2018, and also exposes the weak past coordination between education, research and innovation policies. Coordination was expected to increase with the Technology Innovation Agency (TIA), established in 2009 with the intention to improve the country's capacity to translate a greater proportion of local research and development into commercial technology products and services, bringing the knowledge from universities and public research institutions closer to the business sector. However, in light of the high expectations of TIA, a recent review (DST, 2012) suggested that an immediate review of TIA and further institutional reforms and efforts were needed to ensure systemic coordination. This review of TIA is on-going and is expected to be completed in 2013.

	Recent policy changes	**Assessment of strengths and weaknesses**
Research policy	• Research Information Management System (RIMS) developed in 2008.	• BERD is a strong component of GERD. International niche leadership in capital intensive sectors and significant diversity of capabilities, but relative stagnation over recent years. • Poor monitoring and evaluation of research inputs, outputs, processes and impact. RIMS only partially implemented.
Innovation policy	• Ten-Year Innovation Plan launched in 2008 to guide transition toward a knowledge-based economy. • National Industrial Policy Framework (NIPF) adopted by Cabinet in 2007, containing Innovation and Technology Strategic Programme as necessary condition for industrialisation. • Industrial Policy Action Plans 1 and 2 • Economic Development Department (EDD) New Growth Path adopted in 2010 as the framework for economic policies. • National Development Plan released in 2011 detailing long-term economic strategy	• Broad political support for innovation-led development and growth. However, existing capabilities in the innovation system are not focused on development and growth. • There remains a focus on a few favoured high-technology areas to the detriment of technologies with higher near-term prospects for successful development. • Shortage of HRST likely to hinder the achievement of the 2018 targets set up in the Ten-Year Innovation Plan. • Industrial Policy reflects contestation among interest groups and thereby lacks focus. • The New Growth Path moots a shift toward a more interventionist state role, much as prevailed up to the 1980s. This would strength state policy interventions that are currently vested primarily in the national Competition Commission with limited jurisdiction for intervention. • The Industrial Development Corporation that is now under EDD is strengthening its support of the innovation system with increased support to innovation start-ups and efforts to promote new industry such as biofuels, PV arrays, and green solutions

Education policy	• National Department of Education split into Department of Basic Education and Department of Higher Education and Training in 2009.	• Apartheid and the struggle against apartheid conferred two legacies: chronic shortages of high level skills and a politicised teacher contingent that is now among the highest paid globally, that is deemed to be qualified, but that underperforms on all accepted metrics. This constrains the flow of sufficient numbers of quality school leavers into further and higher education.
Other policies	• Gauteng Innovation Strategy adopted in 2010 important regional innovation policy.	• Innovation in South Africa is heavily concentrated geographically, creating critical clustering benefits, but concentration constrains opportunities in other regions.

Assessment of the national policies/measures

Substantial efforts are devoted to strengthen international cooperation, mobility and knowledge transfer (nationally and internationally); as well as a tendency towards increasing investments in R&D and cutting-edge research infrastructures. However, critical challenges remain. Governance weaknesses (such as poor cross-departmental coordination) and the huge deficit of human resources and skills continue to hamper the national research system.

	Objectives	Main national policy changes over the last year	Assessment of strengths and weaknesses
1	Labour market for researchers	• Human Resource Development Strategy for South Africa (HRD-SA) 2010 – 2030	• Supply of SET human capital a severe constraint to increasing R&D system • Reward for skilled SET individuals is great, but premium makes retention in R&D system difficult • Immigration regulations impede ease of mobility and recruitment of skilled foreigners. • SARChI initiative is an important contribution to revitalising the researcher workforce in the universities.
2	Research infrastructures	• Initiated national strategic infrastructure programme in 2010 identifying 5 critical areas for investment through MTEF • Square Kilometre Array (SKA) – South Africa and Australia will jointly host the world's largest radio telescope (3 EU partners in the consortium) • African Resource Management Constellation (ARMC) agreement, signed in 2009 between South Africa, Nigeria, Algeria and Kenya. Commitment to commence to build a satellite in 2013 – the ZA-ARMC1.	• Rising investment in RI that is aligned to broader policy goals and targets • Accessibility often limited owing to barriers of scale and historic inequities, but transformation is slow • The development of qualified personnel and researchers is a critical prerequisite for the successful implementation of the SKA project in South Africa and the construction of new satellites under the ARMC agreement. • Strengthening of indigenous African environmental, climate change and disaster monitoring and management systems.
3	Strengthening research institutions	• Projected movement towards a national broadband provision system: South African National Research Network (SANREN) • Established Department of Performance Monitoring and Evaluation in 2010 to oversee and enhance impact of government across policy domains and departmental lines	• Development of integrated cross-departmental coordination evolving, still remain silos that need transformation • Several agencies tasked with ensuring S&T policies, but their impacts not broad-based

4	Knowledge transfer	• 2006 R&D Tax incentives scheme, amended in 2012 – Draft Taxation Laws Amendment Bill (TLAB) • Establishment of the National Intellectual Property management Office (NIPMO) in 2011	• Significant but relatively flat performance in knowledge outputs a recognised challenge for policy • Private investment in R&D robust given level of development, but dynamism of that investment not clear despite policy incentives • Intellectual property regimes must enable the openness of the research and innovation system
5	International R&D cooperation with EU member states	• No significant policy changes in last year	• Different levels of development and constraints on mobility impede potential benefits
6	International R&D cooperation with non-EU countries	• No significant policy changes in last year	• Leadership in partnerships across region and the continent through SADC, the AU, and NEPAD • Difficult to unify and coordinate disparate capacity of partners • Large and diverse cooperative agreements across the continent with considered targeted results • Numerous bilateral agreements with third countries, particularly within the SADC region. • SKA project will enhance national and international research infrastructure and capacities. • ARMC to develop Africa's technological and human capacities to monitor Earth observations.

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1 INTRODUCTION

The main objective of the ERAWATCH International Analytical Country Reports 2012 is to characterise and assess the evolution of the national policy mixes of the 21 countries with which the EU has a Science and Technology Agreement. The reports focus on initiatives comparable to the ERA blocks (labour market for researchers; research infrastructures; strengthening research institutions; knowledge transfer; international cooperation). They include an analysis of national R&D investment targets, the efficiency and effectiveness of national policies and investments in R&D, the articulation between research, education and innovation as well as implementation and governance issues. Particular emphasis is given to international research cooperation in each country.

2 PERFORMANCE OF THE NATIONAL RESEARCH AND INNOVATION SYSTEM AND ASSESSMENT OF RECENT POLICY CHANGES

2.1 MAIN POLICY OBJECTIVES / PRIORITIES, SOCIAL AND GLOBAL CHALLENGES

One of South Africa's more distinct historical legacies is the persistence of extreme inequality that manifests in a dual economy, where a highly-developed financial and industrial economy coexists with the large segment of poor rural and urban population living in the informal economy (this latter employs 24% of the labour force including domestic workers (Statistics SA, 2012). Since South Africa's liberation in 1994, the country's agenda for modernisation and socio-economic progress has recognised the importance of research, technology and innovation as key areas of policy. As a result, the last fifteen years have seen attempts at transformation and revision of South Africa's science, technology and innovation (STI) policies and institutions supporting, funding and performing of research, innovation and technological advance.

In order to address its legacies South Africa's national research and innovation system has focused on five 'grand challenges' for the science and technology system. The grand challenge areas are: (1) The 'Farmer to Pharma' value chain to strengthen the bio-economy; (2) Space science and technology; (3) Energy security; (4) Global-change science with a focus on climate change; and (5) Human and social dynamics, to apply science and technology activities to achieve the Millennium Development Goals on livelihoods and affordable access to services. Progress in all these areas is expected to be based on the three foundations: technology development and innovation, human capital and knowledge infrastructure (including the research institutions mandated to promote sector research).

Given South Africa's isolation during apartheid years, international collaboration and cross-border knowledge circulation have been important preoccupations of STI policy since the late 1990s. The Department of Science and Technology (*DST*) is the primary agency responsible for policies and instruments to enhance international knowledge circulation. An important initiative in its efforts is the European-South Africa Science and Technology Advancement Programme (*ESASTAP*), which is focused on enhancing EU-SA S&T co-operation. This programme has significantly increased South Africa's knowledge and participation in the Framework Programmes (FPs) and other cooperation mechanisms, targeting research areas of mutual interest. Beyond EU scientific co-operation, South Africa is committed to the broad development of nations across the African continent and leveraging global resources to achieve this development. In this regard, South Africa strives to advance STI capabilities of other African nations. This support has spanned multi-lateral institutions as well as an array of bilateral agreement with other African nations. South Africa also participates in a variety of other international research initiatives, such as the European Organisation for Nuclear Research (CERN), the African Resource and Environmental Management Constellation (ARMC), and the Square Kilometre Array (SKA) project.

2.2 STRUCTURE OF THE NATIONAL RESEARCH AND INNOVATION SYSTEM AND ITS GOVERNANCE

South Africa has the largest economy in Africa. With just over 50 million inhabitants, it accounts for only 5% of the total population in the continent but generates about one quarter of the African total gross domestic product (GDP). At the national level, South Africa is a middle income country (US$11,300 GDP per capita PPP in 2012) with a relatively competitive[1] and sophisticated economy[2] that has been on a sustained path of economic growth since the mid-1990s until it dropped in 2008, reaching negative growth rates in 2009 mainly due to the global economic downturn. Since 2010, national income has been recovering at a GDP annual growth rate of about 3%. Despite its large representation in the African continent, South Africa is still the smallest of the five BRICS (Brazil, Russia, India, China and South Africa) countries, accounting for 3% of this group's GDP and less than 2% of its population (World Bank, 2012).

South Africa has a well-established national research and innovation system. In Fiscal year (FY) 2010 the gross domestic expenditure on research and development (GERD) reached €1.79b (20.96b Rands), the equivalent to 0.87% of GDP (DST, 2013). R&D expenditures over the past decade have not been sufficient to achieve the target of 1% of GDP sought for 2008. In comparative terms, South Africa's R&D intensity is below all BRICS countries: India with an estimated GERD of 1% of GDP in 2008, Brazil 1.08% and China 1.47% in 2008; and Russia, 1.04% in 2009 (UIS, 2010). Government and industry are the main funders of R&D in South Africa (funding 44.4% and 42.5% of the GERD respectively). However, unlike other emerging economies most of the R&D is performed by the private sector (53.2 %); followed by the higher education sector with 24.3% and government research institutes (including the science councils) with 21.6% (DST, 2013).

At the highest level of policy and legislation, the key actor is the Parliament (which legislates on all policy matters and budgets), which is advised by the Portfolio Committee on Science and Technology. Accountability is overseen by the Presidency (which appoints cabinet ministers) and is assisted by the National Planning Commission and the Department of Performance Monitoring and Evaluation, which provide oversight for all policy. The *Department of Science and Technology* (DST) is responsible for the formulation of policies related to science, technology and innovation and has also direct responsibility of overseeing the coordination, resourcing and management of public science, technology and innovation (STI) institutions. However, other ministries such as the *Department of Trade and Industry* (DTI), *Economic Development Department* (EDD), the *Department of Higher Education and Training* (DHET), and the *Department of Public Enterprises* are also key players regarding policies and programmes that affect research and innovation. In addition, numerous other ministries have public sector research and innovation performers and agencies under their respective portfolios such as The *Department of Mineral Resources*, The *Department of Energy*, The *Department*

[1] The World Economic Forum's 2012-2013 Global Competitiveness Index rated South Africa as the most competitive economy in Sub-Saharan Africa, just below countries such as Brazil, Portugal and Indonesia, and above other comparable developing economies such as India, Russia and Mexico; indicators available at: *www.weforum.org* .
[2] South Africa represented 76% of Africa's technology intensive exports in 2010 (World Bank, 2011).

Agriculture, Forestry and Fisheries, the Department of Environmental Affairs, The Department of Health, the Department of Water Affairs.

