THE SOUTH AFRICAN NATIONAL SYSTEM OF INNOVATION: STRUCTURES, POLICIES AND PERFORMANCE

Background Report to the OECD Country Review of South Africa's National System of Innovation

National Advisory Council on Innovation
SOUTH AFRICA

21 JULY 2006

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Executive Summary

This background report has been prepared as an input to the Organisation for Economic Cooperation and Development (OECD) Country Review of the South African National System of Innovation (NSI). The report was drafted by the National Advisory Council on Innovation (NACI) and has been structured according to the framework of the terms of reference for the OECD Review, as agreed between NACI, the Department of Science and Technology (DST) and the OECD.

Within the African context, the South African NSI is relatively mature and developed. It has a solid governance framework, a clear set of policies, a strong set of performing institutions and funding agencies, and a relatively successful track record as regards innovation itself. Several of the institutions date back to the late 19th or early 20th century, and South Africa has made many important contributions to the domains of both knowledge and technology.

However, over the last thirty years, the NSI has undoubtedly slipped backwards relative to its peer countries (such as South Korea, India and Brazil). There are several reasons for this stagnation in its innovation outputs. Firstly, under the apartheid regime, the NSI became fragmented and isolated. Although in certain areas world-class innovation was undertaken (such as liquid fuels, atomic energy and military hardware), these areas did not link strongly with the intrinsic competitive strengths of the South African economy and hence failed to leverage a long-term sustainable advantage.

The second and more serious aspect of the apartheid policies was their failure to develop the potential of South Africa's human capital. This failure has now become a critical legacy, which is hindering the NSI in its efforts to support the growing South African economy. The human capital pipeline, particularly with respect to the science and technology (S&T) domains, is weak and only slowly responding to the increasing demand for well-qualified and competent scientists, engineers and technologists.

Following the 1994 elections, the new democratic government began a series of initiatives to transform the NSI and to ensure that it could once again be benchmarked favourably against its peer countries. These initiatives included new policies, restructuring of the institutional landscape, new funding instruments, new institutions and a new governance framework. Some of the highlights of the period after 1994 are the creation of a separate line department for S&T (the DST), the publication of the *White Paper on Science and Technology* in 1996, the publication of the *National R&D Strategy* in 2002, the establishment of several agencies to support technology transfer and commercialisation (Godisa and Tshumisano trusts) as well as to support R&D directly within performing institutions (the Innovation Fund and the Technology and Human Resources for Industry Programme), and the introduction of a research and development (R&D) tax incentive system in 2006.

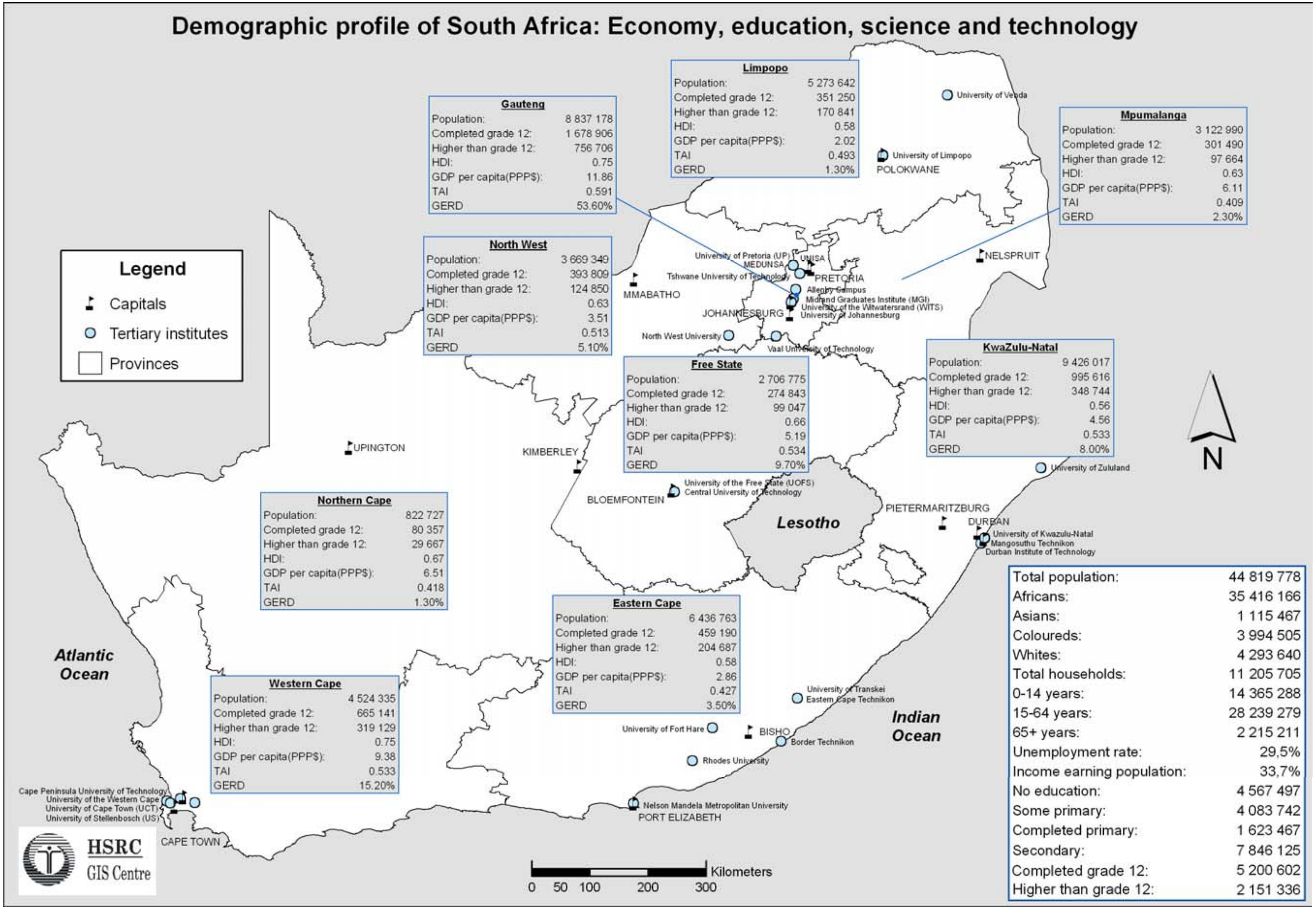
These initiatives are slowly having the desired effect. The ratio of the gross expenditure on R&D (GERD) to gross domestic product (GDP) has grown from a low of 0.69% in 1997 to 0.87% in 2004/05 and is well on its way to reaching the government's target of 1%. The linkages between South African public research institutions, higher education institutions, other parts of the NSI and the international

community are now stronger and more extensive. For instance, South Africa is a significant participant in the European Union Framework Programmes and is the centre of a number of international science projects, including the South African Large Telescope and the Square Kilometre Array.

However, there is still much to be done. Almost all the conventional indicators for S&T outputs are low relative to our peers when these are expressed on a per capita basis. The country needs to raise the participation of all its citizens, at all levels in the NSI, from academics (involved in fundamental or basic research) to industry-based technologists (undertaking incremental innovation). South Africa needs a stronger research cadre that is more reflective of the demographic profile across race and gender dimensions, and a system that is more responsive to the needs of technology entrepreneurs. The country needs to increase the overall pace of innovation, improve patent and publication output, and develop new high-technology industries.

These aspects of the NSI are the challenges for the future. In this report, further details are provided of the history of the system, its governance and structure, its policies and institutions, its inputs and performance, its strengths and weaknesses and some of its unique features. The report concludes with a summary of the main issues and several comments on how the NSI may change in the future.

The following map is provided to assist readers in familiarising themselves with South Africa's demographic profile as illustrated by its economic, education and S&T indicators.


Demographic profile of South Africa: Economy, education, science and technology
Legend
Capitals
Tertiary institutes
Provinces
Limpopo
Population: 5 273 642
Completed grade 12: 351 250
Higher than grade 12: 170 841
HDI: 0.58
GDP per capita(PPP$): 2.02
TAI 0.493
GERD 1.30%
Gauteng
Population: 8 837 178
Completed grade 12: 1 678 906
Higher than grade 12: 756 706
HDI: 0.75
GDP per capita(PPP$): 11.86
TAI 0.591
GERD 53.60%
Mpumalanga
Population: 3 122 990
Completed grade 12: 301 490
Higher than grade 12: 97 664
HDI: 0.63
GDP per capita(PPP$): 6.11
TAI 0.409
GERD 2.30%
North West
Population: 3 669 349
Completed grade 12: 393 809
Higher than grade 12: 124 850
HDI: 0.63
GDP per capita(PPP$): 3.51
TAI 0.513
GERD 5.10%
KwaZulu-Natal
Population: 9 426 017
Completed grade 12: 995 616
Higher than grade 12: 348 744
HDI: 0.56
GDP per capita(PPP$): 4.56
TAI 0.533
GERD 8.00%
Free State
Population: 2 706 775
Completed grade 12: 274 843
Higher than grade 12: 99 047
HDI: 0.66
GDP per capita(PPP$): 5.19
TAI 0.534
GERD 9.70%
Northern Cape
Population: 822 727
Completed grade 12: 80 357
Higher than grade 12: 29 667
HDI: 0.67
GDP per capita(PPP$): 6.51
TAI 0.418
GERD 1.30%
Eastern Cape
Population: 6 436 763
Completed grade 12: 459 190
Higher than grade 12: 204 687
HDI: 0.58
GDP per capita(PPP$): 2.86
TAI 0.427
GERD 3.50%
Western Cape
Population: 4 524 335
Completed grade 12: 665 141
Higher than grade 12: 319 129
HDI: 0.75
GDP per capita(PPP$): 9.38
TAI 0.533
GERD 15.20%
Total population: 44 819 778
Africans: 35 416 166
Asians: 1 115 467
Coloureds: 3 994 505
Whites: 4 293 640
Total households: 11 205 705
0-14 years: 14 365 288
15-64 years: 28 239 279
65+ years: 2 215 211
Unemployment rate: 29,5%
Income earning population: 33,7%
No education: 4 567 497
Some primary: 4 083 742
Completed primary: 1 623 467
Secondary: 7 846 125
Completed grade 12: 5 200 602
Higher than grade 12: 2 151 336
University of Venda
University of Limpopo
POLOKWANE
NELSPRUIT
University of Pretoria (UP)
MEDUNSA
UNISA
Tshwane University of Technology
PRETORIA
MMABATHO
Midrand Graduates Institute (MGI)
University of the Witwatersrand (WITS)
University of Johannesburg
JOHANNESBURG
North West University
Vaal University of Technology
UPINGTON
KIMBERLEY
University of the Free State (UOFS)
Central University of Technology
BLOEMFONTEIN
Lesotho
PIETERMARITZBURG
DURBAN
University of Zululand
University of Kwazulu-Natal
Mangosuthu Technikon
Durban Institute of Technology
Atlantic Ocean
Indian Ocean
University of Transkei
Eastern Cape Technikon
University of Fort Hare
BISHO
Border Technikon
Rhodes University
Nelson Mandela Metropolitan University
PORT ELIZABETH
Cape Peninsula University of Technology
University of the Western Cape
University of Cape Town (UCT)
University of Stellenbosch (US)
CAPE TOWN
HSRC
GIS Centre
0 50 100 200 300 Kilometers
N

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Citation

All references to the official version of the document should be made as follows:

National Advisory Council on Innovation. 2006. *The South African National System of Innovation: Background Report to the OECD Country Review*. Pretoria: NACI.

Preface

The National Advisory Council on Innovation (NACI) was honoured to accept the invitation to compile this background document for the OECD peer review of the South African National System of Innovation for two primary reasons. Firstly, NACI has since 2004 discussed the need to produce an overview of the National System of Innovation to clarify the extent of its evolution during the first decade of democracy. Secondly, it was considered appropriate for NACI to compile such a background document, particularly in the light of the Council's record of objective, relevant and fair evidence-based studies over the past almost ten years.

Three panels of advisors have considered and commented on different drafts of the present document, namely relevant staff and specialists organised by the OECD, members of the Task Team (twice) and members of the Innovation for Competitiveness Sub-Committee of NACI. The Council of NACI has approved the report for submission to the Minister of Science and Technology, who will take responsibility for formal submission of the document to the OECD.

I wish to thank the various groups (see page v) that have contributed to the drafting of this discussion document, including; the team of contributors, the editor and the research assistants, who showed great commitment in completing the task; the Task Team that guided the scoping, set the parameters for the drafting and took responsibility for quality control; and the critical readers that made themselves available to provide feedback on an earlier draft of the document.