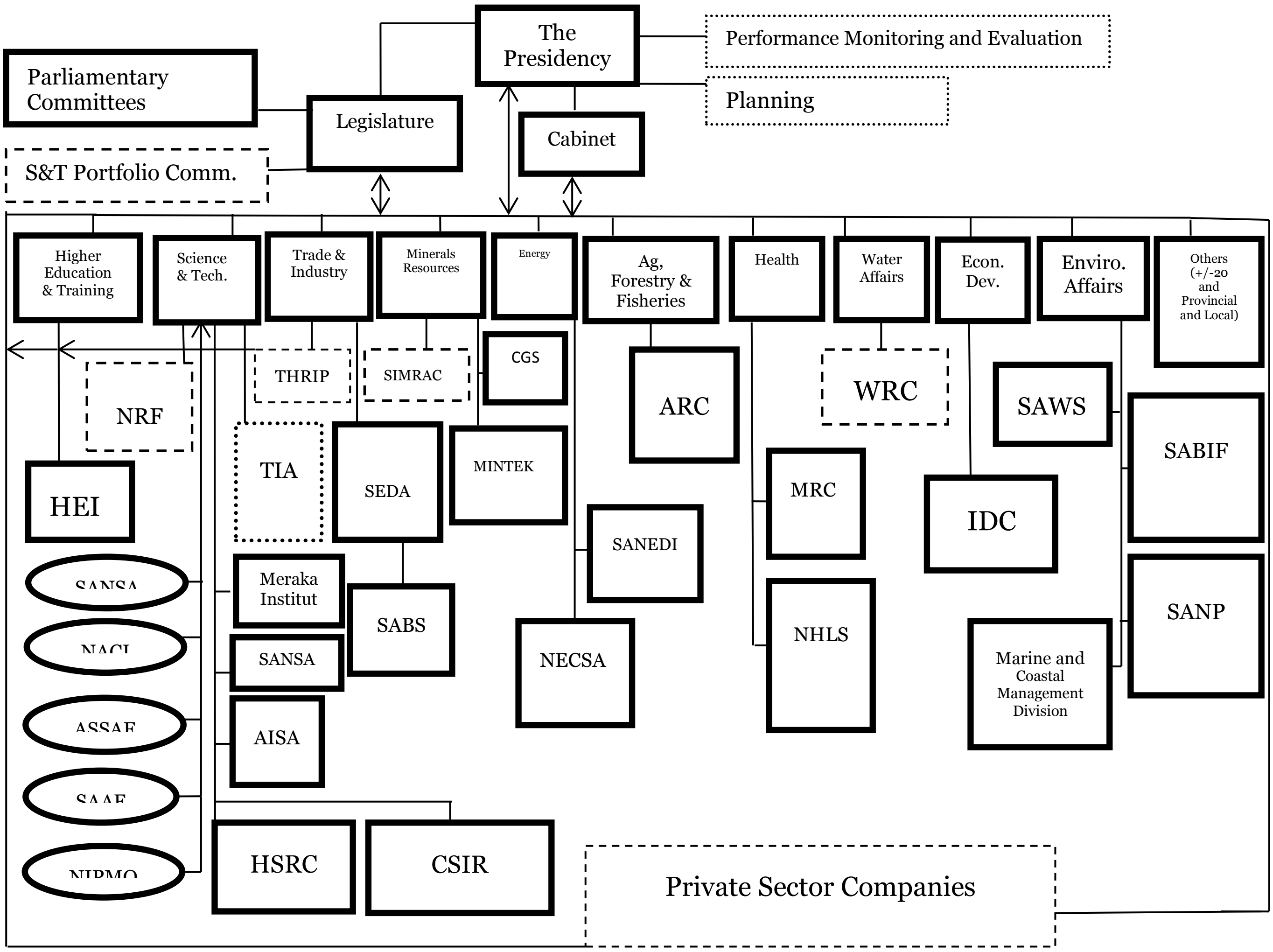
The Council on Higher Education (CHE) and the National Advisory Council on Innovation (NACI) are mandated to advise government on policy issues that pertain to research and innovation. The CHE advises the Minister of Higher Education. DST is advised both by NACI and a group of stakeholders represented in the National Science and Technology Forum (NSTF). While the advisory role of other independent bodies such as the Academy of Science of South Africa (ASSAf) and the South African Academy of Engineering (SAAE) were characterised as being rather limited by an OECD Review in 2007 (OECD, 2007), recently it has been recognised that the role of the ASSAf must be expanded (DST, 2012).

The public funding function is mainly executed by the National Research Foundation (NRF), indirectly executed through the New Funding Framework of the Education of the Department of Higher Education and Training, direct funding flows form DST, the Medical Research Council (MRC) and the recently established Technology Innovation Agency (TIA); other relevant research funders include the Water Research Commission (WRC), and the South African National Energy Development Institute (SANEDI). Finally, the performance of research and innovation is spread across 23 universities, 9 science councils and some fifty public research institutions including museums and government departments with research capacities, the business sector and the non-governmental organisation sector.

The adoption by Cabinet in 2004 of a New Strategic Management Model, redefined the role of the DST assigning it the role of developing key, cutting-edge emerging areas of science and technology, leaving 'mature' areas of technology as the responsibility of their respective line departments. Before the adoption of the framework, the DST was responsible for funding all science councils, but since 2006 the DST only funds the NRF, the Council for Scientific and Industrial Research (CSIR) and the Human Sciences Research Council (HSRC). Funding for the other science councils comes from the line departments to which they report.

South Africa's research and innovation system has formalised and expanded over the last decade. The governance system is populated by a growing number of public institutions, advisory bodies and funding agencies, along with a set of strategies and policies that steer R&D and innovation activities. However, it has been often noted that advances in policy formulation and government commitment have not been matched by their implementation (NACI, 2003; OECD, 2007; DST, 2012). The 2007 OECD review (OECD, 2007) pointed out that some of the most pronounced remaining deficiencies included: (i) the lack of a single high-level horizontal coordinator of research and innovation policy across sectors; (ii) the weak emphasis on 'low-tech' innovation programmes for poverty reduction and the exploitation of South Africa's strong position in 'mature' industries. The conclusions of the OECD review were scrutinised and expanded by detailed findings featured in the final report of the Ministerial Committee assigned to review the Science, Technology, and Innovation Landscape (DST, 2012). This report provides a critical and comprehensive review of the national system of innovation, providing concrete recommendations to address identified constrains in five areas: (1) governance of the national system of innovation (NSI), (2) enabling environment for innovation in the private and social sectors, (3) human capital, (4) monitoring and evaluation, and (5) financing of the NSI. DST is currently analysing the review and the feasibility of its suggestions

Figure 1: Overview of the South Africa's research system governance structure



AISA Africa Institute of South Africa
ARC Agricultural Research Council
ASSAF Academy of Science of South Africa
CGS Council for Geoscience
CSIR Council for Scientific and Industrial Research
HEI Higher education institutions
HSRC Human Science Research Council
IDC Industrial Development Corporations
MINTEK Council for Minerals Technology
MRC Medical Research Council
NACI National Advisory Council on Innovation
NECSA South African Nuclear Energy Corporation
NHLS National Health Laboratory Service
NIPMO National Intellectual Property Management Office
NRF National Research Foundation
SAAE South African Association of Engineering
SABIF South African Biodiversity Information Facility
SABS South African Bureau of Standards
SANEDI South African National Energy Development Institute
SANP South Africa National Parks
SANSA South African National Space Agency
SAWS South African Weather Service
SEDA Small Enterprise Development Agency
SIMRAC Safety in Mines Research Advisory Committee
THRIP Technology and Human Resources for Industry Programme
TIA Technology Innovation Agency
WRC Water Research Commission

The institutional role of regions in research governance

The Constitution of the Republic of South Africa provides for nine Provinces and declares national, shared and provincial competences. Structurally, each of these provinces has the same authority and responsibilities – for example schooling is a provincial competence, but school policy is National. Science and Technology is solely a national competence, whilst Arts and Culture is shared. So there is no explicit role for research policy that regional governments are responsible for; however, each province implements economic development initiatives that attract investment and potential research. Given that Gauteng Province is the economic hub, most R&D and innovation activities take place there. Efforts to shift innovation in new directions have been influenced through intra-regional cluster initiatives such as the *Cape IT Initiative* (Western Cape) – an initiative to support the ICT cluster in the Western Cape – and *Blue IQ* (Gauteng), which invests in and commercialises infrastructure projects in four strategic sectors: business tourism, high value-added manufacturing (high value-add), logistics and ICTs. In addition, innovation strategies at the level of the province have also been developed, such as the Gauteng Innovation Strategy.

Table 1: R&D expenditure by region 2009/10

Province	Share of total GERD	Share of total BERD	Share of total HERD
Gauteng	49.5	54.9	37.7
Western Cape	21.1	18.2	28.2
KwaZulu-Natal	10.3	10.6	13.9
Free State[3]	6.5	9.0	5.4
Eastern Cape	5.4	2.9	10.5
Northern Cape	2.6	2.4	0.6
Mpumalanga	1.9	1.4	2.1
Limpopo	1.6	0.4	1.6
North-West	1.0	0.1	2.7

Source: *South African National Research and Experimental Development Survey 2009/10. DST (2013).*

R&D competences are highly concentrated in the two industrial provinces: Gauteng and the Western Cape. Almost three quarters of all business expenditures for research and development (BERD) in 2009/10 occurred in these two provinces – with Gauteng alone accounting for 55% of all BERD (DST, 2013). These two provinces also host the majority of research-intensive universities, accounting for two thirds of the total higher education expenditure on research and development (HERD). This clustering of R&D activity in the most industrial provinces may through its promulgation of periphery status to the outside areas foster stagnation of R&D in the other seven provinces (Abrahams and Pogue, 2010).

Main research performer groups

GERD in FY2010 amounted to €1.79b (current prices). The key actors that perform R&D in South Africa are the business sector, the universities and the public research institutes (including science councils). There are also international R&D collaborative activities. Business enterprises are the dominant actor as shown in Table 2 below. The domestic business sector funded 42.5% of R&D activities – a large share for a

[3] The high value for Free State arises from the presence of SASOL's main laboratory just over the Vaal River. Without this massive contribution the Free State level would be similar to the other non-industrial provinces.

medium-income country and comparable to more advanced economies such as Italy, Portugal and the UK (Eurostat, 2012). BERD amounted to €0.95b, about 53% of the total R&D expenditures and 0.46 % of the GDP. BERD financed by industry increased from 67.6% in FY2009 to 73.1% in Fy2010. Business R&D is mainly performed by large firms (72% of BERD) such as multinationals and State corporations like Denel, Eskom, Transnet, Sasol that was privatised in 1980s.

The business sector is followed in R&D performance by higher education institutions (23.4%). Among the higher education institutions, the University of Cape Town reported the highest R&D expenditure, followed by the University of KwaZulu-Natal and the University of the Witwatersrand (DST, 2013). Public research organisations, including science councils – the Africa Institute of South Africa (AISA), Agricultural Research Council (ARC), CSIR, Council for Geosciences (CGS), HSRC, MRC, Mintek, NRF and South African Bureau of Standards (SABS) – contributed to 21.6% of R&D expenditures. The not-for-profit sector's share of R&D expenditures has been on a diminishing trend, performing 0.9% of the total R&D in FY2010.

Cross-sector funding is substantial: business funds 12% of the R&D performed by Universities, government funds 12.8% of BERD, and foreign sources fund around 14% of the R&D performed by businesses, 11% in government research institutes, and 9% of R&D in higher education (DST, 2013). This is an indication of the degree of collaboration, sharing and dissemination of research results across sectors. Also it is important to note that the international isolation experienced during apartheid years has been successfully overcome, since the contribution of foreign funding to R&D in South Africa has grown from almost zero in 1994 to over 12% in FY2010. However, the percentage of BERD financed by government decreased from 20.8% in FY2009 to 12.8% in FY2010, while the percentage of BERD financed by industry increased from 67.6% in FY2009 to 73.1% in FY2010.

Table 2: Key performers and funders of R&D in South Africa (FY2010) (€'000)

	Key R&D performers					
Key R&D funders	**Business**	**Government**	**Higher Education**	**NPO**	**Total €**	***% of total***
Business	696,238	10,504	52,092	2,773	761,607	***42.5%***
Government*	122,448	335,732	335,392	3,639	797,211	***44.4%***
Foreign sources	131,580	40,246	37,886	7,329	217,040	***12.1%***
Other**	2,156	445	10,792	2,406	15,798	***0.93%***
Total €	952,421	386,926	436,162	16,146	1,791,656	
% of total	***53.1%***	***21.5%***	***24.3%***	***0.89%***		

Source: South African National Research and Experimental Development Survey 2009/10.
* Government includes science councils
** Other includes contributions from higher education, not-for-profit organisations and individual donations

2.3 RESOURCE MOBILISATION

2.3.1 Financial resource provision for research activities (national and regional mechanisms)

Progress towards R&D investment targets

The National Research and Development Strategy (NRDS) (2002) proposed an investment target of 1% of GERD as a percentage of GDP by 2008. Although R&D expenditures have been steadily increasing in nominal Rand terms since 2002 for all sectors (see Table 3 below), at 0.87% in 2009/10, the 1% target has not yet been achieved. There was a steady increase in GERD as a percentage of GDP from 0.81% in 2003/04 (FY2004) to 0.95% in 2006/07 (FY2007), followed by a decrease to 0.93% in 2007/08 (FY2008) and a further drop to 0.92% of GDP in 2008/09 (FY2009).

The Ten-Year Innovation Plan launched in 2008, targeted an R&D intensity of 2% by the year 2018. The latest policy objective announcement by DST has been to increase R&D intensity as measured by GERD as percentage of GDP to 1.5% by 2014 (PMG, 2010). Each of these historic, near-term and long-term targets has been adopted with the aim of increasing the knowledge intensity of South Africa's economy.

Table 3: R&D expenditures by sector FY2005-FY20010 (€ millions)

	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	*CAGR**
BERD	844	1,042	1,085	1,112	1,023	952	2.4%
GOVERD	313	372	442	418	355	387	4.2%
HERD	316	345	387	375	348	436	6.4%
Not-for-profit	25	29	25	23	20	16	-8.5%
Total GERD	**1,499**	**1,788**	**1,940**	**1,928**	**1,746**	**1,792**	**3.6%**
GERD as % GDP	***0.87***	***0.92***	***0.95***	***0.93***	**0.92**	***0.87***	

Source: Source: South African National Research and Experimental Development Surveys from 2003/04 to 2009/10.
*Note: CAGR= Compound Annual Growth Rate

Research funding mechanisms

The NRDS (2002) provided the initial long-term basis for planning research and innovation activities, but these targets have been recently revised in the Ten-Year Innovation Plan with the intent to guide investments and actions until 2018 (see table 4). However, scepticism has been raised over the ability of South Africa to achieve the targets and a recent evaluation from the Portfolio Committee on S&T has recommended revising some of the targets (such as those for PhD production and GERD as % of GDP). The report of the Ministerial Committee on Science, Technology, and Innovation Landscape (DST, 2012) also highlights existing barriers for national innovation to function and achieve the objectives featured in the Innovation Plan unless substantial measures are taken.

Table 4: RSTI targets the Ten-Year Innovation Plan (2008)

Research and technology enablers	2018
Matriculants with university exemption in maths and science (5.2% maths and 5.9% science in 2005)	10%
SET graduates as percentage of all students in public higher education institutions (28% in 2005)	35%
Number of SET PhD graduates per year (561 in 2005)	3,000
Number of full-time equivalent researchers (was 11,439 in 2005)	20,000
FTE researchers per 1 000 workforce employed (1.5 in 2005)	2.6
SA positioned as knowledge-based economy	**2018**
Economic growth attributable to technical progress (10% in 2002)	30%
National income derived from knowledge-based industries	>50%
Proportion of workforce employed in knowledge-based jobs	>50%
Proportion of firms using technology to innovate	>50%
GERD/GDP (0.87 in 2004; short-term 2008 target was 1%)	2%
Global share of research outputs (0.5% in 2002)	1%
High- and medium-tech exports/services as a percentage of all exports/services (30% in 2002)	55%
Number of South African-originated US patents (100 in 2002)	250

Source: DST (2008)

With these goals in mind, the Ten-Year Innovation Plan focuses on five 'grand challenges' for the science and technology system over the next decade.[4] Progress in all these areas is expected to be based on the three foundations: technology development and innovation, human capital and knowledge infrastructure (including the research institutions mandated to promote sector research).

Detailed targets and measurable objectives are presented in DST's multi-annual Strategic Plans at the level of Programme Strategic Objectives and Activities. The latest Strategic Plan covers fiscal years 2011-2016. In the new governance framework, individual departments report on their own research and development spending. DST assists the coordination of this function through (a) developing five-year research and development plans for the whole of government, and (b) drafting a framework for the national S&T expenditure plan (NSTEP) aimed at providing a holistic view of government's total science and technology spending; and (c) introducing reforms to improve the budgeting process and the management of the S&T system. For this latter purpose, DST in 2008 began the development of a new web-based *Research Information Management System* (RIMS) designed to collect data on research inputs, outputs and processes of all public research institutions (including universities, science councils and other government R&D funding agencies).

Trust between science and society

The *South African Agency for Science and Technology Advancement* (SAASTA) has an educational unit to enhance the communication of science to the public. Its programmes are designed to create awareness, visibility and acceptance about the benefits and safety of emerging technologies in order to foster societal trust and understanding of science. In promoting science education, SAASTA works with schools across the nation to supports science enrichment projects and competitions. It also has a programme that exposes learners to career opportunities in science, engineering and technology and it supports schools with science curriculum;

[4] See Section 2.1 for a list of the 'grand challenges'.

enrichment materials; web-based materials; and online learning. The other primary component SAASTA's efforts to promote trust between science and society are its Science Communication programmes. These programmes include the Public Understanding of Biotechnology (PUB) Programme, the Public Engagement with Nanotechnology programme (PEN) and the Hydrogen and Fuel Cell Technologies and Alternatives Public Awareness, and the Demonstration and Education Platform (HFCT PADE).

Main societal challenges

As mentioned in Section 2.1, exclusion and resulting inequality have defined South Africa's political economy historically and continues to be an intractable reality, with race, class, gender, economic and geographic dimensions. Persistent inequalities imply that some segments of the population still have consistently inferior opportunities – some manifestations include endemic unemployment, high rates of prevalence of HIV/AIDS and chronic poverty. In 2004, the government committed to halving poverty and unemployment by 2014 under the Accelerated and Shared Growth Initiative for South Africa (AsgiSA). However, policy and institutional choices over the past fifteen years concerning the research and innovation system continue to have a limited positive impact on the livelihoods of the lower income segments of the economy and society. The OECD report (2007) found little evidence of R&D being explicitly engaged to advance poverty alleviation. A recent indication of progress in this set of issues is the South African HIV/AIDS Research (and Innovation) Platform launched in 2009 by DST; €3,7m (45 million Rand) have been allocated to this programme, to provide grants to organisations and research groups for basic research on HIV/AIDS.

The not-for-profit sector dedicates most of its R&D efforts to applied research on societal challenges, as indicated by the allocation of R&D according to socio-economic objectives: nearly 50% of R&D funding goes to research on society – of which 30.4% goes to social development and community services and 8.8% to health research; whilst 38% of NPO R&D is dedicated to research on economic development, particularly on issues that address the economic framework (DST, 2013). It is however, worth noting that the not-for-profit contribution to societal R&D has dropped significantly (from nearly 60% in FY2009 to 50% in FY2010). The NPO sector's largest source of funding is derived from international development agencies. Despite its relevance and sustained growth over the years it represents less than 1% of the total R&D. The co-existence of inequality alongside the R&D system creates a tension that must be overturned if a future growth path is to utilise the NSI for inclusive economic and social development. The report of the Ministerial Committee on Science, Technology, and Innovation Landscape (DST, 2012) emphasises the urgent need to create explicit strategies, incentives and institutional arrangements to foster social innovation and ensure the participation of civil society in crafting innovation policy priorities.

Recent policy changes

Two recent policy changes that are likely to have significant impact on the research and innovation system in South Africa are: the Ten-Year Innovation Plan launched in 2008 to guide transition toward a knowledge-based economy, and the establishment of the TIA in 2009 to support the new R&D investment targets and the commercialisation of research outputs. The ministerial review of South Africa's science, technology and innovation (STI) landscape (DST, 2012) recently provided a set of recommendations to restructure the current governance model of the NSI, which would have profound implications if implemented. In addition, the New Growth Path (NGP) is an employment intensive growth strategy adopted in 2010 that includes an explicit focus on increasing the employment and growth impacts of South Africa's science, technology and innovation capacity.

2.3.2 Providing qualified human resources

A critical constraint to the expansion of the R&D system is the development of human resources. The shortage of skills is one of the most cited constraints in South Africa's research and innovation system (OECD, 2007; DST, 2012). Building R&D capacity requires an education system capable of supplying sufficient graduates and researchers, especially at the tertiary level – these goals are referred to as 'enablers' in the main policy documents in South Africa. R&D personnel appears to be concentrated both in the business sector (with 38.9% of R&D personnel FTE), and the higher education sector (with 38.4% of the total FTE researchers including doctoral and post-doctoral students). The DST is working with the DHET to address human capital challenges in the SET strategy for universities. The DST is also currently developing a Human Capital Development Strategy for Research and Innovation, which aims to address these imbalances by supporting a new generation of researchers representative of the entire population, and assisting them to become established researchers. While these strategies are being developed advancement of human capital remains vested within organisational priorities of HEIs and PROs although broadly supported by national research grants, endowments and knowledge generation incentives.

Table 5: Highest level of education for individuals 20 years or older

	2004	2005	2006	2007	2008	2009	2010	2011
None	9.9%	9.6%	9.7%	8.7%	8.8%	7.4%	7.0%	6.5%
Primary Education (Grade 0 to 6)	22.4%	21.6%	21.0%	20.9%	20.1%	28.1%	28.0%	27.2%
Secondary Education (Grade 7 to 12)	57.9%	58.8%	60.2%	60.3%	59.9%	63.4%	63.7%	64.5%
Tertiary Education	**9.6%**	**9.7%**	**9.1%**	**9.9%**	**10.9%**	**10.9%**	**11.2%**	**11.5%**

Source: Statistics South Africa General Household Survey (Statistical Release P0318)

As illustrated in Table 5, there has been an increase in tertiary education of human capital in recent years. This has not translated in scale to increased science, maths and engineering graduates as we discuss in Section 3.3.1. Furthermore, even though there are some initiatives locating entrepreneurial research at HEIs (e.g. Tshumisano Technology Stations Programme at Universities of Technology) there is a shortage of Masters and Doctorate programmes in entrepreneurship and innovation. "Soft skills" (i.e. creativity, problem solving, teamwork, communication skills, etc) are still not widely integrated in the university curricula.

The centrality of the skills shortage constraint in South Africa was confirmed by the OECD review, which characterised human resource development as '...perhaps the issue that will be central to all other aspects of the development of the STI system over the next decade.' (OECD, 2007: 87). This concern arises from the large gap generated by the combination of slow growth in the supply of university graduates capable of undertaking research, and the growing demand for design and engineering skills generated by the increased rate of investment across the economy (OECD, 2007: 7).

The development of human capital receives special attention in the report from the Ministerial Review Committee (DST, 2012), which provided extensive recommendations to revive what it called a “fatigued” system of education policy changes and reforms. It is acknowledged that the constraint imposed on the research and innovation system by a shortage of skills is likely to limit the achievements of other programmes aimed at mastering new emerging technologies as outlined in the Ten Year Innovation Plan. To ensure that the ambitious plans and programmes related to research and innovation are attained, the Ministerial Review Committee recommends (amongst others) the revitalisation of technical colleges, preferential funding schemes for the development of strategic skills, and measures to improve the academic job market by opening opportunities in public and research enterprises (DST, 2012).

Given this widespread concern regarding the shortage of skills and its identification as the most pressing challenge for the evolution of South Africa’s research and innovation system, the Department of Education was divided into the Department of Basic Education and the DHET in 2009. That division led to DHET acquiring responsibility for all post-school education and training (which partly fell before under the Department of Labour). The DHET role is to improve coordination between education and training policy, and strengthen South Africa’s skills and human resources base.

2.3.3 Evolution towards the national R&D&I targets

The business sector remains the largest performer of R&D, spending about €0.95b (11.1b Rand) in FY2010 – a nominal Rand decline of 9.7% from FY2009. Table 3 above shows that from FY2005 to FY2008 BERD increased significantly at an average annual rate of 9.2% (CAGR), followed by a decline at an annual rate of 7.7% since then until FY2010. Businesses moved from performing nearly 60% of the GERD in FY2009 to 53% in FY2010. From 2003 to 2006 the BERD increased from 55.5% to 58.3% of total GERD, followed by a substantial drop in FY2007 to 55.9%, a recovery in FY2009 to 58.6% and a further drop in FY2010 to 53.2%. As a percentage of GDP, BERD intensity has decreased substantially from 0.54% of GDP in FY2008 to 0.46% in FY2010. BERD intensity is less than half of that of the EU27 economies in aggregate, at 1.1% of GDP in 2008. Another feature in comparing South African GERD to ERA countries is the significant exchange rate volatility. Between 2000 and 2012 average annual euro-rand exchange rates have fluctuated between R6.39/euro in 2000 to R12.06/euro in 2008.[5] These fluctuations may distort year on year comparisons in GERD and its components.

Three quarters of business R&D in South Africa is performed by large corporations, such as foreign multinationals and State corporations like Denel, Eskom, Transnet, and Sasol. However, at the same time – according to the latest innovation survey in South Africa – the dominance of large firms and the ensuing lack of competition in key sectors discourage investment from the majority of SME firms in innovation-related activities. According to Blankley and Moses (2009) the second most cited

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[5] The annual exchange rate is published by the South African Reserve Bank (SARB) in its *Quarterly Bulletin* (Time-Series KBP5315J).

factor hampering innovation investments (both R&D and non-R&D) was enterprises' lack of funds, thirdly the high costs of innovation, and fourth the lack of qualified personnel. While South Africa has a strong base of industrial R&D capacity that capacity is challenged by demographic transformation and investment patterns by SMEs (Blankley and Moses, 2009). The report of the Ministerial Committee on the STI Landscape (DST, 2012) points out the need to strengthen the linkages between business enterprises, government and research organisations, as well as increase the response of the system to the demand signals from businesses.

South Africa's share of business sector R&D expenditure in total GERD (53.2%) is at the levels of EU countries (62% in 2009). Some commentators have noted that achieving the ambitious 2% target of GERD as percentage of GDP by 2018 would require boosting private sector investment through a variety of routes including:

(1) **Stimulating greater R&D investment in R&D performing firms** by improving the framework conditions to invest in R&D. This is the rationale of

a) *The R&D tax incentive* programme, introduced in 2007 and amended in 2012, gives a 150% tax deduction for expenditure on eligible scientific or technological R&D undertaken by enterprises or individuals. The 2012 amendment requires companies to apply for pre-approval of their R&D projects in order to qualify; and the venture capital tax company incentive launched in 2009.
b) The *Tshumisano programme* supports R&D in SMEs through a technology stations programme based at Universities of Technology across South Africa.
c) The *Support Programme for Industrial Innovation* (SPII) assists South African industry through competitive bidding on financial assistance for technology development after the basic research phase and through until pre-production of a prototype.
d) The *Technology and Human Resources for Industry* (THRIP) matches investment by industry in projects where researchers from HEIs and other research institutions serve as project leaders and students are trained through projects in industry. It thereby creates opportunities for postgraduates to work with industry while finishing their higher degrees or PhDs, opening prospects for future employment of researchers in the private sector. The funds for such student support are shared between government and industry and constitute the second largest flow of public funds for research (after the New Funding Framework grant). THRIP serves the secondary function of acting as a screening device by bringing industry into contact with potential future employees. This function has been recognised as a successful instrument to integrate the development of research-capable human resources with industry-university co-operation in R&D (HSRC, 2003; OECD, 2007).

(2) **Promoting the establishment of new indigenous R&D firms**. This is pursued through (a) *SEDA STP Technology Business Incubators*, which uses different organisational models to incubate both start-ups and enterprises requiring rehabilitation; (b) Grants by TIA set up in 2009 to support R&D investment targets and associated commercialisation of outputs; and (c) *The Youth Technology Innovation Fund* (YTIF) introduced by TIA in FY2012 for its clients of ages between 18-30 years. This scheme offers vouchers for young clients to access technology innovation support from approved service providers. TIA provides financial and non-financial support during applied research and technology stages. It also sources foreign and domestic funding opportunities and facilitates strategic partnerships

among HEIs, Public Research Organisations (PRO), the Private Sector and other relevant Government Programmes.

(3) **Stimulating firms that do not perform R&D yet**. For this purpose, the DST and other government departments contribute to the government's '*Competitive Supplier Development Programme*' (CSDP), which aims to increase the participation of local companies in major procurement opportunities from large state owned enterprises (SOE). Also programmes such as THRIP, SPII, *Tshumisano* and the R&D Tax Incentive programmes, mentioned above, can serve to encourage non-R&D performers.

(4) **Attracting R&D-performing firms from abroad.** This is not actively pursued through explicit programmes but the Trade and Investment South Africa (TISA) agency (under the DTI) plays an active role in attracting foreign business in key sectors, and develops effective incentives to match those being offered by competitor countries. Thus far this has had limited success in attracting new players, with SAP and Siemens being long-established. In the pharmaceutical sector investment takes two forms: large scale clinical trials, and mergers. Novartis would be an example of the former; India's Cipla of the latter. The inflow of funds for clinical trialling is in the range of €100m - €150m annually (ACRO, 2011). The *Square Kilometre Array (SKA)* project is also likely to attract foreign space-related ventures.