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21 July 2006

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Chapter 1: Introduction

This background report has been prepared as an input to the OECD Country Review of the South African National System of Innovation (NSI). The report was drafted by the National Advisory Council on Innovation (NACI) within the framework of the terms of reference for the OECD Review, as agreed by NACI, the Department of Science and Technology (DST) and the OECD.

The primary objectives of the OECD Review are as follows:

- To provide an independent and comparative assessment of the strengths and weaknesses of the NSI
- To formulate a set of concrete recommendations for optimising South Africa's innovation policies and instruments, drawing on the experience of other OECD countries
- To identify good policy practices from which other OECD countries could learn.

In meeting these objectives, the terms of reference further state that the review will consider the following issues in more detail:

- The role of public and private research organisations, the higher education system and specialised intermediaries in the generation and diffusion of knowledge and its economic valorisation through innovation
- The effects of public policy on the generation and diffusion of science, technology and innovation within the NSI, and how such policies could be improved or further developed into new policies
- The role of public research organisations and universities, and the strength of the linkages between such institutions
- The effectiveness of existing policy instruments in promoting business research and development (R&D)
- The social aspects of innovation, the innovation gap, the supply of S&T human resources and the internationalisation of R&D.

The report was drafted by a team appointed by NACI, enriched by feedback from a number of critical readers, the members of a NACI Task Group and the members of a NACI sub-committee. The Council of NACI approved the report for submission to the Minister of Science and Technology.

The report is also intended to provide background material that will inform the work of the OECD reviewers. As such, it is a comprehensive but not exhaustive reflection on the NSI. Wherever possible, primary source material has been used, and the validity and reliability of all source material has been verified by the authors of each section.

The report is structured as follows:

- Chapter 2 covers the overall macro-economic structure of the South African economy, including the widely used parameters of gross domestic product, exchange rates, inflation rates and per capita income, together with more specific sectoral information. The chapter is offered as necessary background information to a reader who is not familiar with the economic performance of South Africa over the last ten years.

- Chapter 3 offers an overview of the structure and dynamics of the NSI. The chapter begins with a high-level view and then considers in more detail the governance and policies of the NSI, including the *White Paper on Science and Technology* and a number of more specific policies that flowed from that document. The policy section is followed by an overview of the various institutions of the NSI, including all performing institutions and funding agencies. The final sections of the chapter provide a brief overview of the intellectual property regime and a limited set of conclusions summarising the common themes.

- Chapter 4 deals with the inputs to the NSI, including its funding and human resource base. The information in this chapter is extracted from a number of sources, including national R&D surveys, the first innovation survey, a number of reports commissioned by NACI, official government publications and reports by researchers elsewhere in the NSI. Some detail is given of the various public funding schemes, arranged according to the potential beneficiaries (business sector, public research institutions and higher education). The final section of the chapter outlines the human resource base of the system, including its demographic profile.

- Chapter 5 deals with the performance (outputs) of the NSI in terms of quantitative and comparative data on publications, human capital development, patents and royalties, exports of high-technology products, innovation performance and performance with respect to the high-level 'quality of life' indicators.

- Chapter 6 offers an overview of the main strengths and weaknesses of the NSI as perceived from inside the system. The chapter argues that the weaknesses converge around the common denominators of ongoing inflexibility and rigidity within the system (in areas such as funding and the S&T domains), and the huge challenges with respect to the human capital pipeline (which is weak in all areas and is moreover subject to a disjuncture between immigration and economic policy).

- Chapter 7 deals with a number of specific initiatives and responses by the NSI, including the internationalisation of R&D, the social aspects of innovation, black economic empowerment and the redress of past inequities (with respect to race, class and gender) and indigenous knowledge. The chapter has been used to provide more detail on these important issues than would otherwise have been possible.

- Chapter 8 summarises the main conclusions emerging from the report and makes a number of recommendations for the future development of the NSI over the medium term. In particular, it suggests a number of ways of addressing the present weaknesses, the major challenges and the most important priorities for the system.

Chapter 2: Economic Overview

In this chapter, the overall macro-economic structure of the South African economy, including the widely used parameters of gross domestic product, exchange rates, inflation rates and per capita income, is presented. In addition, more specific information on economic sectors, human development, small businesses and the role of the informal sector, is presented. The chapter is offered as necessary background information to a reader who is not familiar with the economic performance of South Africa over the last ten years.

2.1 South Africa at a Glance

2.1.1 Key Macroeconomic Variables

A selection of the key economic indicators over the past five years is shown in Table 1. In terms of purchasing power parity, South Africa is ranked as a middle-income economy. The average GDP growth rate between 1994 and 2004 was 2.81% per annum, but since 2000, the growth rate has been at or above this level, raising hopes that South Africa can meet the current growth targets, as expressed in the Accelerated and Shared Growth Initiative for South Africa (ASGISA)[1] of 4.5% per annum until 2009 and 6% between 2010 and 2014.

The population growth rate is 2.3% per annum, so that income growth per capita was barely above zero from 1994 to 2003, but has been at the respectable level of 2% to 2.5% since 2004. The inflation rate has stabilised within a single-digit range since the early 1990s, and since 2000 the Reserve Bank has successfully maintained inflation within its 3% to 6% target band, except for the spike in 2002, which was linked to the severe but short-lived currency depreciation in late 2001. Low inflation and strong appreciation of the South African Rand have allowed for a more relaxed monetary policy since 2002, with interest rates declining consistently.

[1] ASGISA is a new policy framework put forward in late 2005 (see also Sections 3.4.2 and 6.2).

Table 1. Key economic indicators (2000 to 2005)[2]

	2000	**2001**	**2002**	**2003**	**2004**	**2005**
GDP (current PPP US$ millions)[3]	428 598	455 861	478 433	502 585	533 330	n.a.
GDP per capita, PPP (current international US$)	9 741	10 173	10 551	10 967	11 417	n.a.
GDP growth rate, constant PPP (%)	n.a.	6.00	4.40	3.30	8.30	n.a.
GDP growth rate, constant prices (%)	4.20	2.70	3.70	3.00	4.50	4.90
Consumer Price Index (% change per annum)	5.40	5.70	9.20	5.80	1.40	3.40
Prime interest rate (average)	14.50	11.52	15.75	14.96	11.00	10.50
Nominal R/US$ exchange rate (average)	6.94	8.61	10.54	7.56	6.45	6.36
PPP R/US$ exchange rate	2.15	2.24	2.44	2.50	2.60	n.a.

Fiscal policy performance has also been extremely good, as reflected in budget deficit data shown in the second last row of Table 2. The strong macroeconomic performance has improved private sector business confidence, while also creating room within the public sector expenditure envelope for more fixed investment. As a result, fixed investment has picked up as a share of GDP since 2000, with the increase shared equally between the private and public sectors. This expansionary process can be expected to continue since government plans to spend nearly R400 billion, or PPP US$148 billion (nearly 30% of GDP), on public infrastructure projects over the next five years.

Two difficulties on the macroeconomic front are evident. The first is the low, and declining, level of national savings, reported in the last row. This represents a potential long-term constraint on economic growth, with a secondary problem being the rising debt levels of households, whose overall savings are now close to zero as the share of household consumption increases. Consumption has been encouraged by the positive interest rate climate and the Rand's strong appreciation since 2002. Together with rising investment requiring foreign capital goods, the latter has contributed to the strong rise in imports and stagnation of exports, notwithstanding strong commodity prices, since 2000. As a result, the deficit on the current account of the balance of payments has risen steadily, and in the first quarter of 2006 reached 6.4% of GDP, compared to its 2005 average of 4.23%.

[2] Sources: South African Reserve Bank (SARB) website; International Monetary Fund (IMF), International Financial Statistics; World Bank, World Development Indicators.
[3] The Rand-equivalent US dollar amount is presented to indicate purchasing power parity (PPP).

Table 2. Macroeconomic aggregates as percentage of GDP[4]

	2000	2001	2002	2003	2004	2005	Average
Household consumption	62.98	62.73	61.78	62.50	62.77	63.54	62.7
Government consumption	18.15	18.26	18.42	19.32	19.71	20.18	19.0
Private investment	11.62	11.16	12.05	11.71	13.73	12.87	12.2
Public investment	4.29	3.97	4.09	4.52	4.50	4.87	4.4
Trade balance	2.96	3.89	3.66	1.95	-0.71	-1.46	1.7
Exports of goods and services	27.87	29.96	32.71	27.91	26.57	27.10	28.7
Imports of goods and services	24.92	26.07	29.05	25.96	27.28	28.56	27.0
Current account balance (- deficit)	-0.13	0.12	0.64	-1.33	-3.42	-4.23	-1.4
Capital account balance (- deficit)	0.50	0.01	-0.99	1.10	6.34	6.64	2.3
Net FDI inflows (- deficit)	0.46	8.41	1.04	0.10	-0.26	2.64	2.1
Fiscal balance (- deficit)	-2.23	-0.81	-0.86	-1.75	-2.09	-0.88	-1.4
National savings	15.78	15.41	16.70	15.61	14.08	13.70	15.2

Table 2 shows that the capital account balance has moved into surplus as emerging markets have attracted a larger share of global portfolio investment. As a result, capital inflows have been more than sufficient to finance the growing current account deficit.

2.1.2 Millennium Development Goals

The most recently available development statistics for South Africa, organised according to the framework of the Millennium Development Goals and compared to the data from the early 1990s, are shown in Table 3. The data indicate that South Africa has made slow progress over the last decade in addressing these goals, and the poverty rates indicate a large degree of inequality of wealth and income distribution. For instance, more than one-third of the population still live on less than US$2 per day, while the Human Development Index (combining income, education and health indicators) declined significantly between 1996 and 2003.

It is estimated that 11.4% of South Africa’s population, equivalent to over five million people), was HIV-positive in 2002 (Human Sciences Research Council, 2003). The HIV/AIDS pandemic has been a major factor in South Africa’s regression in respect of life expectancy, infant mortality and education, and ultimately contributing to the rising levels of poverty (see also Section 5.2.4). The drop in the primary school enrolment rate may also be linked to HIV/AIDS, as the number of AIDS orphans in the country was estimated at 660 000 in 2001 (World Bank, 2003).

[4] Data calculated using information from the South African Reserve Bank website

Table 3. South Africa and the Millennium Development Goals (early 1990s and post 2000; actual year in brackets)

Item	Description	Early 1990s	Post 2000
a	Total population (millions)[5]	36.2 (1991)	44.5 (2001)
b	Percent of population living on less than US$ 1 per day	n.a.	10.7 (2003)
c	Percent of population living on less than US$ 2 per day	n.a.	34.1 (2001)
d	Human Development Index	0.69 (1996)	0.66 (2003)
e	Life expectancy at birth (years)	62 (1990)	45 (2004)
f	Under five mortality rate (per 1000 live births)	73 (1990)	85 (2004)
g	Maternal mortality rate (per 100 000 live births)	150 (1992 to 1998)	150 (2002)
h	Adult literacy rate (% of people 15 and over)	81.2 (1990)	85.0 (2004)
i	Net primary enrolment rate (% of age group)	88 (1991)	89 (2003)
j	Urbanisation (% of population)	53.7 (1996)	56.1 (2000)

2.1.3 Macroeconomic Policy

The new government in 1994 adopted a Reconstruction and Development Programme (RDP) as its basic policy framework. The RDP identified economic policy strategies across a wide range of issues and sectors, including macroeconomic policy, but by late 1995, there was general disappointment in its limited growth and employment impact. The government came to the view that a macroeconomic stimulus was necessary, but while policy formulation was still under way, in February 1996 a foreign exchange crisis hit South Africa. Net capital inflows dropped from R11.2 billion in the second half of 1995 to R2.7 billion in the first half of 1996, and a nominal exchange rate depreciation of 18% made devaluation redundant. The new macroeconomic policy, announced in June 1996 as the Growth, Employment and Redistribution (GEAR) strategy, was focused instead on stabilising the foreign exchange market as well as achieving growth. It aimed to raise both foreign direct investment and domestic fixed investment through improved credibility of macroeconomic policy involving tighter fiscal and monetary policy. Further objectives included increased exports through a stable real exchange rate together with enhanced competitiveness from labour market reform, skills training and accelerated tariff reform.

Although GEAR was successful in achieving many of its macroeconomic targets (such as containing the fiscal deficit), it did not manage to reach the explicit targets of 6% annual growth together with 500 000 new jobs (by 2001). The new ASGISA programme is intended to address this more intractable aspect of the economy. Government has set itself the challenge of halving poverty and unemployment by 2014, with an average growth rate of 5% per annum over ASGISA's ten-year horizon.