(5) **Increasing extramural R&D carried out in cooperation with the public sector**. The Ten Year Innovation Plan recognises the importance of collaborative work along value chains to achieve the 'grand challenges'. This involves reinforcing public-private collaboration in R&D and the development of collaborative approaches to optimise R&D value conducted by state-owned enterprises. The TIA and the *Centres of Excellence (CoE) Programme* also intend to stimulate coordination of research expertise in industry, universities and public research institutes. The Ministerial committee report (DST, 2012) insists on the importance of strengthening links between government and the private sector. The decision in 2012 to host the €1.5b project to build the world's largest radio telescope, the *SKA*, in South Africa and Australasia, as well as the expressed commitment in 2012 to spend €37m in a new satellite under the ARMC agreement, are likely to increase government interactions with industry in its implementations – with the need to combine small-scale manufacturing skills with the expertise of civil and infrastructure engineering consultants. While this range of instruments offers South Africa a multitude of mechanisms to support the expansion of GERD, to date, greatest demand has been found from extant R&D-performing firms. These actors have not been explicitly favoured, but have responded to the incentives created by these instruments.

Recent years have seen extensive reform concerning the policy mix supporting R&D and innovation. Multiple programmes have been developed to cover a variety of routes, particularly to stimulate local R&D. However, international and national evaluators have raised concerns about limited resources being spread too thinly (OECD, 2007; Kaplan, 2008; DST, 2012), limiting the scale of activities and their impact. The absence of a critical mass of skills also restricts the extent to which R&D supporting programmes can be fully implemented and targets achieved. Additionally, research categories that qualify for state support may lack focus as some of the 'grand challenges' in the Ten-Year Innovation are too broadly defined (for instance human and social dynamics) (OECD, 2007; Kaplan, 2008).

Other policies that affect R&D investments

The National Industrial Policy Framework (NIPF) was adopted by Cabinet in 2007, and its implementation spelled out in the Industrial Policy Action Plans (IPAP) now on its second round of implementation (IPAP2). The NIPF contains an Innovation and Technology Strategic Programme as necessary condition for industrialisation. Additionally, there are a number of policy initiatives that assist with business resources in South Africa, like the Department of Trade and Industry's Small Enterprise Development Agency (SEDA) and a range of tax incentives for businesses, particularly small and micro enterprises. However, there is a recognised need for a greater support to link firms with funding, especially venture capital. In relation to this latter a venture capital tax incentive was introduced in 2009 to facilitate greater access to equity finance by small and medium businesses, with so far a limited response.

The New Growth Path (NGP) released in 2010, is an important instrument to promote employment and growth in the economy. The framework targets job creation as the country's main priority, and identifies key areas where jobs can be created, which include infrastructure development, agriculture, mining, manufacturing, the "green" economy and tourism. The NGP recognised the persistence of structural challenges in the economy that required close collaboration between key social players, business and government. The National Development Plan (2011) intends to guide policy options to address poverty, inequality and delivery of public services, amongst other challenges.

There is only one tax incentive measure (R&D tax incentive programme); its impact thus far has been disappointing (DST, 2009) and the criteria have since been subject to two amendments to include software development and other R&D activities in financial services. This is a sound decision given that 34% of BERD is in services (Kahn and Hounwanou, 2008). Collaborative funding is a minor component of research funding although a few programmes within the NRF fund research collaboration nationally and internationally. Ironically two policy innovations of the 1980s that are still in effect, the NRF researcher rating system and the journal subsidy scheme, both focus on individuals, thus reducing the scope for collaboration.

2.4 KNOWLEDGE DEMAND

South Africa's GDP grew at an annual average rate of over 3% from 1993 to 2011, peaking at 5% in 2006, but then contracting by 1.7% in 2009 mainly due to the global economic recession. Since 2010, GDP growth recovered to a rate of about 3% in 2011, then reduced its pace of growth to 2.5% in 2012. The expansion over this decade was driven by a continuing structural change in the sources of competitive advantage from the primary sector (mostly mining) to a service-based economy with strong consumer demand although including a vast reservoir of unemployed, unemployable and poor people. As a result, South Africa has moved toward a knowledge-based economy, with an increasing focus on technology, e-commerce and ICT services. The services sector has been the most dynamic during the 1990s and 2000s accounting for 65% of the total GDP in 2012. Within the service sector, finance, real estate and business services are responsible for the largest share, nearly 25% of the GDP. Industry (including construction) is the second largest contributor to the economy, responsible for 31.6% of the total output. The manufacturing sector has been historically concentrated in a few sub-sectors (i.e. automotive industry, basic chemicals, iron and steel). The manufacturing sector's share was declining from 1995, but supported particularly by growth in motor vehicle manufacturing, its rebound in the last two years has been a key driver behind the recovery of economic activity in 2009-2010. Growing external demand for mining products, particularly from China, has also pushed a recent turnaround in the mining sector.

In terms of sectoral composition of R&D, the business enterprise sector is the largest performer of R&D in South Africa. BERD totalled €0,95b in 2010, the equivalent to 53.2% of GERD. Moreover, business funded three quarters of these expenditures. Most BERD was devoted to experimental development, which accounted for 59% of BERD, followed by applied research (30 %) and basic research (11.4%). BERD was mainly concentrated in the field of natural science, technology and engineering (97% of BERD) – particularly engineering sciences (30%) and ICTs (25%) – with social sciences and humanities comprising the remaining 3%. In terms of socio-economic objects of BERD, economic development was the main inclination (74% of BERD), followed by society (11 %), defence (9 %), advancement of knowledge (4%), and environment (2%).

Table 6: Sectoral distribution of BERD (FY2010)

SIC Classification	Percentage of BERD
1 Agriculture, Hunting, Forestry and Fishing	1.9%
2 Mining and Quarrying	4.5%
3 Manufacturing	38.8%
4 Electricity, Gas and Water Supply	8.6%
5 Construction	0.0%
6 Wholesale and Retail	3.9%
7 Transport, Storage and Communication	3.7%
8 Financial Intermediation, Real Estate and Business Services	33.9%
9 Community, Social and Personal Services	4.7%

Source: *National Survey of Experimental Research and Development 2009/10, DST 2013*

The demand for knowledge is intrinsically linked to the productive structure of the South African economy. An important feature of the South African economy is the co-existence of two economic domains in South Africa that are commonly named as the 'first' and 'second' economies. The 'first economy' represents the modern and growing economy of South Africa based on manufacturing and service sectors, which increasingly integrated in the global markets produces the bulk of the national wealth. The 'second economy' is represented by the rural and subsistence agricultural sectors which are constrained by poverty and marginalisation. Gauteng and the Western Cape have become representatives of the first economy as the leading industrial provinces, dominated by business enterprises and research institutions that consume R&D products and services from other sectors such as financial services and ICTs. As Table 6 shows, manufacturing and financial services combined account for 73% of the BERD. However, many of the challenges faced by the 'second' economy also require R&D-based solutions. One of the main challenges of the innovation system is to find mechanisms for articulating the knowledge demands from the second economy and promote relevant R&D accordingly.

In its Ten-Year Innovation Plan (2008-2018), the DST envisages a series of major R&D advances in the area of energy, such as clean coal technologies, nuclear, renewable energy and hydrogen and fuel cells. In this domain there are two actors worth mentioning. Firstly, in the private sector, SASOL (an energy and chemicals company) is the single largest R&D performer in the business sector (5% of total BERD), mostly involved in research on conversion of coal and liquid natural gas to oil, polymers and fertiliser. Secondly, Eskom (the state-owned electricity generator and distributor), was developing the *Pebble Bed Modular Reactor* (PBMR) since the early 1990s (to be completed in 2018), with R&D expenditures that peaked at about €100m (1b Rand) per annum before the project was abandoned in 2011. A major pull in the demand for knowledge will be the implementation of the *SKA project*, an international cooperation project with a total budget of €1.5 billion that is expected to attract further R&D investment and technical skills from both local and foreign sources.

€406m (R4.96 billion) of public funds were allocated to R&D in South Africa for 2012/13 (FY2013), an increase of 32% from the €307m (R3.7b) in 2008. Most of these funds (53%) are allocated to seven entities that fall under DST: the TIA, the NRF, the CSIR, the HSRC, the *South African National Space Agency* (SANSA), the *Africa Institute of South Africa*, and the ASSAf. Remaining funds are allocated to the DST-directed projects (implemented by institutions that perform research and development) and the running costs of DST.

Table 7: GOVERD by research field (FY2008 and FY2010)

	FY2008	FY2010	Variation in nominal terms
Division 1: Natural sciences, technology and engineering	**75.7**	**75.5**	*-7.7*
Mathematical sciences	1.8	2.3	*18.4*
Physical sciences	3.9	1.1	*-73.2*
Chemical sciences	2	2.0	*-4.3*
Earth sciences	14.0	4.5	*-70.6*
Information, computer and communication	7.1	2.6	*-65.7*
Applied sciences and technologies	1.3	0.9	*-39.1*
Engineering sciences	1.2	1.4	*5.9*
Biological sciences	9.8	5.1	*-51.6*
Agricultural sciences	18.1	25.7	*31.7*
Medical and health sciences	15.1	27.0	*65.9*
Environmental sciences	0.7	1.0	*24.8*
Material sciences	0.1	0.0	*-100.0*
Marine sciences	0.6	1.9	*165.5*
Division 2: Social sciences and humanities	**24.3**	***24.5***	***-7.0***
Social sciences	20.4	23.5	*5.9*
Humanities	3.9	1.0	*-75.0*
Total	**100**	**100**	***-7.5***

Source: National Survey of Experimental Research and Development 2009/10, DST 2013

The breakdown of government R&D expenditure by field of science indicates that the domain of 'natural sciences, technology and engineering' is still predominant (75.5% of GOVERD). However, in nominal terms from FY2009 to FY2010both this area and social sciences and humanities have decreased around 7%. In FY2010, agricultural sciences, medical and health sciences and earth sciences jointly concentrate nearly half of the GOVERD and have increased substantially in recent years. Earth sciences dropped considerably from FY2008 to Fy2010, from 14% to 4%, whilst applied sciences and technologies, environmental sciences and marine sciences constitute a minute fraction of GOVERD. This trend threatens the achievement of some of the 'grand challenges' as described in the Ten-Year Innovation Plan, such as positioning South Africa as a world leader in climate change research

2.5 KNOWLEDGE PRODUCTION

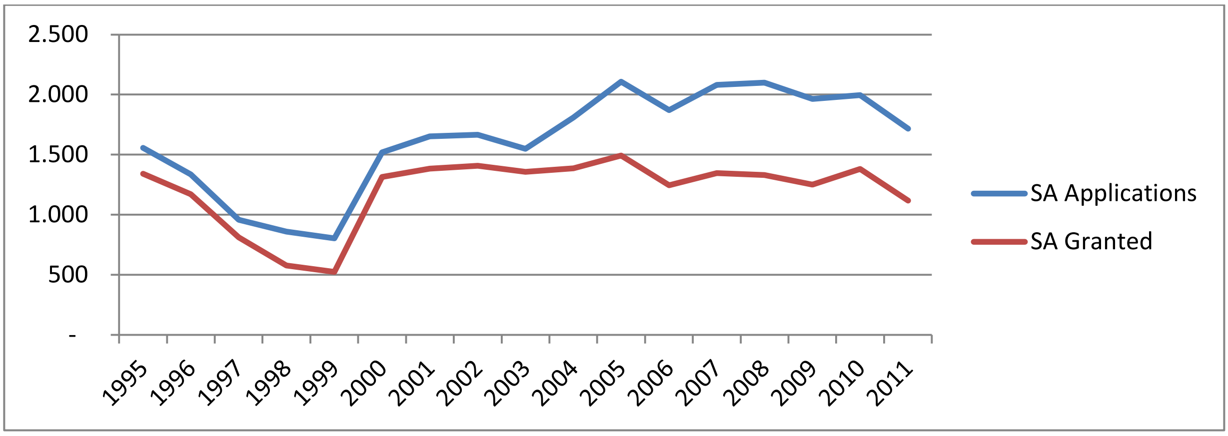
2.5.1 Quality and excellence of knowledge production

As explained in earlier sections, inputs to knowledge production in South Africa have progressed at different rates. GERD has grown in nominal Rand terms from FY2005 to FY2010 at an average annual rate of 2.4%. GERD as percentage of GDP is currently at the same level as FY2005 (0.87%). Human resources, a key enabler of R&D performance, have grown at a much slower rate. Research personnel reached a total of 19,793 FTE in FY2010, while R&D personnel were 30,891 FTE, expanding at a rate of 2.3% and 1.2% per year respectively since FY2005.

In terms of output, South Africa has an established record of research and knowledge production. The number of scientific publications is a widely used indicator of the quality of research production as well as an important determinant of research funding in HEIs, in South Africa and elsewhere. South Africa contributed to 7,848 articles in ISI-listed journals in 2010, a 50% increase as compared to 5,212 in 2006. Publications concentrate in the area of natural sciences (32%), medicine (31%) and life sciences (18%). Scientific publications emerge mainly from the top five research-intensive universities (Cape Town, Witwatersrand, Pretoria, KwaZulu-Natal and Stellenbosch University), which account for about two thirds of all publications in the country. It is worth mentioning that international collaboration in scientific publications have also been on the rise, with an observed higher co-publication with foreign parties (mainly Universities in Europe and the US) – including prolific collaborating institutions with top universities such as Oxford, Harvard, Columbia Universities and the London School of Tropical Medicine in health-related publications focused on infectious diseases (Kahn, 2010).

The World Intellectual Property Office (WIPO) records patent applications and patent grants to South African citizens at foreign patent offices. The applicant data– see Figure 2 below – indicates that between 1999 and 2005 there was steady growth most years with annual applications increasing from 804 to 2,109. Between 2006 and 2010 annual applications stabilized at rate around 2,000. In 2011 there was a decline in applications, but inherent delays in processing patent data may mean that this drop is an anomaly. Somewhat in contrast, patent grants remained practically static since 2000. In terms of locations where South Africans applied for and/or were granted a patent abroad, the United States Patent and Trademark Office (USPTO) was the primary office where protection was sought, but particularly after 2004 there has been a noticeable increase in applications and grants from the European Patent Office (EPO) to South Africans.

Figure 1: South African patent Applications and patents granted



Source: *WIPO online data 2012*

2.5.2 Policy aiming at improving the quality and excellence of knowledge production

Although there is a clear need to improve the efficiency and effectiveness of the research and innovation systems, South Africa does not yet have a system-wide mechanism to monitor and evaluate the research performance of private or public institutions. It is worth noting the 1998 introduction of the Performance Measurement System for the Science Councils, based on Balanced Scorecard methodology that has been widely deployed in that sector, even though lacking statutory force. Aside from the scrutiny of the Auditor-General, there is no standard and consistent monitoring and evaluation framework to determine the performance of the various actors in the system.

The performance of public organisations, including public research institutes, higher education institutions and science councils is monitored and published in their annual reports. Some capacities to monitor research performance have been developed in the two advisory councils: NACI and CHE are responsible for advising the DST and DHET respectively. CHE has a Monitoring and Evaluation Directorate, responsible for monitoring the activities of higher education institutions. Its functions relate exclusively to the assessment of the quality of teaching and learning programmes rather than research activities.

At the level of policy strategy, part of the oversight task of the Portfolio Committee on Science and Technology is to specifically evaluate some elements of the strategic and annual performance plans as presented by DST. The DST monitors its performance through the targets included in the Ten-year Innovation Plan and other commonly used indicators for tracking the country's progress in STI. However, there is still a need for regular and systematic performance evaluation. The New Strategic Management Model (NSMM) of South Africa's public S&T system approved by Cabinet in 2004 recommended that DST should submit a national S&T expenditure plan to Cabinet annually. By 2012 no plan had yet been tabled. In parallel, DST in 2008 embarked on the construction of integrated RIMS. This web-based tool is currently being rolled out and is designed to collect statistical information on R&D activities (inputs, outputs and processes) by universities, Science Councils and other government R&D funding agencies. RIMS is planned to be fully operational by 2013. This system will be critical for policy making and the monitoring of the Science & Technology capacity and research productivity. However, its successful implementation and maintenance will require considerable human capital development.

2.6 KNOWLEDGE CIRCULATION

2.6.1 Knowledge circulation between the universities, PROs and business sectors

Cross-sector funding gives an indication of the degree of research collaboration and circulation of knowledge across sectors. Section 2.2 showed that in FY2009/10 cross funding of R&D was significant: the business sector funded 2.7% of GOVERD and 12% of HERD, whilst foreign sources funded about 12% of R&D performed in all sectors. However, looking at the evolution of cross-sector funding over time, we see that business enterprises are funding less R&D activities in other sectors in 2010 than in 2006, especially with government (dropping their funding of GOVERD from 8% in 2006 to 2.7% in 20010). On the contrary, foreign funding of R&D has increased across the board although not very significantly (around 1-3% increase in each sector). The Ten-Year Innovation Plan (2008) envisages that the foreign funding component of should increase to 15% of the total GERD in 2018, which could be achieved if this rate of growth continues.

The concept of an NSI is at the basis of recent national strategies for research and innovation, recognising the importance of knowledge-based interactions across multiple agents, including the private sector, universities, government organisations and civil society. With this goal in mind, The TIA was established to stimulate the development of technology-based products and services. TIA will provide financial support to the NSI through a number of instruments as well as technical support, technology incubators, and commercialisation advice for technology development and the commercialisation of technologies. Most of TIA's programmes to fund innovation and R&D activities have amongst their objectives the facilitation of knowledge circulation and interactions between HEIs and industry.

Some of the sectoral platforms under TIA that have been developed to facilitate knowledge circulation include the Biotechnology Regional Innovation Centres (BRICs), the Advanced Manufacturing Technology Strategy (AMTS), and the Tshumisano Trust. These platforms have bridged graduates and R&D outputs from universities to firms (especially SMEs) in selected sectors to improve the competitiveness and innovation capacity. The Ten-Year Innovation Plan (2008-2018) continues with this tradition, acknowledging that progress in the five identified 'grand challenges' can only be achieved through greater networking and collaboration (domestic and international) across all sectors (academia, science councils, industry and government).

TIA, with a budget in 2013/2014 (FY2014) active portfolio of €42.5m (521m Rand) of active projects and available funds – a nominal Rand increase in the budget of 14% from FY2013 – will provide competitive funding for the commercialisation of domestic R&D (TIA has absorbed some of the prior key programmes of competitive funding namely the Innovation Fund, Tshumisano Trust and the Biotechnology Regional Innovation Centres). Other important funding agencies include the Small

Enterprise Development Agency (SEDA) – that manages the Technology Transfer Fund (TTF) for small enterprises, and the Industrial Development Corporation (IDC), the WRC, the SANEDI, and the MRC. An important flow of research funding outside the scrutiny of the Portfolio Committee is that from the Department of Public Enterprises toward Denel, Eskom and Transnet.

THRIP (described in section 2.3.3 above) is another programme specifically designed to foster collaboration among industry, HEIs and SETIs by: (a) funding business research projects where project leaders are the academic staff of universities, (b) matching investments by industry in projects where researchers from Science, Engineering and Technology Institutions (SETIs) serve as project leaders and students are trained through the projects, and (c) promoting the mobility of researchers through the Transfer of People (TIPTOP) schemes that promote the mobility of researchers and students between the industrial participants, HEIs, and SETIs. This instrument has been examined by several observers and has been recognised as a successful instrument to integrate the development of research-capable human resources with industry-university co-operation in R&D (HSRC, 2003; OECD, 2007).

Other instruments that facilitate the circulation of knowledge generated in research institutions and industry are: the Patent Support Fund (PSF), which supports commercialisation of the inventions and innovations arising from the research institutions, covering up to fifty percent (50%) of the patenting costs of students and researchers, and the IP Fund operating within the same guidelines as the PSF. The PSF and the IP fund have recently migrated to be managed by NIPMO with the coming into effect of the Intellectual Property Rights from Publicly Financed Research and Development Act 51 (IPR-PFRD Act) in 2010. The Act intends to stimulate innovation and economic growth by the identification of commercialisation opportunities arising from publicly funded research and development and benefit sharing. Also, the Seed Fund offered by DST, which facilitates the transition to the stage of commercialisation of R&D products. It has been designed for researchers who have a prototype finalised but need the start-up capital to begin the marketing and distribution process.

2.7 OVERALL ASSESSMENT

Despite its enduring significance, there are indications that South Africa's contribution to global research output has lagged other emerging economies and not contributed enough to its socio-economic development. Increasing the knowledge output has therefore become a key policy priority. To mobilise resources several investment instruments have been developed over the past five years. New targets for the R&D system have been set up in the Ten-Yen Innovation Plan, including rising R&D investment to 2% of GDP.

However, the qualitative and quantitative transformation of the national human capital pipeline (the ‘enablers’ such as the number of SET graduates and PhDs, as well as number of researchers) remains a critical priority. Policy efforts to address this issue have led to tentative results, but as yet the quantum of skilled human capital required for the rapid development of the national R&D system remain insufficient. This deficit of skills hinders the possibilities to boost R&D investments by the private sector. Increasing skills delivery will be facilitated by better alignment of human resources policy targets in order to further leverage the opportunities from a relatively large share of BERD. Creation of the Department of Higher Education and Training (DHET) can improve coordination between education and training policy, but may impede NSI coordination. Deepening international S&T cooperation is creating additional opportunities for skills development, but these are needed as employment equity and immigration policies combine to drive organisational staff churn, loss of research capacity and restrict employment of foreign, including African nationals, and graduates.

The bifurcated nature of the South African economy has created structural policy challenges in that national RDT capabilities are significant, but not aligned to address the national legacies of inequity. As a result, R&D in poverty reduction programmes needs urgent attention. Persistent inequality and clustering of R&D in industrial regions limits R&D investment opportunities to geographic and demographic minorities. Further complicating policy effectiveness is a tendency to focus on medium and high-tech despite South Africa possessing low-tech and medium tech manufacturing competitiveness. The minerals-energy-complex also has significant research capabilities and competitive human capital capable of contributing significantly to R&D investments if supported systematically by South Africa's R&D policy.

3 NATIONAL POLICIES FOR R&D&I

3.1 LABOUR MARKET FOR RESEARCHERS

3.1.1 Stocks of researchers

Ensuring an adequate supply of researchers is one of South Africa's five Grand Challenges in its Ten-Year Innovation Plan. In FY2010 South Africa counted with a total of 19,793 FTE researchers and 30,891 FTE R&D personnel; the equivalent to 1,5 researchers per 1,000 total employment and 2,3 R&D personnel per 1000 total employment. Increasing the supply of HRST is a priority in the Ten-Year Innovation Plan. However, alongside increasing the supply of researchers and R&D personnel, it is essential to establish and maintain a labour market that ensures that these skills are demanded, used and retained. In South Africa much of the data on the mobility of researchers remains under-reported.

The FY2010 R&D Survey estimated the R&D personnel headcount at 59,494, with researchers including doctoral and post-doctoral students accounting for 40,797. This translates into a full-time equivalent of 1,5 researchers per 1,000 total employment and 2,3 R&D personnel per 1,000 total employment. These figures are low both by EU-27 standards (5.8 researchers per 1000 employed) and also in comparison with other middle income countries.

In FY2010, researchers accounted for 68% of the total R&D personnel, while the remaining part were technicians (16.5 %) and other personnel directly related to R&D (15.5 %). Business enterprises employed most of the R&D personnel (38.9%), followed by higher education institutions (38.4%) and Science Councils (15.5%). R&D personnel has grown very slowly, at an average annual rate of 0.6% from FY2005 to FY2010 – this rate is almost one third of the already sluggish 1.7% annual growth rate for the number of researchers for the same period.

The R&D marketplace still suffers racial imbalances with 54% of the employed R&D personnel being white. This imbalance rises with the level of qualification: 70% of the R&D personnel with doctoral qualification, 57% with Master's Degree of equivalent, and 44% with a Diploma are white.

By world 'standards' female representation in the pool of researchers is relatively high, comprising about 40% for the last five years. The NPO sector has the largest concentration of female researchers (55% of female researchers). However, the HEIs sector outnumbers all other sectors in total number of female researchers, accounting for over 65% of all women researchers in South Africa. In government (including the science councils) and business the female representation is lower (38% of female researchers in government and only 30% in business in FY2010). Regarding this aspect, it is interesting to note that South Africa has a good representation of female students in higher education, accounting for 57% of the enrolments in 2010.

In order to reach the target of 2.6 FTE research personnel per 1,000 employed by 2018, South Africa will need to devote more resources to tertiary education, increase university enrolments and graduation rates, attract South African researchers and PhD graduates living abroad, and actively promote immigration of the highly skilled. South Africa's expenditure on higher education been estimated as 0.57% of GDP in

2007 (De Villiers and Steyn, 2007: 140), lagging behind the EU average (1.3%) and also below other BRICS countries (such as Russia and Brazil at 0.8%) (OECD, 2009).

3.1.2 Providing attractive employment and working conditions

Despite the relatively large amount of resources invested in R&D, South Africa's pool of researchers is still very small. Some commentators have attributed this fact to the higher salaries commanded by South African research workers in comparison to similar countries (Kaplan, 2008) – the huge skills deficit in the South African Labour Market drives up the price of all qualified participants above the level of other professions. As a result of these high salaries demand for researchers is put under downward pressure reducing thereby the number of researchers. Another factor explaining the small pool of researchers may be the difficulty of capturing them in national surveys of R&D capacity were complex research value chains that serve industry are quantified as 'current expenditures' but are not quantified as researchers.

Table 8: Monthly earnings by occupation (2010)

All occupations	Manager	Professional	Technician	Clerk	Sales & services	Skilled agriculture	Craft & related trade	Plant & machine operator	Elementary	Domestic worker
€ 288	€ 1,081	€ 1,030	€ 772	€ 463	€ 249	€ 223	€ 299	€ 290	€ 156	€ 103

Source: Statistics South Africa Monthly earnings of South Africans, 2010 (Statistical Release P0211.2)

DST has been active in efforts to boost the researcher cadre. This involves six thrusts:

(1) At the postgraduate level the *Research Professional Development Programme*, is targeted at young doctorate level researchers conducting research in key areas in Science Councils and National Facilities. (2) The *South African Research Chairs Initiative* (SARChI) focuses on the development of scientific capacity in South African HEIs by increasing the number of internationally recognised researchers through specially funded positions. This programme also indirectly attracts skilled South African researchers living abroad. In 2012 DST also announced a commitment to add an additional 62 Research Chairs to the 92 already awarded to the South African Research Chairs Initiative (SARChI). (3) *The Postdoctoral Fellowship Programme*, seeks to encourage enriching high level HRST capacity in South Africa. (4) *The Centres of Excellence Programme* (CoE Programme) provides concentrated opportunities for development of high-level skills and specialisation in SET. (5) The *Women in Science Awards*, encourage women to enter and remain in SET careers through several categories of annual awards recognising scientific excellence by South African women. (6) The science and technology graduate internship programme in partnership with Da Vinci Institute and the TT100 companies.

Several components of these initiatives by DST are designed to attract and retain researchers in an environment challenged by migration of researchers (both abroad and across sectors). It has also been mentioned that South Africa's research capacity in a particular technology is likely to exert a great influence on the mobility and potential entry of R&D personnel and researchers in that field. Therefore, sectoral research priorities in a few key technologies linked to the 'grand challenges' are likely to influence the mobility of researchers over the next decade.