[5] Sources: a, b, c, e, f, h, i: World Development Indicators; d. United Nations Development Program; g, j: Gelb (2003).

2.2 Main Economic Sectors

A breakdown of the contribution by the major economic sectors to aggregate output over the period 2000 to 2005 is given in Tables 4 and 5. The overall picture shows that economic activity and employment are moving from the production of goods into the provision of services, a trend that has now persisted for two to three decades.

2.2.1 Agriculture

The agricultural sector's share of total value added is very small and has been slowly declining, from 3.9% in 1995 to 3.2% in 2000 and 2.84% in 2005. Moreover, agriculture has made only a minor contribution to gross fixed capital formation (see Table 5). The decline in agriculture's share is partly attributable to low efficiency levels in the agricultural sector related to inward-looking policies during the apartheid era.[6] Exogenous factors such as low rainfall and droughts have also played a role.

Table 4. Economic activity by sectors (2000 to 2005)[7]

Sector	**Gross value added (% of GDP)**					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Agriculture, forestry and fishing	3.27	3.08	3.16	3.00	2.83	2.84
Mining and quarrying	7.56	7.34	7.14	7.21	7.10	6.98
Manufacturing	18.98	19.04	18.85	18.05	18.08	17.93
Construction	2.52	2.57	2.62	2.72	2.88	3.02
Total Industry	*29.06*	*28.95*	*28.62*	*27.98*	*28.06*	*27.93*
Electricity, gas and water	2.72	2.55	2.54	2.51	2.46	2.38
Trade, catering and accommodation	14.64	14.50	14.29	14.77	14.95	15.12
Transport, storage and communication	9.65	9.93	10.44	10.72	10.74	10.81
Finance, insurance, real estate and business services	18.64	19.60	20.07	20.29	20.90	21.45
Community, social and personal services	22.02	21.39	20.89	20.72	20.07	19.47
Total Services	*67.66*	*67.97*	*68.22*	*69.01*	*69.12*	*69.23*
Total	**100**	**100**	**100**	**100**	**100**	**100**

[6] World Bank, "South African Agriculture: Structure, Performance and Options for the Future", Informal Discussion Paper no 6, 1994.
[7] Data sourced from the South African Reserve Bank

Table 5. Value added and fixed capital formation by sectors (2000 to 2005)

	Average share of value added (% of GDP)	**Average gross fixed capital formation (% of GDP)**
Agriculture, forestry and fishing	3.03	3.17
Mining and quarrying	7.22	9.38
Manufacturing	18.49	20.38
Construction	2.72	1.71
Total Industry	**28.43**	**31.47**
Electricity, gas and water	2.53	4.52
Trade, catering and accommodation	14.71	6.93
Transport, storage and communication	10.38	13.35
Finance, insurance, real estate and business services	20.16	23.58
Community, social and personal services	20.76	17.00
Total Services	**68.53**	**65.38**

South African agriculture is largely capital-intensive, but nonetheless accounts for a larger share (6.8%) of formal employment than its share of GDP, as well as 12.1% of informal employment (see Table 6). The period 2000 to 2005 saw a substantial decline in agricultural employment of almost 30%, most from formal agriculture. The main focus of agricultural policy in South Africa is not so much increasing output and food production *per se*,[8] but the transformation of the sector to produce efficiently, generating farm incomes and employment. Given the large number of unemployed in the rural areas, increasing the labour absorption of the agricultural sector is an important challenge to the present government.

The main source for growth in the agricultural sector is exports. Increasing agricultural exports requires enhanced competitiveness, via *inter alia* factor productivity growth. Land reform and the removal of incentives towards capital-intensive production and the trade liberalisation efforts are important steps in this process. Nevertheless, improved labour and capital productivity in the agricultural sector remain significant challenges, as does improved access to export markets in developed countries via lowered tariff and non-tariff barriers.

[8] Rooyen, J. Van, (2000), *op cit*.

Table 6. Employment by sector (September 2001 and 2005)[9]

	Formal (% of total)		Informal (% of total)		All employment (% of total)		Total change (%)
	2001	**2005**	**2001**	**2005**	**2001**	**2005**	
Agriculture	9.8	6.8	16.3	12.1	10.5	7.5	-21.5
Mining	7.1	4.8	0.1	0.1	5.0	3.3	-25.8
Manufacturing	17.9	16.8	8.6	9.1	14.5	13.9	5.3
Construction	4.3	6.8	11.7	12.4	5.7	7.6	47.5
Electricity, gas and water	1.2	1.1	0.0	0.1	0.8	0.8	6.4
Trade, catering and accommodation	18.4	21.1	42.1	43.0	21.9	24.6	23.2
Transport, storage and communication	5.5	5.3	4.5	5.5	4.9	5.0	12.8
Finance & business services	12.2	14.2	3.3	2.6	9.3	10.5	25.2
Personal social and community services	23.3	23.0	13.1	15.1	27.0	26.5	7.9
Unspecified	0.3	0.1	0.2	0.0	0.4	0.2	-31.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Total Industry	**29.3**	**28.4**	**20.5**	**21.5**	**25.1**	**24.8**	**27.0**
Total Services	**60.6**	**64.8**	**63.0**	**66.3**	**64.0**	**67.4**	**75.5**

2.2.2 Industry

The industrial sector, including mining, manufacturing and construction, contributed 28.4% on average to South Africa's GDP over period 2000 to 2005. The small share of industry and the large services share are atypical for a middle-income country, and result from the historical development of South Africa as a dualistic economy under apartheid. The output shares of both mining and manufacturing have fallen consistently, continuing a trend that started during the 1980s. Within manufacturing, labour-intensive sub-sectors such as food and beverages, textiles and clothing, and footwear grew slowly at around 0.2% per annum, and their share of manufacturing value-added (MVA) declined, while basic metals, wood products and chemicals (all capital-intensive) were the fastest-growing sub-sectors. The share of formal employment of both mining and manufacturing has fallen (see Table 6). In absolute terms, the last column of the table shows that mining suffered enormous employment losses between 2000 and 2005, shedding over 25% of its labour force, while manufacturing increased jobs by 5.3% (a smaller increase than the overall growth of employment during the same period). The construction industry, however, employed almost 50% more workers during this period and increased its share of both formal and informal employment.

[9] Data sourced from Statistics South Africa, 2005.

2.2.3 Services

The fastest growing sub-sectors across the entire economy were transport, storage and communications, and financial and business services. Services contribute more than two-thirds to the growth in value-added and employment, and as a result its share of these totals rose during the period 2000 to 2005, both in aggregate terms and in all sub-sectors except community, social and personal services (see Tables 4, 5 and 6). The latter together with financial and business services are the largest contributors to gross value added, while employment is largest in community, social and personal services. The trade, catering and accommodation sub-sector is the second-largest employer, and the largest by far in the informal sector. Services employment grew by 76% in the period, though domestic workers (not included in the table) dropped by 7.6% from 930 000 in 2001 to 859 000 in 2005. Overall, services contribute 65% of gross fixed capital formation, with the financial and business services sub-sector alone contributing almost one-quarter of national fixed investment.

2.2.4 Sectoral Productivity

A shown in Table 7, labour productivity has grown rapidly since 2000, including the manufacturing sector productivity levels, although less consistently. In addition, the capital-output ratio has fallen during this period, suggesting that capital productivity has also risen significantly.

Table 7. Sectoral changes in productivity ratios (%)[10]

Year	Labour productivity		All sectors		
	All non-agricultural sectors	Manufacturing	Output-labour ratio	Capital-output ratio	Capital-labour ratio
2000	7.1	n.a.	2.25	-4.00	-1.00
2001	4.0	5.5	0.77	0.00	0.98
2002	3.2	4.2	1.85	-4.17	0.90
2003	4.9	-0.4	1.24	0.00	0.41
2004	2.5	5.9	2.79	-4.35	0.09
2005	4.3	n.a.	3.42	-4.55	0.69

2.3 Human Development

Comparisons of income distribution before and after 1994 are difficult as a result of the lack of official data or estimates for the earlier period, and the unreliability of the early official estimates after 1994. Unofficial estimates during the 1980s, however, have suggested that South Africa was among the two or three most unequal countries in the world, with a Gini coefficient of about 0.67 that was thought to have remained relatively constant between 1975 and 1991. The first official estimates of the Gini coefficient in 1995 placed it much lower than previous estimates at about 0.56, deteriorating to 0.59 in 2000. An unofficial but careful estimate using official data

[10] Data sourced from the South African Reserve Bank

suggested a smaller decline between 1992 and 2000 from 0.57 to 0.58, levels close to the official figures (Hoogeveen & Özler, 2004).[11]

Notwithstanding the uncertainty over the level of inequality, aggregate inequality (within the population as a whole) appears to have increased only slightly over the past 30 years, as income shares have shifted from both rich and poor groups towards the middle classes. There is also wide agreement that in contrast to the population as a whole, inequality within the four (apartheid-defined) race groups[12] has risen steadily since the mid-1970s. Since 1994, a systematic process of black economic empowerment (BEE; see Section 7.2), focusing especially on affirmative action in the labour market and ownership transfers of equity in the capital market, has accelerated the upward mobility of the black middle classes, especially managers and professionals (as distinct from entrepreneurs).

Not surprisingly, race is a significant determinant of both poverty and inequality. In 1999, 32% of households in South Africa were below a poverty line of US$ 251 per month per household (1995 prices), equivalent to US$ 81 per month per individual, and the poverty gap (the difference between the average income of poor people and the poverty line, as a proportion of the poverty line) was 13%. Within the African population, however, 52% were poor, and 95% of poor people were African (Woolard, 2002).

Inequality and poverty also depend heavily on employment status. Wages account for 66% of inequality across all households, and remittances and state transfers for 28% of inequality. Only 22% of people living in poor households were employed (Bhorat et. al, 2001). In 2005, only 26.9% of the working age population were employed in the formal sector and 8.3% in the informal sector (see Table 8). A further 6% were in the agricultural sector and private households,[13] so that the official rate (counting only those willing and able to work, and who have actively looked for work in the previous four weeks) of unemployment was 26.7%. The broad definition of unemployment includes 'discouraged' individuals who want to work but have given up searching, and on this criterion, the unemployment rate was 38.8%. The broad definition is widely believed to be more appropriate in the South African context given the disjointed spatial settlement patterns and structural mismatch of skills demand and supply, due to the legacy of apartheid. Even on the narrow definition, however, unemployment is extremely high. Encouragingly, there was robust employment growth in 2005, with 658 000 new jobs being created, but the unemployment rate rose nonetheless, as the number of new labour force entrants grew even faster than did jobs.

Race and gender are both significant determinants of employment status. Over the period 2001 to 2005, 32.7% of women were unemployed compared to 24.4% of men. Since a greater proportion of discouraged workers are female, the gender differential is even larger if the broad definition is used (Statistics South Africa, 2005). The

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[11] The UNDP (2003, p 43) estimated a much higher value of 0.635 for 2001 (1995: 0.596). This underlines the difficulties of estimation as well as data collection.

[12] Of SA's 2001 population of 44.5 million, 79% were African, 9.5% white, 9% coloured (mixed race) and 2.5% Asian.

[13] Agricultural labourers and domestic workers are excluded from the formal and informal sector categories due to difficulties in measuring and categorizing these types of labour.

average unemployment rate among Africans over the period under review was 33.8% compared to 21.9% among coloureds, 17% among Indian/Asians and only 5.5% of whites. A substantial drop in the broad unemployment rate was observed in 2005, despite a moderate rise in the narrow unemployment rate (see Table 9). Over the five-year period, both unemployment rates have declined slowly, but need to drop at a substantially faster pace if South Africa is to meet its Millennium Development Goals.

Table 8. Working age population (2005)[14]

	Number (1 000s)	% of working age population	% of economically active population
Total population age 15–65	29 697	100.0	n.a.
Employed in formal sector (excluding agriculture and domestic workers)	7 987	26.9	39.7
Agriculture	925	3.1	4.6
Employed in informal sector (excluding agriculture and domestic workers)	2462	8.3	12.2
Domestic workers	859	2.9	4.3
Unemployed (narrow definition)	4 487	15.1	26.7
Unemployed (broad definition)	7 799	26.3	38.8
Totally economically active (broad definition)	20 100	67.7	100.0
Not economically active (broad definition)	9 597	32.3	n.a.