As mentioned above, female researchers account for about 40% of total researchers – this percentage has remained relatively static for the last 5 years – and three quarters of them are employed in HEIs. Maternity leave, career breaks, wages and so forth are guided by the Basic Conditions of Employment Act, the Employment Equity Act (EEA) (1998), and South Africa's National Policy Framework on Women's Empowerment and Gender Equality (NPFGW), adopted in 2000. Although shortcomings remain (such as gender stereotyping, lack of flexibility options for women, unequal remuneration, etc), there is lack of systematic data regarding recruitment, retention and advancement of women in research environments. Nonetheless, some institutional advances include: (1) The *Science, Engineering and Technology for Women* (SET4W), which is an advisory committee established in 2003, comprising a team of experts who works through the NACI to advise DST on gender mainstreaming in the STI environment; and (2) the set of 'Principles and Good Practice Guidelines for Enhancing Women's Participation in the STI', which was launched by DST in 2010. Despite these valuable efforts, a measurable strategy to advance women's leadership in STI remains absent.

3.1.3 Open recruitment and portability of grants

South Africa has seen an inflow of expatriate SET skills from other parts of Africa since 1994. While many restrictions for students specify South African Nationals, other funds and research posts are typically open to any qualified individual with the requisite (inherently scarce) skills. However, promotion and career advancement of these individuals can be constrained by Employment Equity regulations that explicitly preclude foreign nationals from targets. In practice, many employers do not differentiate between Black South Africans and other African Nationals, but there is little systemic evidence to support this as equity targets are tracked primarily through self-reported classifications.

Regional and international collaboration are central to DST's strategy of human capital development (HCD). This strategy led to €1m in official development assistance for HCD in addition to €15.2m that was received in 2009. In addition, DST, DHET, and the Department of Home Affairs are developing a skills-importation strategy for scarce and exceptional skills. That strategy has to address a cumbersome quota system for companies seeking individuals whose exceptional skills are not readily available, as first it must be proven that the skills of the foreigner are not available by any individuals in the South African job market. There are also several other programmes that supporting international mobility of researchers, such as ESASTAP that facilitates EU-South African mobility of researches; and the Equipment Related Mobility Grants, which supports access of researchers to equipment that is not nationally available.

3.1.4 Enhancing the training, skills and experience of researchers

Collaborative leveraging of resources is also being used by DST domestically to enhance HCD. In this regard, DST is working to improve linkages between its national research facilities and public HEIs by making provisions for related departments at HEIs to utilise laboratory space and equipment at national research facilities with the intention to expand HEIs capacity to enrol master's and doctoral students.

Through the NRF's Human and Institutional Capacity Development (HICD) Directorate a range of funding schemes are available to support postgraduate training in parallel with development of institutional research capabilities and infrastructure. However, despite the targeted nature of many of the programmes, there currently is no specific postgraduate training aimed at increasing standardisation of doctoral programmes beyond the existing national programme accreditation frameworks. However, the NRF does utilise its rated researchers' initiative in order to establish nationally recognised standards for researcher quality and achievement.

3.2 RESEARCH INFRASTRUCTURES

Research infrastructures (RIs) are a key instrument in the creation of new knowledge and, by implication, innovation, in bringing together a wide diversity of stakeholders, helping to create a new research environment in which researchers have shared access to scientific facilities.

In order to complement its targeted HCD, South Africa has initiated a National Strategic Infrastructure Programme targeting investment in high quality research equipment and infrastructure. The Programme has identified five critical areas for investment: 1) Scientific equipment; 2) Specialised facilities – physical and organisational structures that ensure the optimal performance of research equipment; 3) Cyberinfrastructure; 4) High-end infrastructure – infrastructure at the interface between research and development, and commercialisation; and 5) Global infrastructure – networked international infrastructure both single-sited and distributed. DST prioritises these areas through its Medium Term Expenditure Framework (MTEF) that guides medium-term (five year) expenditures by the department.

In 2006, the NRF in partnership with DST initiated the Research Infrastructure Support Programme (RISP) Grants that support the acquisition, upgrade and development of state-of-the art research equipment. As a consequence, two sub-programmes, the National Equipment Programme (NEP) and the National Nanotechnology Equipment Programme (NNEP) were established. (1) The NEP is designed to improve the competitiveness and expand the capacity of South African research and training. This programme facilitates the acquisition of large and/or specialised equipment likely to advance scientific research and train students to compete in a knowledge-based economy. The applicant's institution is required to contribute one-third towards the purchase price of the equipment. (2) The National Nanotechnology Equipment Programme (NNEP) intends to position South African research globally in the emerging areas of nanoscience and nanotechnology by supporting the acquisition of equipment and human capacity development in the critical socioeconomic areas of Water, Energy, Health, Chemical and Bio-Processing, Mining and Minerals, Advanced Materials and Manufacturing. In addition, the 'Equipment-related Mobility Grants', facilitate researchers' access to state-of-the-art research equipment that is not available nationally. This latter grant aims at enhancing research collaborations and supporting the development of specialised skills required to sustainably manage and operate state-of-the-art research equipment. The report of the Ministerial Committee on Science, Technology, and Innovation Landscape cites estimates that annual inputs of €70million for a period of six to seven years are required to renew the South African knowledge infrastructure (DST, 2012).

The most significant development in the South African research infrastructure has been the recent announcement of the joint award of the SKA. The SKA project is a €1.5billion project to build the world's largest radio telescope. It is a consortium of eight partners (Australia, Canada, China, Italy, New Zealand, South Africa, The Netherlands and United Kingdom) that represents a lighthouse project for global cooperation on research infrastructure, and puts South Africa at the frontier of many scientific fields. This project will explore not only the knowledge of the universe, but also new means and technologies for communication and innovation, as well as test viable solutions to secure energy supply.

3.3 STRENGTHENING RESEARCH INSTITUTIONS

3.3.1 Quality of National Higher Education System

Higher education in South Africa is dominated by 23 public universities, which are differentiated by research-oriented "Traditional Universities" (11) that offer undergraduate and post graduate degrees and research capacity; combined academic and vocationally oriented "Comprehensive Universities" (6); and vocationally-oriented "Universities of Technology" (6) that offer undergraduate and post-graduate degrees and research capacity. In addition to these public universities there are 88 registered and 27 provisionally registered private higher education institutions but these institutions are overwhelming focused on instruction rather than research. Significant progress has been made in empowering the Black community to attend the Historically White Universities (HWUs). However, access to higher education remains constrained by the severe unequal distribution of income. The National Student Financial Aid Scheme (NSFAS) helps poorer students to access to higher education. Although the proportion of students from disadvantaged backgrounds has increased, so have drop-out rates; unable to supplement the additional costs of higher education, students often fail to complete their studies. Additionally, the burden of student debt discourages people from taking higher degrees (OECD, 2007). There is a minimum admissions requirement for all programmes, but universities can set their own admissions policies beyond those minima.

Table 9: Enrolments in Higher Education in South Africa (2007-2011)

	2007	2008	2009	2010	2011	% 2011	CAGR
Total enrolments	761,087	799,387	837,779	892,936	938,201	100%	5.2%
Level of study							
Undergraduate	650,685	680,779	709,032	754,326	786,502	83.8%	4.7%
Postgraduate	110,402	118,608	128,747	127,020	138,537	14.8%	5.7%
Doctoral degrees	10,051	9,994	10,529	11,590	13,162	1.4%	6.7%
Field of study							
Science, Engineering and Technology	228,735	234,607	237,058	251,334	264,447	28.2%	3.6%
Business	214,341	224,948	236,256	278,843	288,487	30.8%	7.4%
Humanities	318,011	339,832	364,463	362,759	385,267	41.1%	4.8%

Source: Department of Education (2007 & 2008) and Department of Higher Education and Training (for 2009 to 2011)

In 2011, 938 201 students were enrolled in public higher education (HE) institutions. The majority were in humanities-related programmes (41.1%) – including education, humanities and social sciences — compared to the lowest share in science, engineering and technology (SET)(28.2%) and business-related programmes (business and management (30.8%). While there has been some progress in SET subjects, enrolments rates have grown below the 5.2% average of all subjects, at 3.6% per year from 2007 to 2011. Table 9 also shows that the public higher education sector remained primarily at the undergraduate level, accounting for 83.8% of all enrolments in 2011, with only 1.4% enrolled in doctoral degrees.

At the undergraduate level one of the main instruments to boost skills development has been the *National Student Financial Aid Scheme* (NSFAS). This fund provided financial aid to 659,000 students, and distributed more than €1b (12b Rand) in student financial aid from 1999 to 2008. However, an evaluation of *NSFAS* (2010) indicated that the programme suffers from a number of shortcomings including high rate of drop-outs (72% of the students), insufficient funding to meet the needs from qualifying applicants and very low loan repayment rates. One of the challenges in South Africa is to improve the graduation rate, which has remained largely unchanged during the last decade and is below the international norm (in 2011 only 17,1% of HE students graduated).

Table 10: Enrolments and graduates in SET in the HE system in South Africa

	2006	2007	2008	2009	2010	2011
Total Enrolment	741,383	761,087	799,387	837,779	892,936	938,201
Total number of graduates	124,676	126,618	133,241	144,854	153,325	160,625
Total number of SET graduates	35,562	36,429	38,819	40,973	42,760	46,099
SET as % of Total Graduates	28.5%	28.8%	29.1%	28.3%	27.9%	28.7%

Source**:** Department of Higher Education and Training: Higher Education Management Information System (HEMIS)

In addition to these universities, South Africa has further education and training (FET) colleges that offer post-secondary qualifications below the level of HEIs. There were in 2012 50 public FET colleges and 491 private FET colleges with combined enrolment of 325,000 (DHET, 2013).

The significant expansion of the supervisory and research capacity of universities is dependent on the number of academics and researchers with doctoral degrees. Currently only 36% of all university academics have a doctoral degree (2010 HEMIS data). It will require significant and sustained investment to achieve the long-term target of 80% of all university academics having a doctoral degree. Research and Development expenditures by HEIs (HERD) totalled €74 million in FY2010, accounting for 18% of total HERD. HERD is being increasingly funded by the government. In FY2005 government funded 63% of all HERD while the rest was funded by the business sector, foreign and other sources, However, in FY2010 government funded 77% of all HERD. And the business contribution to HERD had dropped from 20% in FY2007 to only 12% of these expenditures. Basic research accounted for 48% of HERD, followed by applied research 34% and experimental development 18%. The natural science, technology and engineer fields accounted for the largest share (66% of HERD) with Social sciences and humanities comprising the remaining 34%.

According to the ranking *Web of World Universities*, South African universities are at the top of African Universities (9 out of the top 10 African universities are South

African). However, the *Academic ranking of World Universities* (ARWU) for 2010 indicates that the University of Cape Town is the only South African university in the Top 300 of the Shanghai university rankings, followed by University of Witwatersrand and University of KwaZulu-Natal that make it into the Top 500. South Africa's contribution to global publications is rather small with 0.61% of scientific (ISI) publications in 2009 (a modest increase since 1995 when it was 0.51%). It has been suggested that the slow rate of growth in publications is likely to delay accomplishing the target of 1% of global ISI publications set by 2018 until 2022 (NACI, 2009). In 2009, South Africa published 7,045 articles in ISI-listed journals, compared to 6,356 in 2006 (NACI, 2009). The top universities in the country produce about two thirds of all publications in the country (Cape Town, Witwatersrand, Pretoria, KwaZulu-Natal and Stellenbosch Universities). Despite the concentration of publication activity in a few universities, International collaboration in scientific publications has been on the rise, especially with top Universities in Europe and the US – see section 2.4.1. Quality assurance is the responsibility of the statutory advisory body, the CHE. Its Higher Education Quality Committee (HEQC) conducts academic audits of universities.

3.3.2 Academic autonomy

By statute Universities are autonomous institutions regarding methods of teaching and assessment, research, establishment of academic regulations and the internal management of resources. However, they are accountable to the Department of Higher Education and Training. Autonomy within each of South Africa's HEIs is vested within a Council. The Council's responsibilities include determining the mission, objectives, goals, strategies and policies for the progress of the institution. It must also ensure an environment conducive to efficient, effective, economical and ethical attainment of these goals. In addition, the Council has the responsibility of maintaining and ensuring a financially secure, healthy and viable environment and is ultimately responsible for all decisions made at the institution. At least 60% of the Councils' membership must consist of the executive officers, and other internal stakeholder of the institution (staff, faculty, and students), while the rest of members are made up of a wide range of external stakeholders. South African HEIs are also required to have Senates who are accountable to the Council for all the teaching, learning, research, community engagement and academic functions of the University. The institution's Senates consists of internal constituents and usually include the Vice-Chancellor and Deputy Vice-Chancellors, the Deans and Deputy Deans of faculties, the Heads of Departments, the professors, peer elected faculty, staff and student representatives. Day-to-day management and administration of the University is handled by the institutions' executive officers.

Accreditation (institutional and programme accreditation) is mandatory for both public and private providers of higher education. The CHE is an independent statutory body responsible of ensuring that all higher education programmes meet minimum quality and aligns with international standards; this includes masters and doctoral programmes.

3.3.3 Academic funding

The government is the largest funder of the research activities in HEIs in South Africa. In aggregate 77% of HEIs budgets were derived from a combination of government-sourced block funding and university 'own' funds including student fees.

These block funds include incentives for research outputs for faculty which account for approximately 12% of HEI budgets. The New Funding Framework (NFF) for Public Higher Education has been applied by the government since the 2004/05 financial year. Funding allocations are tied to research outputs of performance weighed by (a) publication units; (b) research masters graduates, and (c) doctoral graduates and are also differentiated by institutional type. The implementation of this funding incentive has contributed to South Africa moving-up two positions in world rankings of publication share between 2000 and 2010 (Pouris, 2012).

Research activities in universities and public research institutions are largely funded by the government through block funding. For the universities this is based on the New Funding Framework that awards universities on the basis of their designated research outputs of postgraduates and scientific outputs. Currently, NRF operates six national research facilities and manages competitive funding programmes for the universities through its Research and Innovation Support Advancement (RISA), which distributes research grants, scholarships and fellowships to researchers on a competitive basis – not only to businesses but also to HEIs and researchers in national research facilities.

3.4 KNOWLEDGE TRANSFER

3.4.1 Intellectual Property (IP) Policies

The *Intellectual Property Rights from Publicly Funded Research and Development Act* of 2008 was adopted to ensure that taxpayers' investment in research at higher education institutions and through government-funded projects is protected by patents and other forms of intellectual property protection and that South Africans benefits from the projects in the form of job creation, business creation and access to the new products. The Act compels universities and other publicly financed research and development institutions to establish technology transfer offices (TTOs). These offices are responsible for screening the invention disclosures made by academic researchers for commercial and/or social benefit, and then deciding on the appropriate form of protection. The Act also provides for the establishment of regional offices in cases where IP output does not warrant individual offices.

In order to put a mechanism in place to encourage, monitor and quantify intellectual property resulting from publicly funded R&D, DST has established a *National Intellectual Property Management Office* (NIPMO) in 2011. This office will also directly support development of the TTOs at public HEIs and public research institutions to identify, protect and, where appropriate, commercialise their intellectual property. Currently, NIPMO has been established on an interim basis as an office within the DST but its plan is to become an independent organisation in government within two-years. While at least six universities and other publicly financed institutions had established TTOs several years before the Act, other institutions are developing TTOs (Wolson, 2007). In development of TTO capacity, NIPMO supports institutions with total funding of €1.7million over a three-year period, IP analysis tools, and training (DST, 2012c). The TIA complements NIPMO by actively promoting commercialisation and technology transfer by and at South African research institutions.

3.4.2 Other policy measures aiming to promote public-private knowledge transfer

Spinoffs

Policy strategy has given priority to technology platforms that have attracted significant research funding through a range of direct and indirect mechanisms. Such funding has created a set of positive conditions to facilitate the creation of spin-off companies from universities and research institutions in sectors such as biotechnology and space technology. The generation of spinoffs is facilitated by programmes at the new technological universities such as Tshumisano Technology Stations, focused on SMEs at the new technological universities. In 2010 the Tshumisano Technology Stations amalgamated with six other agencies to form the TIA. There are indications of an existing degree of entrepreneurial and interactive capability that can create spin-off firms, as well as some government support for such initiatives. Through FY2012, a total of 1,918 SMEs had received technology support through the Technology Stations Programme (DST, 2012c). However, questions have been raised regarding the ability of spinoff companies to remain competitive over time.

Inter-sectoral mobility

Recent empirical data of the mobility of South African researchers across sectors is practically inexistent. Lack of reliable data implies the absence of a reliable way of quantifying the inflows and outflows of researchers in various sectors. A study on the mobility of R&D workers in South Africa (Kahn et al, 2004), suggested that mobility of researchers in South Africa was significant, although there is a tendency of researchers to migrate to non-R&D managerial and specialist positions in private industry and government within South Africa, in search for higher remuneration or better job conditions.

Promoting research institutions - SME interactions

SEDA's Technology Transfer Division (TTD) provides significant and important incubation services aimed at the development and growth of SMEs. Services offered include: (1) Improving access to technology information by small enterprises, (2) Improving access to technology transfer funding through structured referrals to funding institutions, (3) Facilitating access to technology through business-to-business linkages, including linking inventors/ universities or science councils with small enterprise or entrepreneur with matching needs, (4) Technology consulting including development and implementation of technology audit tool, assessments of gaps in the technology deployed by small enterprises, and (5) Improving access to technology transfer funding through structured referrals to funding institutions.

The *Technology and Human Resources for Industry Programme* (THRIP) has effectively bridged R&D human resources in universities with industry needs by supporting R&D cooperation. According to the OECD review (2007) this programme when compared with similar schemes in other countries has been recognised internationally as particularly successful when compared with similar schemes in other countries.

Involvement of private sector in the governance bodies of HEIs and PROs

As mentioned in section 3.3.2 a cross-section of stakeholders serve on the governing council of all public HEIs in South Africa. These stakeholders include private sector leaders and representatives. Similarly, private sector representatives serve on the governing councils of South Africa's PROs.

Regional Development policy

Each province implements economic development initiatives that attract investment and potential research even though there is not an explicit role for research policy that these regional governments are responsible. Nonetheless, research is indirectly influenced through intra-regional cluster initiatives such as the Cape IT Initiative and Blue IQ. In addition, innovation strategies such as the Gauteng Innovation Strategy have also been developed.

3.5 ASSESSMENT

Despite the relatively large amount of resources invested in R&D, South Africa's pool of researchers is still very small. This is in part a result of limited inflows to the higher education system as well as capacity within the higher education system itself. Transformation of inferior education systems and retention within the research system are also major challenges in the provision of researchers. Currently, only 37% of all academic staff at South Africa's public higher education institutions holds a doctorate. In spite of these challenges South Africa's research capacity has shown strong performance in several areas, particularly in knowledge generation. Nonetheless, until researchers become more representative of the majority and/or increased international inflows of researchers are encouraged, the entire research system will be constrained by the limited number of researchers nationally.

4 INTERNATIONAL R&D&I COOPERATION

4.1 MAIN FEATURES OF INTERNATIONAL COOPERATION POLICY

Given South Africa's isolation during the apartheid years, international collaboration and cross-border knowledge circulation have been important preoccupations of STI policy since the late 1990s. DST is the primary agency responsible for policies and instruments to enhance international knowledge circulation. These are organised under three sub-programmes:

(1) *Overseas/bilateral Cooperation Programme*: Since 2009, this new international cooperation strategy has been implemented to align international relationships with both the Ten-Year Innovation Plan and the NRDS.

(2) *Multilateral Cooperation and Africa*: This programme develops South Africa's participation in strategic African bilateral agreements and multilateral organisations on STI. The sub-programme strives to attract FDI into the science system and promote S&T networks through strategic multilateral partnerships. Its focus on Africa includes deepening S&T linkages with regional and African partners and implementing the Southern African Development Community (SADC) STI Protocol as well as the African Union/ New Partnership for African Development (AU/NEPAD) Africa's Science and Technology Consolidated Plan of Action (CPA), which are designed to increase knowledge production, build capacity, and enhance technological innovation regionally and across the Continent.

(3) *International Cooperation and Resources* sub-programme: This programme works to increase the inflow of resources by facilitating access to international STI skills and global projects. These efforts include maintaining highly functional bilateral and multilateral relationships with international partners for the benefit of South African STI. Its efforts are also targeted at integrating partnerships with donor countries into the DST's national and regional S&T activities.

The European South Africa Science and Technology Advancement Programme (ESASTAP) enhances EU-SA S&T co-operation. It has done this by increasing South Africa's knowledge about and participation in the Framework Programmes (FPs) and other cooperation mechanisms as well as targeting research areas of mutual interest. Some of the tools used include workshops, conferences, supporting researcher mobility, and developing S&T networks between Europe and South African scientists and institutions. Under the ESASTAP Seed Funding Instrument, the DST is able to support the travel costs of South African researchers travelling to Europe and vice versa.

Maintaining and operating research infrastructure are complex activities requiring specialised skills, which are in short supply. To address this issue, under the Research Infrastructure Support programme offered by NRF and DST, 'Equipment-related Mobility Grants' facilitate the mobility of researchers to access state-of-the-art research equipment that is not available nationally. This grant aims to enhance research collaborations and support development of specialised skills required to sustainably manage and operate state-of-the-art research equipment. In 2006, the National Advisory Council on Innovation (NACI) conducted a comprehensive study of South Africa's research infrastructure requirements. South Africa participates in international research infrastructures, such as CERN on nuclear physics and as mentioned in section 3.2 it is of the SKA project with Australasia.

4.2 NATIONAL PARTICIPATION IN INTERGOVERNMENTAL ORGANISATIONS AND SCHEMES

International cooperation and leveraging of complementary resources to maximise research capacity is an important tenant of South Africa's international STI strategy. The DST actively and strategically establishes close STI cooperation with other countries. This cooperation typically involves bilateral partnerships to promote STI for development, enhancing political and economic regional integration, and encouraging the mobility of scientists along with associated exchanges of information on science and technology. Increasingly, South Africa is partnering with the EU on Pan-African STI development initiatives. While these partnerships are among its most developed, its STI agreements with other African nations are strategically paramount. South Africa is also significantly increasing S&T cooperation with other emerging nations. An important multilateral partnership in this regard is the India-Brazil-South Africa (IBSA) coordinating mechanism through which they have established a tri-lateral Memorandum of Understanding on Science and Technology. In April 2011, South Africa became an official member of the Brazil, Russia, India, China and South Africa (BRICS) group of emerging countries. This informal group of the biggest and fastest growing emerging markets is developing formal multi-lateral coordination in a variety of political, economic and development initiatives. South Africa also participates in a variety of other international research initiatives, such as its previously mentioned participation CERN and SKA. These initiatives strengthen and enhance training, skills and experience of researchers as well as expand knowledge production and facilitate achievement of it grand challenges.

4.3 COOPERATION WITH THE EU

4.3.1 Participation in EU Framework Programmes

International cooperation in R&D between the EU and South Africa has expanded in recent years. The first intergovernmental agreement on Science and Technology Cooperation between South Africa and the European Union was signed in 1996, affording South African researchers the opportunity to participate fully in the EU's Framework Programmes for Research and Technology Development. Currently there are a number of initiatives in place that aim to improve South African R&D collaborations with the EU. As noted above, ESASTAP is a dedicated platform for the advancement of European - South African S&T cooperation. ESASTAP is implemented by DST and funded by the European Commission (EC). Through enhanced networking and partnering, scientists and institutions from the EU and South Africa jointly explore new and emerging scientific and technological areas, anticipate future science and technology needs, and cooperatively seek to resolve major global issues.

In 2008, the European Commission proposed the Strategic European Framework for International Science and Technology Cooperation to strengthen science and technology cooperation with non-EU countries. The strategy identifies general principles which should underpin European cooperation with the rest of the world and proposed specific orientations for action to: 1) strengthen the international dimension of ERA through FPs and to foster strategic cooperation with key third countries through geographic and thematic targeting; 2) improve the framework conditions for international cooperation in S&T and for the promotion of European technologies worldwide. Having in view these aspects, the following section analyses how national policy measures reflect the need to strengthen the international cooperation in S&T.

The South African reciprocal agreement with the European Co-operation in Scientific and Technical Research (COST) programme is designed to deepen interactions between South African and European researchers. COST will avail funding for European researchers to undertake short-term scientific missions to South Africa, whilst ESASTAP funds South African researchers undertaking such missions to Europe.

Table 11: South Africa participation in FP7

		All submitted		Mainlisted			Success Rate: applicants in mainlisted proposal / applicants in all submitted proposals - applicants from South Africa
Proposal SP Description	Proposal Program	Number of Proposals	Number of Applicants	Number of Proposals	Number of Applicants	Proposal Total Cost	
SP1-Cooperation	ENERGY	17	23	4	5	30,812,672	21.74%
SP1-Cooperation	ENV	139	176	26	34	112,689,082	19.32%
SP1-Cooperation	HEALTH	136	164	31	40	142,913,503	24.39%
SP1-Cooperation	ICT	112	128	21	23	36,756,928	17.97%
SP1-Cooperation	KBBE	129	162	31	35	156,220,110	21.60%
SP1-Cooperation	NMP	17	24	4	5	28,877,524	20.83%
SP1-Cooperation	SEC	13	15	2	2	2,408,444	13.33%
SP1-Cooperation	SPA	38	51	11	15	30,896,268	29.41%
SP1-Cooperation	SSH	89	102	11	12	58,092,028	11.76%
SP1-Cooperation	TPT	34	45	11	14	98,221,739	31.11%
SP2-Ideas	ERC	8	8				
SP3-People	PEOPLE	173	203	58	74		36.45%
SP4-Capacities	INCO	17	25	11	16	19,795,120	64.00%
SP4-Capacities	INFRA	29	33	9	11	43,231,390	33.33%
SP4-Capacities	SiS	17	18	4	5	7,973,945	27.78%
SP4-Capacities	SME	11	11	4	4	7,120,535	36.36%
SP5-Euratom	Fission	5	6	4	5	23,454,023	83.33%
	Sum:	**985**	**1,195**	**242**	**300**	**799,463,311**	**25.10%**

In order to support and aid potential South African Framework Programme participants, the DST has created a number of dedicated support instruments: First, the Framework Programme Seed Funding Instrument DST is able to supports the travel costs of South African researchers travelling to Europe to engage with European partners regarding Seventh Framework Programme (FP7) collaboration. Alternatively funding can be granted to support the travel of European researchers to South Africa. Second, under the Framework Programme Strategic Co-investment Instrument, successful South African FP7 participants which do not receive full funding from the European Commission for their FP7 project costs can apply for a strategic co-investment in their participation and receive funding for part of the remaining projects costs from DST. Third, the European and Developing Countries Clinical Trials Partnership (EDCTP) Co-investment Instrument allows South Africans to gain more insight into the relationship between health services and clinical trials with the aim of promoting synergy and ensuring sustainability of health services by participating in the European and Developing Countries Clinical Trials Partnership. Finally, there is the IRSES Seed Funding Instrument through which the DST supports South African participants in FP7 Marie Curie IRSES projects.

Successful South African participation in FP7 is demonstrated in Tables 11 &12. South Africa has applied for nearly 1,000 FP7 projects and these applications were successful nearly one-quarter of the time. In total, the budget for the successful proposals was over €735m. Most of South Africa's participation involved collaborative projects, followed by coordination and support actions and Marie Curie support for training and career development of researchers.