Table 9. Unemployment rate (%; narrow rate unless otherwise specified)[15]

Year	2001	2002	2003	2004	2005	Average
Total	29.4	30.4	28.0	26.2	26.7	28.1
Male	25.8	25.9	24.7	23.1	22.6	24.4
Female	33.8	35.9	32.0	30.2	31.7	32.7
African	35.7	36.4	33.9	31.3	31.5	33.8
Coloured	21.2	23.0	21.1	21.8	22.4	21.9
Indian/Asian	18.8	20.4	16.6	13.4	15.8	17.0
White	5.8	6.0	5.0	5.4	5.1	5.5
Broad rate	40.6	41.9	41.8	41.0	38.8	40.8

The educational profile of the working age population according to various employment categories is given in Table 10. The low level of education is noted; 21.8% of the formally employed had post-secondary schooling, compared to only 3.78% of those employed in the informal sector. Less than 10% of the 859 000 domestic workers in 2005 had matriculated and none had acquired post-secondary education. Individuals who had completed grades 8 to 11 made up the largest portion

[14] Source: Statistics South Africa (2005).
[15] Data obtained from Statistics South Africa (2005).

of the unemployed population (43.2%), with only 4.2% of the unemployed comprised of individuals with post-secondary schooling.

Table 10. Employment status by educational attainment (September 2005)[16]

	No schooling-Grade 7	Grade 8-11	Matricu-lants	Post-secondary	Other	Total
Working age population	28.6	39.9	21.5	8.5	1.3	100
Employment total	24.9	30.2	26.6	15.8	2.1	100
Employment formal	16.9	26.9	31.9	21.8	2.5	100
Employment informal	42.0	37.3	15.7	3.8	1.0	100
Employment domestic	49.0	40.6	9.0	0.0	0.4	100
Not economically active (narrow)	34.2	48.0	14.0	3.0	0.7	100
Unemployment rate (narrow)	22.6	43.2	28.9	4.2	0.8	100

2.4 Small, Medium and Micro Enterprises

Annual turnover is a common indicator of firm size but probably underestimates the proportion of micro and small enterprises. For instance, small enterprises not complying with tax filing requirements may be recorded as economically inactive even though they are still trading. Moreover, sole proprietorships and partnerships (typically smaller entities) are not formally incorporated in South Africa.[17] In 2003, 49% of all registered entities were micro enterprises, 39% were very small, 8% small, 2% medium and only 1% were large enterprises (see Figure 1).

The distribution of small businesses differs greatly between the formal and informal sectors (see Figure 2). More than three-quarters of small business activity centres on services rather than the production of goods. Financial and business services form 44% of formal small corporations, compared to 7% of informal small corporations. For trade, the figures are 23% and 70% respectively. Construction, community, social and personal services and agriculture each comprise less than 10% of small business activity in both the formal and informal sector.

[16] Data as of September 2005 and obtained from Statistics South Africa (2005).
[17] Department of Trade and Industry (2003) *op cit.*

Figure 1. Size distribution of registered firms in South Africa (2003)

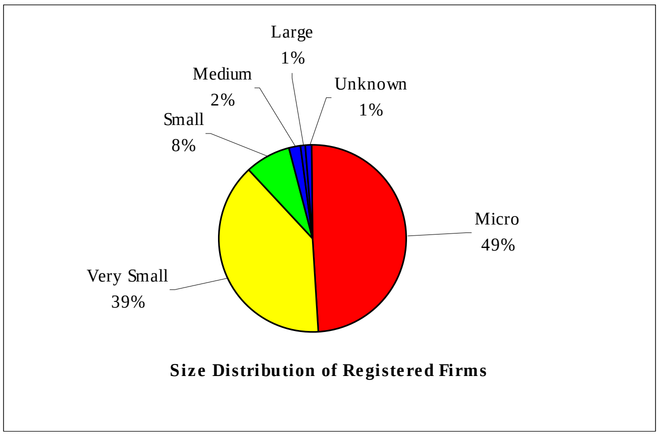
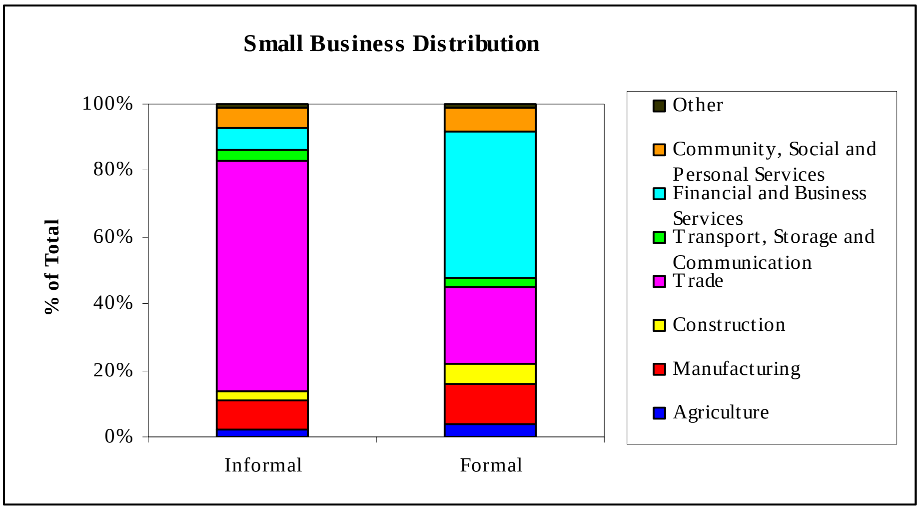


Figure 2. Distribution by sector of small businesses, formal and informal[18]



Small, medium and micro enterprises (SMMEs) accounted for 36.1% of gross domestic product in 2003 (see Table 11) and provided the majority contribution to GDP in the agricultural, forestry and fishing sector, the construction and transport, and the storage and communication sectors (56.4%, 50% and 48.1% respectively). Their smallest contribution to sector-specific share of GDP was in the mining and quarrying sector, where SMMEs contributed only 6.3% to the sector's share of GDP.

[18] Data obtained from Department of Trade and Industry (2003).

Table 11. Percentage contribution to GDP by firm size (2002)[19]

Sector	Micro (%)	Small (%)	Medium (%)	Large (%)	Total (%)
Agriculture, forestry and fishing	3.4	9.2	43.8	43.6	100
Mining and quarrying	1.6	1.9	2.8	93.7	100
Manufacturing	4.9	7.5	21.2	66.4	100
Construction	2.8	32.5	14.7	50	100
Trade, catering and accommodation	4.2	14.6	12.1	59.1	100
Transport, storage and communication	8.8	19.1	20.2	51.9	100
Community, social and personal services and Finance and business services	15.7	13.9	2.6	67.8	100
Total	**5.9**	**14.8**	**15.4**	**63.9**	**100**

The contribution to employment of SMMEs by sector is shown in Table 12. Micro, very small and small enterprises accounted for approximately 72% of total employment and 77% of employment in the trade, catering and accommodation sector. Of all micro industrial sector entities, micro construction enterprises contributed the most to employment, with 36% of total sector employment provided by micro enterprises. With the exception of the utilities sector, large enterprises contributed less than 5% to total employment.

Table 12. Percentage contribution to employment by firm size (2002)[20]

	Micro (%)	Very small (%)	Small (%)	Medium (%)	Large (%)	Total (%)
Agriculture, forestry and fishing	32	12	36	18	1	100
Mining and quarrying	4	9	4	82	1	100
Manufacturing	15	17	20	46	2	100
Electricity, gas and water	0	0	16	59	24	100
Construction	36	33	17	12	1	100
Trade, catering and accommodation	44	19	14	34	2	100
Transport, storage and communication	30	27	20	32	2	100
Financial and business services	18	28	23	32	2	100
Community, social and personal services	45	41	7	3	4	100
Total	**33**	**23**	**16**	**26**	**2**	**100**

The survey of employers and self employed conducted by Statistics South Africa in March 2001 provides some useful information about informal sector businesses, taken to be businesses not registered for VAT. An estimated 74.9% of non-VAT-registered business owners in non-urban areas were in trade, catering and accommodation,

[19] Data obtained from Department of Trade and Industry (2003).
[20] Data obtained from Department of Trade and Industry (2003).

compared with just under two-thirds (65.4%) in urban areas. Less than 3% of non-VAT-registered business owners in non-urban areas were in finance and business services, as against 10.5% of urban owners of informal firms. In other words, activities related to distributing ready-made products and services to consumers were significantly more prominent in small and micro-businesses in non-urban areas than in urban areas.

Non-VAT-registered businesses in construction (46.5%), transport, storage and communication (44.4%), and agriculture (41.0%) were more likely to be employers than in other sectors. Employees of informal businesses in transport, storage and communication industry were paid the highest average wages, followed by finance and business services (25% lower) whilst those in manufacturing received the lowest wage (only 30% of the highest wage).

2.5 Entrepreneurship

The SMME sector in South Africa is relatively underdeveloped given the level of per capita income.[21] The Global Entrepreneurship Monitor, an international survey of business start-up activity, reports that South Africa's Total Early-stage Activity (TEA) rate was 5.1% in 2005. In other words, 5% of South African adults between the ages of 18 and 64 own and manage a start-up business (less than 3.5 years old). South Africa's rate has remained relatively stable between 4.0% and 6.5% since 2001, but is extremely low, the lowest of all developing countries in the survey. Also lowest among the developing countries is the 'opportunity entrepreneurship' rate, reflecting businesses started in response to perceived market opportunity (as distinct from started for necessity, or survival, reasons). Only 1.3% of South Africans own and manage an established business that has survived for more than 3.5 years, compared to more than 10% of adults in Brazil, Thailand, Greece, New Zealand and China. South African firms also have a poor success rate in comparison with most other developing countries.

The monitor also reveals that entrepreneurship correlates with age (individuals aged between 24 and 44 are most likely to be entrepreneurs), and race (Indian and white individuals are more likely) and education, but not with gender. However, men are 2.3 times more likely than women to employ people, while entrepreneurs with tertiary education have 2.5 times greater potential to create employment than those with only secondary education, and 11 times greater than those without secondary education. It was also found that very few new and established firms have a high level of customer orientation, are differentiated from competitors or are technology orientated.

Government policy has typically tried to target specific groups of entrepreneurs, such as historically disadvantaged, women, youth or disabled, which are more likely to be poor and unemployed or without opportunities. However, the data show that as a result of the legacy of apartheid, especially unequal access to education, these groups are the least likely to create successful businesses or expend employment. Allocating resources to these groups involves a trade-off between the job creation and redistribution. Regardless of policy priorities, improved educational access, improved mathematics and science teaching and entrepreneurship education are critical.

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[21] Lewis (2001), *op cit*.

Chapter 3: Policies, Governance and Structure of the NSI

This chapter describes the history, governance, present policies and institutional structure of the NSI. If ‘innovation’ is defined as “implemented technologically new products and processes” as well as improvements in such products and processes (*Oslo Manual*, 1997: 47), the term ‘national system of innovation’ can, in line with current literature, be used to denote “the arrangement of the relationships among all organisations that are involved in the entire range of innovation activities from enablement through creative processes to the implementation stage” (*White Paper on S&T*, 1996; Marais, 2000). This relatively broad definition includes the functions, their enabling structures (in both the public and private sectors), policies and context as essential parts of the NSI.

In short, the NSI includes the full value chain ranging from R&D (OECD, 2002c) through to “implemented new products and processes” (*Oslo Manual*, 1997: 47), but excludes economic framework conditions and related downstream components of the innovation value chain, such as manufacturing capacity and marketing structures.

3.1 History and Transformation of the NSI

Science and technology in South Africa have a long history; the first traces of such activities include pigment mining (4 000 BCE), mummification (dating back about 2 000 years), iron metallurgy (3rd to 4th century CE) and gold mining and processing (12th century CE). However, the first formalised scientific endeavours date back only to the latter half of the 18th century (in the fields of astronomy and botany). The establishment of the Royal Observatory in the Cape Colony in 1820 is generally accepted as the start of the institutionalisation of science in the country, while the first higher education institution (HEI), which later became the University of Cape Town, was founded in 1829, the same year that marked the launch of the first two professional societies. The first official initiative to support academic and industrial research, namely the Industries Advisory Board, dates back to 1917 (for an overview see Marais, 2000).

Over the next seventy years, a number of HEIs, advisory bodies, funding agencies and public research institutions were established. Many human resource development and S&T policies were introduced, and the system itself expanded at a reasonable rate. The main drivers of development over this period were the growing sectors of mining (mainly gold, diamonds and coal), agriculture, manufacturing and energy, the roots of which were inextricably linked to South Africa’s abundant natural resources. In addition, the Second World War stimulated South Africa’s manufacturing industry (with manufacturing overtaking mining as the most important economic sector in the 1940s) and created an urgent need for organised research in support of technological development.