Table 12: Contract type of the FP7 projects with South Africa's participation

Proposal Sub Funding Description	Total proposals submitted	Proposals Mainlisted
Collaborative project for specific cooperation actions dedicated to international cooperation partner countries (SICA)	220	40
Collaborative project (generic)	42	9
Collaborative Project targeted to a special group (such as SMEs)	21	2
Collab. Proj. Specific International Cooperation Actions (SICA)	16	1
Coordinating action	97	36
Industry-Academia Partnerships and Pathways (IAPP)	11	2
Initial Training Networks (ITN)	44	4
Integrating Activities / e-Infrastructures	14	4
International Incoming Fellowships (IIF)	13	1
International Outgoing Fellowships (IOF)	21	4
International Research Staff Exchange Scheme (IRSES)	84	47
Large-scale integrating project	68	15
Research for SMEs	10	4
Small or medium-scale focused research project	174	29
Small or medium-scale focused research project INFSO (STREP)	48	4
Supporting action	87	40
All others	15	
Sum:	**985**	**242**

South Africa is also a partner in CAAST-Net and ERAfrica; both EC-funded projects aimed at promoting EU collaboration with Africa in the field of science and technology research for innovation and sustainable development (see section 3.5.3). South Africa has continued to provide active support to the strengthening of broader African-EU S&T partnerships through the DST's role as Vice Chair of the Joint Expert Group of the Science, Information Society and Space Partnership of the Joint Africa-EU Strategy. DST has played a central role in preparing the Africa, Caribbean and Pacific (ACP) S&T Programme, which is jointly funded through the European Development Fund and the EU Development Cooperation Instrument for South Africa.

4.3.2 Bi- and multilateral agreements with EU countries

South Africa has other S&T agreements with ERA nations including: Flanders, Bulgaria, Croatia, France, Germany, Greece, Hungary, Italy, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Turkey and the United Kingdom. South Africa has approved joint research agreements with countries such as Poland, Belgium, and Germany, with a view to aligning activities with the objectives of the Ten-Year Innovation Plan and NRDS. Innovation instruments have also been concluded between TIA and the French innovation agency OSEO. TIA signed a letter of intent with Spain's Centre for the Development of Industrial Technology in order to foster greater collaboration on innovation management. In addition, DST and the German Government are facilitating the implementation of the *Southern Africa-Germany Technology Transfer Capacity Development Programme*, under which technology transfer capacity development needs and interventions have been identified for participating countries including Botswana, Namibia and Zambia.

In April 2013, Germany and South Africa concluded a Year of Science 2012-13, which strengthened higher education and science collaboration between the two countries and launched dozens of joint research projects in various fields including Astronomy, Bioeconomy, Social Sciences & Humanities, Human Capital Development, Health Innovation, Climate Change and Urbanisation/Megacities.

4.4 COOPERATION WITH NON EU COUNTRIES OR REGIONS

4.4.1 Main Countries

South Africa is committed to the broad development of nations across the continent and leveraging of global resources to achieve this development. In this regard, South Africa strives to advance the STI capabilities of other African nations. Therefore, DST actively and strategically establishes close STI cooperation with other African countries. This cooperation typically involves bilateral partnerships to promote STI for development, enhance political and economic regional integration, and encourage the mobility of scientists along with associated exchanges of information on science and technology. DST has entered into approximately 17 formal bilateral agreements with other African countries in the area of science and technology including countries such as Algeria, Angola, Botswana, Egypt, Ghana, Kenya, Mozambique, Namibia, Nigeria, Tanzania, Tunisia, Uganda, and Zambia. Many of those agreements are focused within the Southern African Development Community (SADC) to promote regional integration in STI. In addition, as part of its bid to host the SKA, South Africa will work together with eight African partner nations: Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia.

In addition to its African bilateral agreements, South Africa also has bilateral S&T agreements with non-African nations including: Argentina, Australia, Bahamas, Belarus, Cuba, India, Indonesia, Iran, Israel, Japan, Malaysia, Mexico, Norway, Oman, Pakistan, Peoples Republic of China, Peru, Republic of South Korea, Romania, Russia, Saudi Arabia, Switzerland, Ukraine and United States of America. In terms of S&T resources, the most important of these agreements are those with Argentina, China, Japan, India and Russia.

South Africa has funded the original NEPAD S&T Directorate providing space and operational costs in Pretoria. Through this commitment it has expanded to support and host AU/NEPAD S&T initiatives such as the African Mathematical Institutes Network (AMI-NET) that promotes postgraduate teaching and research in the mathematical sciences across Africa, and the Southern Africa Network for Biosciences (SANBio); a regional network in biodiversity, biotechnology and indigenous knowledge.

Since 2006 South Africa has, through DST and HSRC/CeSTII, played a leading role in the AU/NEPAD African Science and Innovation Indicators (ASTII) initiative, and in the moves toward establishing the African Observatory on STI (AOSTI) located in Malabo, Equatorial Guinea. This support has taken the form of capacity building, provision of resource materials, policy development and survey instruments.

South Africa also cooperates with other African countries in the formation of skills related to the SKA project through the African SKA Human Capital Development Programme, which has been operating since 2005. In 2012, the programme awarded about 400 grants for studies in astronomy and engineering from undergraduate to post-doctoral level, while also investing in training programmes for technicians. Astronomy courses are being taught as a result of the SKA Africa project in Kenya, Mozambique, Madagascar and Mauritius.

4.4.2 Main instruments

South Africa utilises a wide array of instruments and modalities to implement international cooperation. These include bilateral, multi-lateral and regional engagements. The engagements utilise inter-agency agreements, partnerships, funding programmes and human capital exchanges. These instruments translated into €22.2m (224.1m Rands) in total financial resources in support of international STI cooperation in FY2012 (DST, 2012). The total value of overseas funding for international STI cooperation equalled €18.3m. This foreign funding consisted of €12.8m in direct funding, €2.4m from in-kind contributions through official development assistance and €7.0m in FP7 funding. South African support of STI cooperation comprised the remaining €4.6m in resources for international STI cooperation in FY2012. South African STI support was received from the following nations and multi-lateral programmes: Australia €319,128; Canada €668,880; European Union €11,110,000; France €490,585; Greece €29,732; Japan €1,662,339; and United States €61,744 (DST, 2012c).

4.5 OPENING UP OF NATIONAL R&D PROGRAMMES

These efforts are driven by the international cooperation and resources programme within the DST. While this allows for the participation of non-nationals in R&D programmes on a residency basis, these non-nationals are not eligible to participate as equity candidates even if they are from less economically developed nations or disadvantaged communities in their home country. In general, funding targets South African nationals with programmes such as the SARCHi research chairs initiative to promote world class expertise, which formally focuses on retaining and encouraging the repatriation of South African experts. Importantly, despite this preference, most programmes are not exclusive to nationals, with expatriate researchers playing an important and growing part of South Africa's research fabric (Kahn et al, 2004).

Typically there has not been any explicit geographical differentiation among non-nationals. While other African nationals are a significant share of the foreign expatriate researchers in South Africa, other Africans would be expected to be owing to their relative proximity. However, migration data has not been systematically collected since 2004 nor is country of origin systematically reported for non-nationality R&D programme participants, which makes it difficult to draw any strong conclusions about implicit geographical tendencies and/or biases.

4.6 RESEARCHER MOBILITY

4.6.1 Mobility schemes for researchers from abroad

Concerns have often been raised that top South African researchers tend to migrate to industrialised countries with more attractive R&D environments – although the estimations are varied and the extent of the 'brain drain' remains poor. It has been estimated that about half of the skilled South Africans living abroad are academics/researchers in a variety of fields (engineering, natural sciences, health, humanities, etc). There are a number of initiatives that aim to bring back or connect and attract skilled South Africans who have been working overseas, such as the "Homecoming Revolution" and the South African Diaspora Network (SADN). Other commentators have highlighted the existence of other type of migration of researchers from R&D jobs to non-R&D jobs (managerial and specialist positions) within South Africa, attracted by higher remunerations (Kahn et al, 2004).

4.6.2 Mobility schemes for national researches

South Africa's HEIs have seen a marked increase in post graduate foreign students, particularly those from other African nations. According to the OECD (2009) South Africa is the 12th most preferred destination of foreign students enrolled outside of their country of citizenship, attracting 1.8% of global foreign students. The majority of the inflow of some 50,000 foreign students comes from African countries. This inflow provides potential human capital in SET for South Africa and facilitates a greater integration with the rest of the continent. Of these students the 30,000 from the SADC Member States pay fees at this same level as local students. This is in accordance with the SADC Protocol on Education and Training, and is effectively a subsidy to SADC paid by the South African taxpayer. Even so immigration law acts to discourage retention of these students after graduation. However, besides bilateral agreements for R&D cooperation, there are no specific schemes designed to attract researchers from third countries. The SARChI explained in section 2.2.3 is the closest to an overseas recruitment strategy. The mobility of South African researchers abroad is facilitated by a number of schemes explained in section 2.5.2. The SARChI programme is open to non-nationals as the objective of the programme is to attract researchers living abroad. In general, research funding programmes tend to be only open to all South African residents. In 2012 DST announced a commitment to add an additional 62 Research Chairs to the 92 already awarded to the South African Research Chairs Initiative (SARChI). Also in 2011, the ASSAf established the South African Young Academy of Science (SAYAS) to provide a national platform where leading young scholars from all disciplines in the country can interact, and also access international networking and career development opportunities.

5 CONCLUSIONS

The knowledge triangle in South Africa continues to be shaped by historic drivers and path dependencies. Innovation policy and institutional choices over the past fifteen years have given priority to a few technology platforms in high-tech sectors. Other sectors with larger socio-economic impact and larger job-generating potential are getting relatively less attention, and research funding is the policy domain of other departments of state. These include the low-tech and medium-tech sectors to support manufacturing, the construction sector and the services sector. The co-existence of inequality alongside the innovation system creates a tension which must be addressed if expansion of the R&D system is to significantly leverage development across research, education and innovation.

South Africa's severe shortage of research skills in key areas is likely to hinder the achievement of the ambitious plans set up in the Ten-Year Innovation Plan (2008-2018), and also exposes the weak past coordination between education, research and innovation policies. It remains to be seen if coordination will improve through the activities of the TIA. This was established in 2009 to improve the country's capacity to translate a greater proportion of local research and development into commercial technology products and services, which would bring the knowledge from universities and public research institutions closer to industry.

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7 LIST OF ABBREVIATIONS

ACP	Africa, Caribbean and Pacific
AISA	Africa Institute of South Africa
ASSAF	Academy of Science of South Africa
AMTS	Advanced Manufacturing Technology Strategy
ARC	Agricultural Research Council
AU	African Union
BERD	Business Expenditures for Research and Development
BRICS	Brazil, Russia, India, China, and South Africa
BRICs	Biotechnology Regional Innovation Centres
CERN	European Organisation for Nuclear Research
CGS	Council for Geosciences
CHE	Council on Higher Education
CIPRO	Companies and Intellectual Property Registration Office
CoE	Centres of Excellence
COFISA	Cooperative Programme on Innovation Systems between Finland and South Africa
COST	European Cooperation in Science and Technology
CPA	Consolidated Plan of Action
CSDP	Competitive Supplier Development Programme
CSIR	Council for Scientific and Industrial Research
CTP	Committee of Technikon Principals
DST	Department of Science and Technology
DTI	Department of Trade and Industry
EC	European Commission
EDCTP	European & Developing Countries Clinical Trials Partnership
ERA	European Research Area
ERA-NET	European Research Area Network
ERP Fund	European Recovery Programme Fund
ESA	European Space Agency
ESASTAP	European - South African scientific and technological Advancement Programme
ESFRI	European Strategy Forum on Research Infrastructures
FP	European Framework Programme for Research and Technology Development
FY	Fiscal Year
EDD	Economic Development Department
EPO	European Patent Office
EU	European Union
EU-27	European Union including 27 Member States
FDI	Foreign Direct Investments
FET	Further Education and Training
FP	Framework Programme
FP7	7th Framework Programme
GBAORD	Government Budget Appropriations or Outlays on R&D
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
GOVERD	Government Intramural Expenditure on R&D
GUF	General University Funds

HCD	Human Capital Development
HEI	Higher education institutions
HEMIS	Higher Education Management Information System
HERD	Higher Education Expenditure on R&D
HES	Higher education sector
HESA	Higher Education South Africa
HSRC	Human Science Research Council
HRST	Human Resource in Science and Technology
HFCT PADE	Hydrogen and Fuel Cell Technologies and Alternatives Public Awareness, Demonstration and Education
IDC	Industrial Development Corporations
IERI	Institute for Economic Research on Innovation
IP	Intellectual Property
IPR	Intellectual Property Rights
JPO	Japanese Patent Office
MINTEK	Council for Minerals Technology
MRC	Medical Research Council
MTEF	Medium Term Expenditure Framework
NACI	National Advisory Council on Innovation
NECSA	South African Nuclear Energy Corporation
NEPAD	New Partnership for African Development
NHLS	National Health Laboratory Service
NIPMO	National Intellectual Property Management Office
NRDS	National Research and Development Strategy
NRF	National Research Foundation
NSI	National System of Innovation
NSTF	National Science and Technology Forum
PEN	Public Engagement with Nanotechnology
PMG	Parliamentary Monitoring Group
PRO	Public Research Organisations
PUB	Public Understanding of Biotechnology
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
RDI	Research and Development Infrastructure
RI	Research Infrastructures
RTDI	Research Technological Development and Innovation
SAAE	South African Association of Engineering
SAASTA	South African Agency for Science and Technology Advancement
SABIF	South African Biodiversity Information Facility
SABS	South African Bureau of Standards
SADC	Southern African Development Community
SAJS	South African Journal of Science
SANEDI	South African National Energy Development Institute
SANP	South Africa National Parks
SANSA	South African National Space Agency
SAQA	South African Qualifications Authority
SARCHI	South African Research Chairs Initiative
SAUVCA	South African Universities Vice-Chancellors Association
SAWS	South African Weather Service
SEDA	Small Enterprise Development Agency
SETI	Science, Engineering and Technology Institutional

SF	Structural Funds
SIMRAC	Safety in Mining Research Advisory Committee
SME	Small and Medium Sized Enterprise
SOE	State Owned Enterprises
S&T	Science and technology
SPII	The Support Program for Industrial Innovation
STI	Science, Technology and Innovation
STP	Seda Technology Programme
THRIP	The Technology and Human Resources for Industry Programme
TIA	Technology Innovation Agency
TTD	Technology Transfer Division
TTF	Technology Transfer Fund
TTO	Technology transfer offices
TWAS	The Academy of Sciences for the Developing World
USPTO	United States Patent and Trademark Office
VC	Venture Capital
WIPO	World Intellectual Property Office
WRC	Water Research Commission