A second and more unique feature of the system, which began in the 1960s in response to the increasing isolation of the country as a result of apartheid, was a strong focus within both public and private S&T institutions on self-sufficiency in a narrow set of strategic areas, including energy, liquid fuels and defence. The result was a relatively strong military-industrial complex (characterised by atomic weapons, missiles and other military hardware), and the emergence of Sasol (for liquid fuel production) and the Atomic Energy Corporation (for nuclear power), both of which received substantial government support over that period.

The first democratic government took office in 1994, a year that represents a watershed in the history of the country and marked the start of massive policy changes to address the inequalities of the past, on the one hand, and to align the system with international policy thinking, on the other. The public missions of the apartheid regime (such as defence, energy and food self-sufficiency) were abandoned, and new missions were articulated.[22] The new public missions, as described in the *National R&D Strategy*, are biotechnology, information technology, technology for advanced manufacturing, technology for and from natural resource sectors and technology for poverty reduction (see Section 3.4.2). In broad terms, these missions and other current policies for publicly funded S&T are positioned to address the following main challenges:

- Relevance to the needs of all the people
- Economic growth
- Human resource development
- Alignment to appropriate best practices elsewhere
- Sufficient allocation to basic research
- Improved coordination within the system
- Normalisation of international relations.

It should be noted that the NSI has undergone extensive transformation since the country's conversion to an inclusive democratic constitution in 1994, including:

- Rationalisation of structures and actors within the system
- Realignment of the system's priorities to address South Africa's social and economic development imperatives
- Closer alignment of policies with international trends, including strengthening linkages within the system and with the systems of other countries
- Transformation of the human resource base to more closely reflect the country's demographic profile
- Re-allocation of resources to ensure greater participation and inclusion of all institutions, especially previously disadvantaged institutions.

In keeping with the strong democratic culture developed through organised political resistance in the latter part of the 20th century, this transformation process has been highly consultative, involving groups from civil society and the government. Some of these initiatives are incomplete and as a result ongoing, as will be discussed in subsequent chapters. The post-1994 NSI can therefore still be considered as a 'work in progress'.

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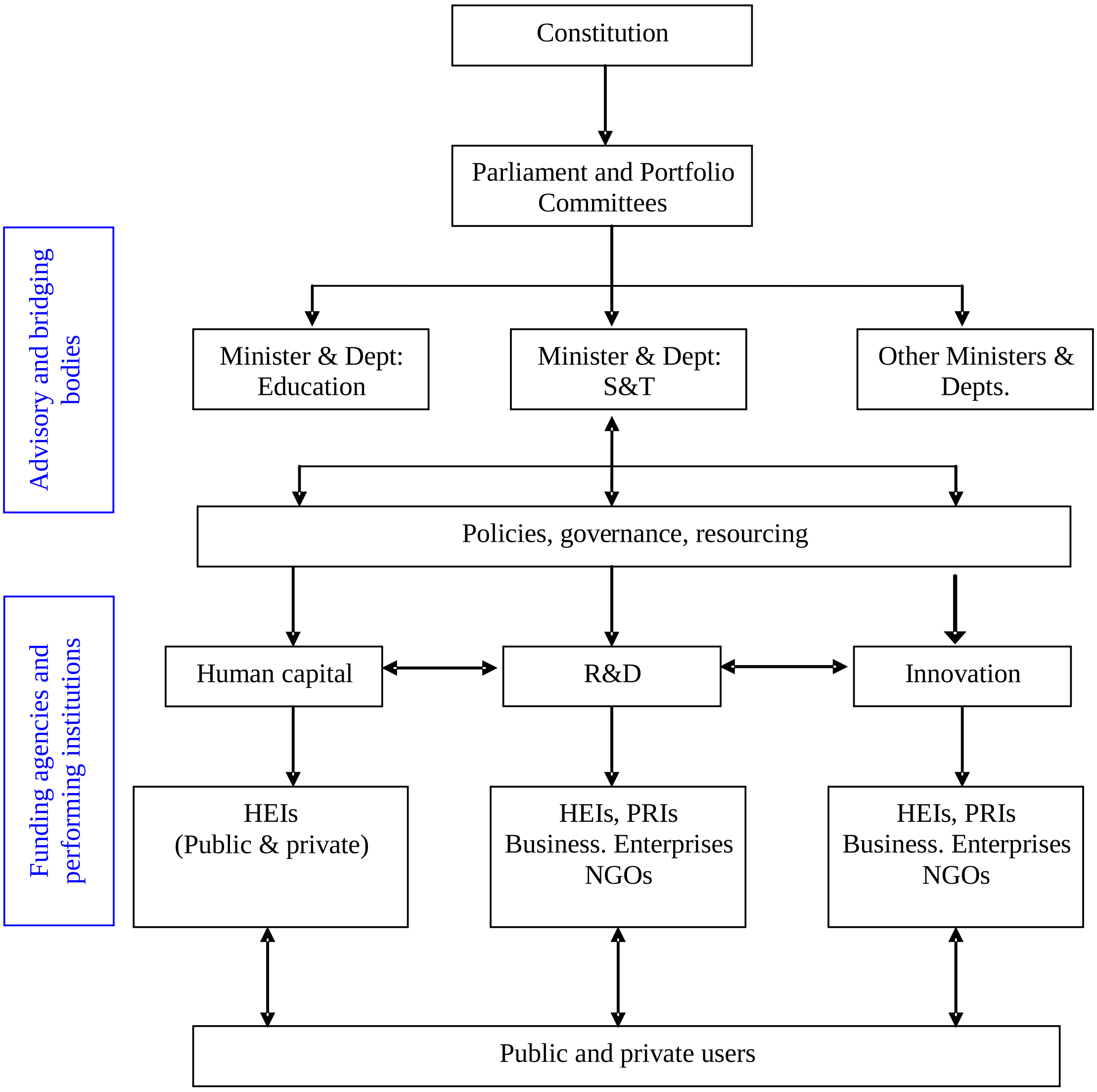
[22] It should be noted that no new S&T missions were clearly articulated until the acceptance of the *National R&D Strategy* in 2002. One of the consequences of the time lag between the lapse of the old missions and the advent of the new was a drop in the GERD/GDP ratio from 1.03% in 1991 to 0.69% in 1997 (see also Section 4.2).

3.2 Overall Structure of the NSI

The NSI consists of at least five intersecting national sectors (each comprising a set of institutions with a common objective) and four interdependent functions (see Figure 3), all of which operate within an important international context.

Figure 3. Overall structure of the NSI



[Note: The international context impacts directly and indirectly on all elements of the structure]

The national sectors are as follows:

- The Department of Science and Technology (DST),[23] which is responsible for overseeing the resourcing and management of public NSI institutions and has direct line management responsibility for S&T
- The Department of Education and higher education institutions, the combined role of which is to provide a pool of high-level human resources and to generate new core knowledge
- The departments of Trade and Industry, Minerals and Energy, Environmental Affairs and Tourism, Agriculture, Water Affairs and Forestry, Health and other government departments, which both fund and perform R&D, focusing on a number of core public sector functions such as agriculture, health, weather services, the promotion of innovation within industry, energy research and environmental management
- The business sector, including industry and state enterprises such as Eskom, where knowledge is transformed into innovation
- The non-governmental organisation (NGO) sector, which undertakes R&D principally in areas of high public interest (such as social or environmental research) or in the event of market failure.

The four S&T functions are:

- Policy formulation and policy advice: this function resides with the ministries and departments already listed. In addition, the DST has been given the function of coordination and oversight and is involved in several new initiatives to increase coordination within the NSI. There are several advisory bodies with functions ranging from extensive and statutory to additional and self-initiated. It should be noted that only the Council on Higher Education and NACI have statutory Ministerial advisory functions.
- Funding: this function is fulfilled by a large array of agencies and funding bodies (for further details, see Section 4.3), split between directed funding and funding for self-initiated research, based on open calls. The latter type is funded principally by the National Research Foundation and the Medical Research Council. In recent years, the proportion of total funding disbursed through performance-based block funding has decreased in favour of competitive and directed funding; this trend is in line with world trends to improve the relevance and output of innovation systems.
- Performance: this function is located in all the performing agencies, including HEIs, public research institutions (PRIs)[24] and the business sector. The PRIs act in a similar way to those in other countries, undertaking R&D in accordance with a clearly defined mandate and operating in terms of a mixed income model (funded through both a government core grant and contract research income).

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[23] The department in 1994 originally came into being as the Department of Arts, Culture, Science and Technology, but split into two separate departments in 2004 (see Section 3.4.3); in this report DST also refers to its pre-2004 predecessor, DACST.
[24] Given the increase in the number of public research-performing institutions, it has been decided, for the purposes of this background document, to categorise such institutions collectively as ‘public research institutions (PRIs)’. Of the institutions in this category, only the Medical Research Council has a dual research-performing and research-funding role.

- International relations in S&T: in post-1994 South Africa, a key strategic priority for the system has been the normalisation of international relations after two decades of relative isolation of the South African scientific community under the apartheid regime. The DST has been a primary role-player in ensuring that this new function becomes widely adopted and assimilated within all parts of the system.

3.3 Governance of the NSI

A new approach to the governance of the NSI was initially outlined in the *White Paper on Science and Technology* (DST, 1996) and was further revised and enhanced by a proposal to Cabinet adopted in 2004. The latter has been a highly influential document over the last two years in clarifying the role of the DST and other government departments with respect to S&T management. The main components (and modal relationships) of the policy formulation, steering and governance functions in the NSI are discussed in this section. The budgetary process, which is particularly important in determining the pattern of government spending and hence the overall response of the system to government priorities, is also addressed.

3.3.1 Political Oversight

Political oversight of the NSI is invoked through National Parliament, the activities and authority of which extend to S&T matters. Most of this work, including the consideration of draft legislation and oversight of the work of the DST and its associated institutions, is undertaken by the Parliamentary Portfolio Committee for S&T (comprising members of Parliament), which meets on a regular basis. The DST and many PRIs brief the portfolio committee annually on their respective business plans and annual reports.

Coordination within government takes place through clusters, each of which focuses on a national sector. At an executive level, strategic S&T issues are addressed through the agenda of the Ministerial Cluster for Economics, while operational and implementation issues are discussed at meetings of the Directors-General Cluster for Economics and Investment. In broad terms, these clusters are coordination bodies for S&T, with the role of ensuring the effective implementation of government policy (through agencies of state) and preventing the development of contradictory or disjointed policy. The Ministerial Cluster functions as a forum at which new draft policies, strategies and high-level initiatives are discussed and agreed upon with other departments in that cluster.

3.3.2 Governance of the Public Component of the NSI

Governance of the public component of the NSI is primarily a central government competency; provincial governments contribute to the systems only through the relatively minor portfolios of primary and secondary education and local industrial development. At central government level, South Africa follows a system whereby various government departments, with the exception of the DST, assume responsibility for different areas of S&T and for specific institutions, such as the Department of Education (responsible for HEIs), the Department of Agriculture (responsible for the Agricultural Research Council), the Department of Minerals and

Energy (responsible for Mintek, the Council for Geoscience, the National Energy Research Institute and the Nuclear Energy Corporation of South Africa), the Department of Trade and Industry (which supports innovation at industry level) and the Department of Health (which manages the Medical Research Council).

The DST is also responsible for specific institutions (the Council for Scientific and Industrial Research, the National Research Foundation and the Human Sciences Research Council), but has a cross-cutting and steering function for areas such as S&T liaison across departmental line functions and sectors; large-scale, broad-scope new S&T platforms and challenges (such as astronomy, human palaeontology and indigenous knowledge); and system-wide oversight functions, including establishing and maintaining a common governance framework, priority setting, and performance and budgetary monitoring systems. Other government departments are responsible for sector-specific S&T activities such as energy research (Department of Minerals and Energy) and animal health (Department of Agriculture).

The mandates of the DST and the Department of Education include responsibility for creating and overseeing the implementation and funding of S&T policy and instruments – the DST primarily with regard to R&D institutions and programmes and the Department of Education with regard to the training of high-level human resources and the support of university research (see the Higher Education Act No. 101 of 1997). Support of university research takes place through two mechanisms, namely a postgraduate component in the subsidy formula and an R&D publication subsidy.

The work of these departments overlaps in two respects. Firstly, the funding and political accountability of the National Research Foundation, which supports a considerable amount of research within HEIs, are the responsibility of the DST. Secondly, the DST has since 2005 also had an oversight function for several basic research programmes within the NSI, particularly in the HEIs and PRIs. The DST and the Department of Education are supported and advised by two Ministerial statutory bodies (NACI and the Council on Higher Education respectively). Each of these departments would generally consult relevant stakeholders, directly and/or indirectly, before finalising new policy initiatives.

3.3.3 Government Budget and Policy Formulation

Given the governance role of Parliament and the policy role of the government, it is important to understand the process followed in setting short- to medium-term priorities and its relationship with the determination of government budgets. Medium-term policy, priorities and budgets provide all stakeholders across the system with a clear idea of the direction in which the NSI is being steered. In essence, the cyclical process consists of the following phases, listed here from the institutional to the national level:

- Firstly, at institutional level, each PRI is required to submit to its line department (and Minister) a detailed motivation and budget for the next year, based on its strategic plan, its report on key performance indicators for the previous year and its business plan for the next year. These documents are then incorporated into the departmental submission to the National Treasury. The strategic plans, performance reports and business plans become public documents once approved by the relevant Minister.

- Secondly, at sectoral level, each department submits a detailed motivation and budget for the next year to the National Treasury, which then prepares the national budget for the following year. These submissions are informed by the above institutional requests, the department's own strategic plan and interpretation of the needs of the particular system, and inputs from Ministerial advisory bodies. The departmental strategic plans become public documents once they have been submitted to Parliament.
- Thirdly, after interaction with departments and having gone through two further specialist committees, the National Treasury produces the so-called *Estimate of National Expenditure* (National Treasury, 2006), which informs the President's annual State of the Nation Address each February and serves as the background document to the budget speech by the Minister of Finance. The *Estimate of National Expenditure*, which is a public document, contains concise strategic overviews, accounts of expenditure for the previous three years and estimates of expenditure for the current year and the following three years for each programme in each department.
- Finally, the budgetary loop is closed when the *Estimate of National Expenditure*, as the official basis for the annual budget, is subsequently accounted for in revised departmental strategic plans, while the departmental feedback to the institutions is finally accounted for in their strategic and business plans. The respective Ministers' budget speeches to Parliament follow in March and offer general overviews, salient new developments and justifications for the budgetary allocations.[25]

This process illustrates the initiating and sectoral priority-setting role played by government departments, the testing, cross-sectoral prioritising and filtering role of the National Treasury and the legislative role of Parliament. In general, institutional strategic and business plans offer relatively high-resolution overviews of the contribution of institutions to national innovation policy objectives. More comprehensive overviews of national policy objectives are to be found in departmental strategic plans, whereas the *Estimate of National Expenditure* offers a comparative overview of national priorities across all sectors. The short- to medium-term highlights of the portfolio of each Minister are usually covered in the annual budget speech.

Finally it should be noted that all PRIs, with the exception of universities, are required to comply with the Public Finance Management Act (Act No. 108 of 1966), the intention of which is "to secure transparency, accountability, and sound management of the revenue, expenditure, assets and liabilities of the institutions to which this Act applies". This Act is an important governance instrument for the state.

[25] Parliament annually produces a useful summary of the implications for each government department of the State of the Nation Address; there is unfortunately a time lag between the presidential speech and the publication of the document (Parliament of South Africa, 2005).

3.3.4 Priority Setting

The foregoing summaries of the governance and policy formulation arrangements imply that priority setting in the STI system takes place as an integral part of the cyclical budgetary process and that it is not a separate dedicated process that takes place once every so many years. The DST is the main author of national STI priorities to the extent that it has been given a cross-cutting and steering function within the system. In this regard, it is guided by the framework established by the *National Research and Development Strategy* (see Section 3.4.2), international developments and inputs received from various role-players in the system. It can be assumed that the *National R&D Foresight Study* (DST, 1999) directly and indirectly still serves as a backdrop to considering priorities.

3.4 Policies of the NSI

As mentioned in Section 3.1, the policies of the NSI were substantially revised post-1994. These changes were driven by the commitment of the new government to reconstruct and develop the country in such a way that it could become a just and equitable place in which to live and work. A new set of national priorities was articulated, covering issues (which were sometimes conflicting) such as increasing the international competitiveness of the economy, the eradication of poverty and the development of highly marginalised rural areas. As a result, S&T had to compete for government resources on the basis of its tangible contribution to the national vision, rather than in other terms such as building South Africa's international prestige in S&T or increasing the numbers of postgraduate students at HEIs. Within this context, S&T has done relatively well in terms of the number and scope of policies approved, the re-organisation of the institutional landscape, the launching of new 'flagship' programmes under the *National R&D Strategy* and funding. Details of the new policies, strategies, programmes and restructuring initiatives now follow.

3.4.1 New Policies: 1994 to 2004

The first major initiative was to upgrade the S&T function to ministry and departmental level with the formation of the Department of Arts, Culture, Science and Technology in 1994. This later split to become the Department of Science and Technology (DST) and the Department of Arts and Culture. The next major policy initiative was the publication in 1996 of a new consolidated policy, the *White Paper on Science and Technology* (see box) (DST, 1996), which was followed in 2002 by the *National R&D Strategy* (DST, 2002a). The equally important *White Paper on Education* was published in 1997 (DoE, 1997; see box). The period since 1996 has seen the approval of at least nine major S&T sectoral/thematic policies and strategies and the establishment of 19 new institutions/programmes.

The pertinent changes in science, technology and innovation policy since 1994 can be summarised as follows.

- At the macro (policy) level, the scope, focus and missions of the system were aligned with the new democratic government's national goals and objectives of economic growth and international competitiveness on the one hand, and on the other hand redressing the entrenched inequities of the past, based primarily on race but also on gender (see also Section 7.4), leading ultimately to improved quality of life for all, especially for the previously disadvantaged. This new emphasis is most clearly manifested by the shift from S&T policy to innovation policy, the recognition of new modes of knowledge production and the establishment of new collaborative ventures.

- At the meso (institutional) level, the focus fell on evaluating the role and performance of all institutions within the system and then transforming the strategies and governance to ensure delivery against the national challenges, and transforming the management and human resource structures to better reflect the demographics of the country.
- At the micro (programme) level, the impact of these changes was a movement towards directed basic/strategic research by universities and towards applied research/experimental development by other role-players in the government system, such as PRIs.

White Papers

White Paper on S&T: The main thrusts of this policy were to broaden the existing policy framework from an S&T model to a national system of innovation model; to revise the national imperatives and ensure system alignment with the relevant issues of the day; to outline the need and process for regular institutional performance evaluation; and finally, to scale the dimension of the required transformation in order to achieve more representative demographic participation within the system (Marais, 2000). The policy was largely successfully implemented within five years after the approval of the *White Paper on Science and Technology* (NACI, 2003d).

White Paper on Education: The main features of this policy, which was approved in 1997, of relevance to the S&T landscape are the recognition of Mode 2 knowledge production; the need for quality control at both institutional and programme levels; the need for university R&D to contribute to development; the need for demographic transformation to achieve human resource equity at staff and student levels; and the need to reduce the number of institutions. The implementation of the policy directives reached its final stage with the merging of higher education institutions to create 23 institutions from the original 36.

3.4.2 New Strategies: 2000 to 2006

Flowing from these policy documents, a number of specific strategies have been approved by the South African Cabinet; some have already been implemented and others are being implemented. The following list (in order of importance) provides a selective overview of strategies approved over the period 2000 to 2006:

- *National R&D Strategy* (DST, 2002a): The main objectives were to provide further details on the implementation of the principles contained in the *White Paper on S&T*; to promote innovation and new national technology missions (biotechnology, information technology, technology for advanced manufacturing, technology for and from natural resource sectors and technology for poverty reduction); to improve and diversify human resources; to promote a new set of science missions (in areas in which South Africa has an obvious geographic advantage, such as astronomy, human palaeontology and biodiversity, as well as in areas in which South Africa has a clear knowledge advantage, such as indigenous knowledge and deep mining); and to create an effective government S&T system. Most of the strategic objectives are already being implemented.

> The *National R&D Strategy* is probably the most important strategic document associated with the NSI to have emerged over the last ten years. In addition to providing a new set of S&T missions, it also proposes a set of performance measures according to which the progress of the NSI should be monitored (see Chapter 4). The implementation of the strategy is being steered by the DST and is being used as a frame of reference by all the PRIs. Several review articles of the strategy have been published (Kaplan, 2004a; Muchie, 2003).

- *National Biotechnology Strategy* (DST, 2001): This strategy proposed a number of key initiatives to support the development of a bio-economy in South Africa, including the formation of the Biotechnology Regional Innovation Centres and extensive funding for close-to-market biotechnology R&D.

- *Accelerated and Shared Growth Initiative for South Africa* (ASGISA) (South African Presidency, 2006): This initiative aims to address over the short to medium term the constraints to higher sustainable economic growth, including the volatility of the currency, cost and efficiency of logistics, skills shortages, barriers to competition, dysfunctions of the regulatory environment and deficiencies in state organisation. While the initiative is mostly aimed at economic growth in general, successful implementation is expected to have an impact on various aspects of the NSI. Examples include emphasis on broad-band ICT infrastructure, and the *Joint Initiative on Priority Skills Acquisition* (JIPSA), which includes problems such as unemployed graduates, work placements for ICT graduates, and institutional capacity of further education and training colleges.

- A number of other important strategies, including the *National Skills Development Strategy for South Africa* (Department of Labour, 2004), *Open Source Software and Standards Strategy* (DST, 2002), *Towards a Framework for the Monitoring and Evaluation of South African Higher Education* (Department of Education, 2004), *Advanced Manufacturing Technology Strategy* (DST, 2002b), *Indigenous Knowledge Systems Policy* (DST, 2005), *Nanotechnology Strategy* (DST, 2005) and the *Higher Education Qualifications Framework* (Department of Education, 2004).

In addition to the above, a *Framework for Intellectual Property from Publicly Financed Research* (see Section 3.6), a *Technology Transfer Strategy*, the *Hydrogen Economy Initiative* and the *Advanced Metals Initiative* are currently being developed by the DST, and a *Gender Equity Strategy* is being developed by NACI. The *Integrated Manufacturing Strategy*, developed by the Department of Trade and Industry in 2002, was also an important document, although it has not been formally adopted by Cabinet. The latter department is also responsible for competition policy, which is being clearly articulated in the document "*A Framework for Competition, Competitiveness and Development*" and in the Competition Act (Act No. 89 of 1998).

3.4.3 Restructuring of the Institutional Landscape

While funding and other policy instruments exhibit a degree of flexibility, institutions within any country are slow to change and probably represent the most rigid components of a national system. Nevertheless, institutional change is necessary and important, and South Africa is no exception in this regard. Historically, the NSI has been characterised by fragmentation and a slow rate of technology transfer from the academic to the industrial environment. Restructuring the institutional landscape was therefore very necessary to ensure more effective technology transfer; stronger linkages between HEIs, PRIs and the business sector; increased coherence and focus within the system; and better alignment between the strategic priorities of government and the objectives of R&D projects, including support for the sectoral strategies. A brief summary of some of these changes follows:

- The S&T function was elevated to its own central government department (the DST) in 2004.
- The DST moved from the Social to the Economics and Investment Cluster, thereby confirming a change in the perceived mission of the department.
- The funding of research in the natural and social sciences was brought under a single umbrella with the establishment of the National Research Foundation.
- Certain HEIs were merged, thereby reducing the number of such institutions and creating universities of technology.
- New S&T points of gravity were established. Firstly, a number of centres were established (such as the South African National Energy Research Institute, the Innovation Hub, the Automotive Industry Development Centre and the South African Centre for Epidemiological Modelling and Analysis), and a programme was launched to establish six Centres of Excellence at HEIs. Secondly, a number of existing PRIs were strengthened (such as the upgrading of the Africa Institute of South Africa to a formal PRI, the establishment of the South African Earth Observation Network as a national facility and the embedding of the National Zoological Gardens within the National Research Foundation). Thirdly, a number of S&T promotion trusts were established and centres launched under their control (such as technology incubators under the Godisa Trust and technology stations under the Tshumisano Trust).
- The Foundation for Education, Science and Technology, a former agency of the DST, was moved to the National Research Foundation and converted to the South African Agency for S&T Advancement in order to better promote the public understanding of S&T.

3.4.4 National Investigations and Programmes

The DST has in recent years launched a number of national investigations in order to provide the required information for future policies. Examples of such initiatives include:

- *National R&D Foresight Study* (completed in 1999)

- *National Roadmap Studies* (on information and communications technology [ICT] and biotechnology)
- Annual R&D survey (according to the *Frascati Manual*) and periodic Innovation Surveys (according to the *Oslo Manual*)
- Gender in the S&T system
- *Technology Development Trends Study* (undertaken by the Department of Trade and Industry in 2005).

In addition to these studies, the DST has recently launched a number of national programmes following the adoption of the *National R&D Survey,* including:

- The National Antarctic Programme
- The Square Kilometre Array project and the Southern African Large Telescope
- R&D support for the Hydrogen Economy and the Pebble Bed Modular Reactor.

3.4.5 Promotion of International Research Collaboration

One of the strategic priorities in 1994 was to normalise international relations after two decades of relative isolation of the South African science community. Since then, participating in international programmes has remained a strategic priority at all levels of the NSI, as reflected in the following paragraphs:

- Multilateral strategic partnerships are high on the agenda. An example is South Africa's contribution to the mainstreaming of S&T as a key factor in sustainable development at the World Summit on Sustainable Development in Johannesburg in 2002. Another example is the country's participation in European Union initiatives. South Africa participated in more than 180 projects under the European Union's Fourth, Fifth and Sixth Framework Programmes. Participation in the Fifth Framework Programme is estimated at close to €40 million. A landmark for this country was the inauguration of the Southern African Large Telescope in 2005, which is the result of collaboration among a number of countries, and the proposal to establish the Square Kilometre Array in South Africa.
- In the African context, South Africa plays an active role in promoting S&T, an example being its prominence in the context of the New Partnership for Africa's Development (NEPAD)[26] at administrative level as well as by initiating and/or participating in a series of major projects, including the Coelacanth Conservation and Genome Resource programmes and the Southern African Large Telescope. Approximately R17.8 million (PPP US$ 6.8 million)[27] has been budgeted for the 2006 financial year for the NEPAD component of international collaboration.
- The country currently manages 32 bilateral S&T agreements, yielding a total of approximately 400 projects of varying sizes.

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[26] The New Partnership for Africa's Development (NEPAD) is a vision and strategic framework for Africa's renewal. The NEPAD strategic framework document arises from a mandate given to the five initiating Heads of State (Algeria, Egypt, Nigeria, Senegal and South Africa) by the Organisation of African Unity (OAU) to develop an integrated socio-economic development framework for Africa. The 37th Summit of the OAU in July 2001 formally adopted the strategic framework document.

[27] The Rand-equivalent US dollar amount is presented to indicate purchasing power parity (PPP).

- International collaboration is a strategic priority for all public research institutions, for which the Council for Scientific and Industrial Research (CSIR), cooperating with some 23 African countries, serves as an example. The CSIR recorded international income of R96.3 million (PPP US$ 37 million) in 2005; the total external contract income for the same period was R619 million (PPP US$ 238 million).

Another indicator of the country's international sensitivity is the fact that about 10% of South Africa's R&D is funded from non-South African sources.

3.5 Institutions of the NSI

3.5.1 Funding Agencies

There is a diverse array of funding agencies within the NSI, including non-governmental organisations, many private companies, institutions in government and international agencies (see also Section 4.2). This section focuses mainly on public support of R&D.

The central government uses two primary modalities for funding performing institutions in the NSI. Firstly, there is performance-based block funding, which comes directly from government departments (such as the Department of Education and the DST); secondly, there are funding agencies such as the National Research Foundation and the Medical Research Council (the latter of which also performs R&D). In addition, public funding for R&D is also delivered through a number of sector or industry bodies that raise funds from levies within a particular sector, such as the Safety in Mines Research Advisory Committee, the Water Research Commission and the Maize Trust.

The most important public funding agencies that support proposal-driven basic and applied research within a competitive environment are the agencies of the National Research Foundation (which supports all fields except medicine and has a total annual budget of R1.3 billion [PPP US$ 0.5 billion] for 2006/07) and the Medical Research Council (which provides similar support as the funding agency for medical research and has a budget of R18 million [PPP US$ 6.9 million] for the 2006/07 financial year). The National Research Foundation is governed by a board appointed by the Minister of Science and Technology, and the Medical Research Council by a board appointed by the Minister of Health. The boards are mandated by the respective Acts of Parliament to define the general policies of the organisation, develop its multi-year programmes and ensure compliance with statutes. The boards comprise representatives from the fields of science, business and policy-making. Each agency is managed by a chief executive officer (who is also the chief accounting officer) appointed by the relevant Minister. After ministerial approval of their strategic and annual corporate business plans, the agencies are autonomous with regard to their internal functioning (see the specific Acts and annual reports listed in Appendix A).

Both funding agencies follow germane national strategies and allocate funds so as to ensure alignment between South Africa's needs and the areas of R&D being undertaken (the relevance factor). Funds are granted according to internationally accepted peer-evaluation based approaches with respect to evaluating, awarding and monitoring research grants (including a public call for applications, explicit award criteria and related guidelines, panels of independent evaluators, and the staff of the funding agency fulfilling only an administrative support role). The grants range from postgraduate scholarships (with the entry point being an honours degree, which is the first year after a bachelors degree) to post-doctoral grants and 'large' research grants (up to R1.5 million [PPP US$ 0.6 million] per year), and include funding for international collaborative research. The National Research Foundation has developed a researcher rating system that allows certain researchers to access block grants awarded for a cycle of five years; in April 2005 there were a total of 1 399 rated researchers, 50 of whom were in the 'A-rated' category.[28]

Other important funding agencies include the Godisa Trust, the Industrial Development Corporation, the Tshumisano Trust and the Biotechnology Regional Innovation Centres (see Section 4.3.3.2).

3.5.2 S&T Performing Institutions

The country inherited a British-colonial type system of R&D performing institutions, which has over time evolved into a system complying with national public conditions, requirements and needs. The public research performance component of the NSI consists of three sub-sectors (namely higher education institutions, PRIs and other public bodies). This section offers an overview of this component of the NSI.

3.5.2.1 Higher Education Institutions

The first South African university was established in 1829. South African universities have had a research mission since the early 20th century, and today research remains an essential component of their activities. Legislation passed in the last few years provided for the rationalisation of this sector through mergers between selected institutions, which has resulted in a total of 23 universities, four of which are classified as universities of technology (see Department of Education, 1997). Universities differ from one another with respect to the funding of their research function. It is generally assumed that members of the teaching staff spend approximately 20% of their time on R&D work. The higher education sector accounts for 23% of research expenditure and 33% of full-time equivalent (FTE) human resources engaged in research. There are approximately 50 000 postgraduate students enrolled at South African universities. In 2003, HEIs produced some 3 500 publications (see also Section 5.1).

The governance structures of South African universities are regulated at a high level by the Higher Education Act (Act No. 101 of 1997), which sets the statutory governance framework for all universities. Each university has an approved statute that enables it to function as a public university and to promote effective management. At an institutional level, the university council, is empowered to govern the institution, while the powers of senate include the academic and research functions. Although not necessarily specified in the Higher Education Act and statutes, all universities produce annual reports and most also publish R&D and innovation

[28] For more information, see www.nrf.ac.za/evaluation/Content/About/About.htm.

reports. In terms of the new governance framework for R&D, it is expected that the Department of Education and the DST may have to revisit their respective roles. Work is thus in progress to develop “an institutional mechanism for the integration of Higher Education Research by the Department of Education and the DST” (DST, 2005d: 11).

The HEIs face a number of challenges within the present system (Council on Higher Education, 2004). Firstly, the combined effects of financial constraints on public expenditure on the one hand and higher performance expectations on the other are shifting the institutions away from their original and traditional roles. At least in theory, universities are the main South African locations of fundamental and basic research and postgraduate education; universities of technology are associated with industry-specific applied research; and PRIs predominantly undertake national mission-oriented or strategic research, with a market-focused approach. However, this picture is undergoing dynamic transformation because of financial constraints. The missions are perceptibly changing as both universities and PRIs increasingly seek and access private and international donor funds – a process that is referred to as ‘mission creep’ within the NSI.

Secondly, the higher education sector is the nexus of the reorganisation of institutions through mergers (with higher education institutions consequently reduced from 36 to 23). There has been a sharp growth in student numbers (from 522 658 in 1994 to almost 718 000 in 2003). The higher education sector is a key player in addressing the goals of racial equity in a post-apartheid South Africa (see Section 7.4 for further details). The compound effect of these three forces has been to create considerable stress on the productive capacity of the system, with academics being pushed to conduct original research, seek external income and undertake research. This challenge is partly reflected in the output statistics (see Section 5.1). Although the absolute number of research publications has grown over the last ten years, South Africa’s share of world production declined from 0.57% in 1990 to 0.48% in 2003.

3.5.2.2 Public Research Institutions

There are currently 12 major PRIs, which are exclusively R&D performing institutions, with the exception of the Medical Research Council, which also has an agency function (see Section 3.5.1). The first and largest PRI, the Council for Scientific and Industrial Research, was established in 1945, although the model dates back to the mid-1930s in certain other Commonwealth countries. The other PRIs are the Agricultural Research Council, the Human Sciences Research Council, Mintek (for minerals processing research), the Medical Research Council, the South African Bureau of Standards, South African Weather Services, the Council for Geoscience, the South African National Energy Research Institute, the South African National Biodiversity Institute, the Marine and Coastal Management division (a division of the Department of Environmental Affairs and Tourism) and the Africa Institute of South Africa. In principle, the funding of the PRIs consists of a Parliamentary component (on average 50% of the total budget of the institution) and income generated through contract activities, which accounts for the rest of their budgets. The most recent

National R&D Survey shows that science councils[29] accounted for 17.3% of total national expenditure on R&D and employed 23% of the total FTE R&D workforce.

Each PRI is mandated by an Act of Parliament to undertake R&D to the benefit of the country (examples of specific Acts are given in Appendix A). The governance structure of most PRIs comprises a board and the chief executive officer, appointed by the relevant Minister, who also approves the business plan and annual report. (A new political governance instrument, being introduced in 2006, is a compact between the PRI and the relevant Minister, essentially committing the institution to execute its approved business plan, especially the performance targets approved by the Minister.) The board is responsible for standard governance functions such as determining institutional policies, objectives, budget and the submission of an annual report to Parliament though the relevant Minister.

3.5.2.3 Business Sector

The business sector is the major performer and funder of R&D in South Africa (see Section 4.2). It is also the location of most innovation in the NSI and is thus the most important actor with respect to the translation of new knowledge into novel goods, services and processes (see Section 5.5). In this section, the most significant components of the business sector are covered briefly; in other sections, R&D expenditure and innovation activities are covered in more detail.

In-house R&D in the business sector accounts for 58% of total national R&D performance and 45% of expenditure (see Section 4.2). The business sector also accounts for 25% of all R&D workers employed. Manufacturing is the largest component of the business sector, and by far the largest contributor to R&D expenditure (accounting for 44% of total business sector expenditure on R&D).

In the past, certain components of the sector were well supported by government, especially within certain strategic sectors, such as energy (Eskom, Atomic Energy Corporation and Sasol), defence (Armscor) and mining. Although much of this highly focused funding has been terminated, ongoing support for business R&D remains high on the policy agenda, to the extent that the importance of business is referred to in almost all NSI policies. This general statement is supported by a higher education policy that encourages cooperation between universities and business (Council on Higher Education, 2004), while the *White Paper on S&T* and the *National R&D Strategy* emphasise the strategic position of innovation as a link between research and business.

[29] The following institutions are categorised as science councils: Africa Institute of South Africa, Agricultural Research Council, Council for Scientific and Industrial Research, Council for Geoscience, Human Sciences Research Council, Medical Research Council, Mintek, National Research Foundation and South African Bureau of Standards. Because the science councils include both research-performing and research-funding institutions, the collective term 'public research institution' (PRI) is used in this report to distinguish research-performing institutions as a collective group (see footnote 24). All the science councils, with the exception of the National Research Foundation, are classified in this report as both science councils and PRIs.

3.5.3 Bridging Bodies and Policy Advisory Bodies

Bridging bodies exist in both the higher education and the PRI sectors (namely the Higher Education Association of South Africa and the Committee of Heads of Organisations of Research and Technology). While these bodies do not have statutory authority in the NSI, each individually represents a functional and productive forum for addressing challenges common to the institutions in that sector and the formulation and communication of a common position to government.

Three statutory bodies are mandated to advise government on policy issues. The National Advisory Council on Innovation (NACI) advises the Minister of Science and Technology, proactively and reactively, on matters concerning innovation. The larger Council on Higher Education advises the Minister of Education on all higher education matters and, through its Higher Education Qualifications Committee, also evaluates and accredits university teaching programmes. The Academy of Science of South Africa, like similar bodies in industrialised countries, promotes common ground in scientific thinking across disciplines and can, proactively and reactively, provide expert, technical and scientific advice to government (further information on all the above institutions can be obtained from the relevant legislation and annual report, which are listed under *Acts* and *Annual Reports* in Appendix A). It is also noted that legislation is currently being prepared to pave the way for a statutory South African Engineering Academy, to be established in 2007.

3.5.4 Other Institutions

Finally, there are three classes of R&D bodies that should be listed in this section. Firstly, there are the academies (the Academy of Science of South Africa, with its statutory dual role as an Academy and an advisory body to government [see Section 3.5.3], the Engineering Academy, the South African Academy of Science and Arts and the Royal Society of South Africa),[30] as well as non-governmental bodies such as the National Science and Technology Forum, which are at least partly funded by government and are involved in research, coordination of research bodies, policy advice and related activities. Their research activities are self-initiated and the resultant outputs are normally intended for the public domain or to assist the government in policy formulation. The National Science and Technology Forum is a multi-stakeholder body, consisting of representatives of eight major constituencies, namely education, business, government, civil society, PRIs, labour, non-governmental organisations, and state corporations. It meets with the Minister of Science and Technology from time to time to discuss and negotiate important S&T policies and programmes.

A second category of R&D bodies that should be listed here comprises a range of other public R&D units that have been established by government departments to serve functions integral to their core functions, including the National Health Laboratory Services (administered by the Department of Health) and the Water Research Commission (a funding agency reporting to the Department of Water Affairs and Forestry). These units are mostly governed and funded by the relevant department and managed by specially appointed staff. Their R&D outputs are

[30] The Academy of Science of South Africa is currently the only statutory academy in the country.

intended primarily for utilisation by the line department and only secondarily for the general public.

A third class of ‘other’ R&D performance units comprises dedicated and special R&D programmes, which are launched by a government department that governs them in important respects, but are located or embedded in one or more of the universities or PRIs. The following list gives an idea of the range within this category: Advanced Manufacturing Technology Strategy, Advanced Metals Initiative, National Laser Centre, Meraka Institute (for ICT), Biotechnology Regional Innovation Centres, South African AIDS Vaccine Initiative, South African Bioinformatics Initiative, Automotive Industry Development Centre, Innovation Hub, South African Centre for Epidemiological Modelling and Analysis, South African Malaria Initiative, and the S&T centres of Armscor. It is estimated that the total budget of these units was approximately R500 million (PPP US$ 192 million) in the 2004/05 financial year.

3.6 Intellectual Property Rights

In comparison with other countries, South Africa has not substantially improved its performance in local or international patenting over the last decade (see Section 5.3). Analysis of the patent patterns for South African institutions shows very low levels of patenting by publicly funded institutions. Moreover, South African PRIs and HEIs have had fairly weak policies and programmes with respect to patenting publicly funded research.

In response to this situation, discussion has taken place among key stakeholders and role-players regarding intellectual property protection and publicly funded R&D, particularly in the context of patents. As a result, a new *Framework for Intellectual Property Protection* (DST, 2006a) has been developed and is currently in the final phase of consultation prior to formal adoption by Cabinet.

The following are some of the aspects addressed in the draft framework:

- Benefit distribution from successful commercialisation
- The obligation of inventors using public funding to declare potential inventions
- Granting the right to institutions to secure income from commercialisation of publicly funded R&D
- Institutional support structures and arrangements
- Identification of preferred licensees, such as small and medium enterprises, black economic empowerment and South African firms
- Criteria to determine the relationships between parties in relevant collaborative R&D.

In the initial formulation of this framework, a range of stakeholders were assessed in relation to their work along the value chain. It was found that existing programmes could be clustered into three main areas, namely capacity building, funding and business services, and policy interventions:

- With respect to capacity building, a number of groups have implemented high-level training programmes on issues pertaining to intellectual property.

- In the area of funding, business and intellectual brokering services, the DST (through the Innovation Fund) has set up an Innovation Fund Commercialisation Office, which is responsible for disseminating a Patent Wholesale Fund through the accreditation of Intellectual Property Management Offices. This office provides financial incentives for high-quality patents secured from publicly financed research. The title to such patents is held by the public institution. The office also co-finances patent costs arising from publicly financed research in universities and PRIs. This financial support is linked to strict performance requirements.
- At policy level, the DST (together with NACI and other role-players) has led discussions for a proposed South African framework for intellectual property rights. South Africa has also participated in global reviews of good practice, in particular through its membership of the OECD Committee for Science and Technology Policy.

In this section, it may be worth noting that South African policy-makers and institutions are actively responding to emerging international intellectual property issues, as shown in the following paragraphs:

- *Open source and open access.* The CSIR/DST-funded Meraka Institute is spearheading the open source movement in South Africa. A working group is addressing intellectual property in the context of open access.
- *Biotechnology and the health sector.* The DST has a working group in place to explore the issue of bioethics. Within this, the aspect of intellectual property rights and patenting is further explored. The pharmaceutical and drugs licensing spectrum in the context of 'public interest' will also be addressed in this area.
- *Indigenous knowledge systems (IKS) and traditional medicines.* South Africa, through the DST, is currently exploring the patenting and protection of traditional knowledge through the IKS working group.
- *Plant breeders rights* have emerged from the stakeholder discussions on the policy framework and can be expected to be pursued further with the Department of Agriculture.

At the institutional level, the following are being pursued in line with international trends:

- *Patent mapping* activities to look at sector and geographic strengths in order to assess economic activities. This is being done through the Innovation Fund Commercialisation Office.
- *Patent clubbing and pooling*. South African PRIs and tertiary education institutions are exploring potential pooling of intellectual property.

In addition to the development of a policy framework for the protection of intellectual property, a NACI-supported intellectual property audit, outlining and assessing the work of various role-players in this area of the NSI, is being undertaken. The audit will highlight a number of issues, including intellectual property management systems, institutional programmes, funding allocated for patenting and commercialisation activities, and capacity-building initiatives. Once the audit is complete, an evaluation report, highlighting both strengths and weaknesses in the present system, will be undertaken. The audit is due for completion during 2006.

Chapter 4: Inputs of the NSI

4.1 The National R&D Survey

In the previous chapter, the main institutions of the NSI and the governance/policy framework within which these institutions operate were described. In this chapter, the inputs to the system in terms of both funding and human capital are considered in some detail. The data are drawn from a number of sources, of which the *National R&D Survey* and the *Innovation Survey* are the most important.

National R&D surveys are essential in any country's efforts to exploit the potential of innovation to improve the welfare (both economic and social) and quality of life of its citizens. As a result, such surveys have been used over a long period to measure both the inputs to and outputs of a national R&D system. South Africa is no exception; R&D surveys in the country date back to the early 1960s. As from 2001, these surveys have been undertaken by the Human Sciences Research Council (HSRC), Centre for Science, Technology and Innovation Indicators (CeSTII) and follow the format and scope specified in the *Frascati Manual* (OECD, 2002c).

It should be noted that the South African S&T indicators are part of the DST's long-range strategic and operational planning. The DST regularly reviews the scope, methodology and data integrity of the survey in order to improve its utility and compliance with international standards. Much of the expertise to undertake the surveys now resides within the HSRC, which also assists the DST in training its staff in this field and in managing the S&T indicators programme.

4.1.1 National and OECD Accreditation

Following the release of the 2001/02 survey, it was agreed at Cabinet level that the Minister of Science and Technology should interact with Statistics South Africa in order to bring the *National R&D Survey* within the official national statistics portfolio. These interactions and discussions led to the signing of a memorandum of understanding between Statistics South Africa and the DST, setting out the framework for achieving this incorporation and resulting in data from the *National R&D Survey* being adopted as part of the country's official statistics in 2005.

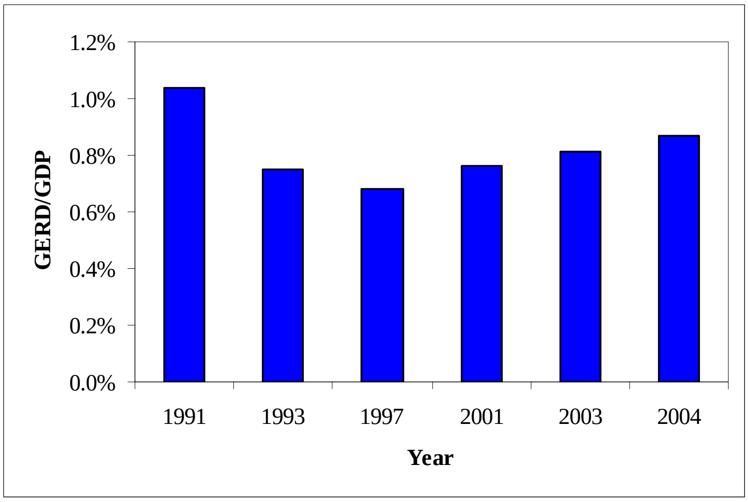
In 2005, South Africa made a successful submission to the OECD's National Experts on Science and Technology Indicators to have the South African data on R&D included in its *Main Science and Technology Indicators* publication.

4.2 An Overall Summary of R&D Expenditure

According to the 2004/05 survey, South Africa's gross expenditure on R&D (GERD) was R12.0 billion (PPP US$ 4.6 billion),[31] or 0.87% of gross domestic product (GDP), which represents an improvement on the equivalent 2003/04 figure and is part of a longer-term increase from the low of 1997, when expenditure of R4.1 billion (PPP US$ 2.3 billion) (0.69% of GDP) was recorded (see Figure 4).

[31] The Rand-equivalent US dollar amount is presented to indicate purchasing power parity (PPP).

Figure 4. GERD as a percentage of GDP (1991–2003)[32]



The GERD data are an interesting reflection on the change in national policy priorities in the period 1991 to 1997, during which support for the military-industrial complex, particularly support for its R&D needs through government funds, was significantly downscaled. This change has been extensively documented (Blankley & Kahn, 2005).

In recent years, the government has sought to reverse the GERD decline, and as indicated in Section 3.4.2, adopted the *National Research and Development Strategy* in 2002, which aims to double government investment in S&T by 2008 and increase the GERD/GDP ratio to at least 1%. Reaching this target will put South Africa in the same league as Brazil, New Zealand, Spain and the Czech Republic, but still far below the OECD average and that of countries such as Sweden and the US (see Figure 5).

The business sector in South Africa is the major performer and financer of R&D in the country, funding 45% and performing 58% of total R&D. The higher education sector undertakes 21% of all R&D, and government performs 21% but finances 33% of total R&D. About 15% of South Africa's R&D is funded from international sources (see Figure 6 and Table 13) and 6% by the non-governmental sector. Much of the foreign funding for local business R&D comes from parent or associated private sector firms and organisations abroad, while foreign funding for R&D within PRIs and HEIs is derived from a number of competitive public funds such as the European Union Framework Programmes, the Ford Foundation, the National Institutes of Health, various United Nations and World Bank programmes and funding for bilateral and multilateral S&T agreements managed through the DST and its counterparts abroad.

[32] Data obtained from the National R&D Surveys (DST, 2004d, 2005a, 2006c).

Figure 5. Country comparison of GERD/GDP[33]

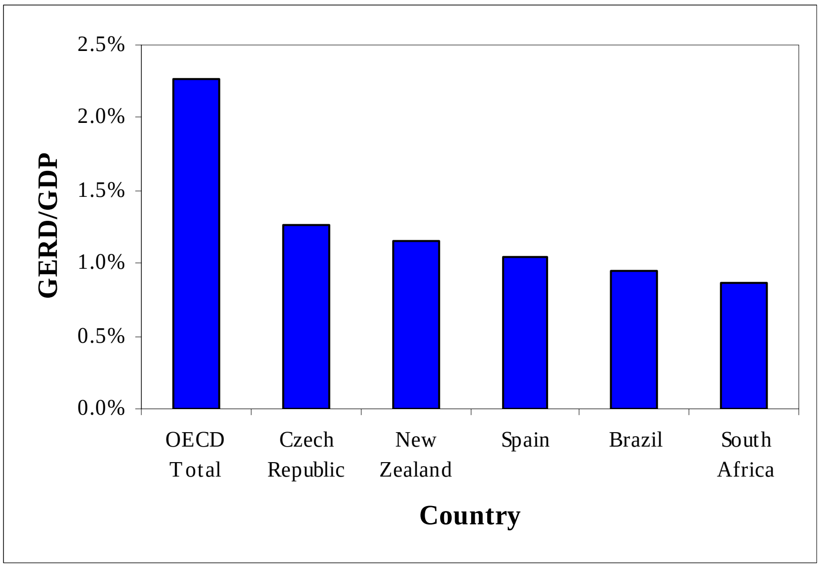
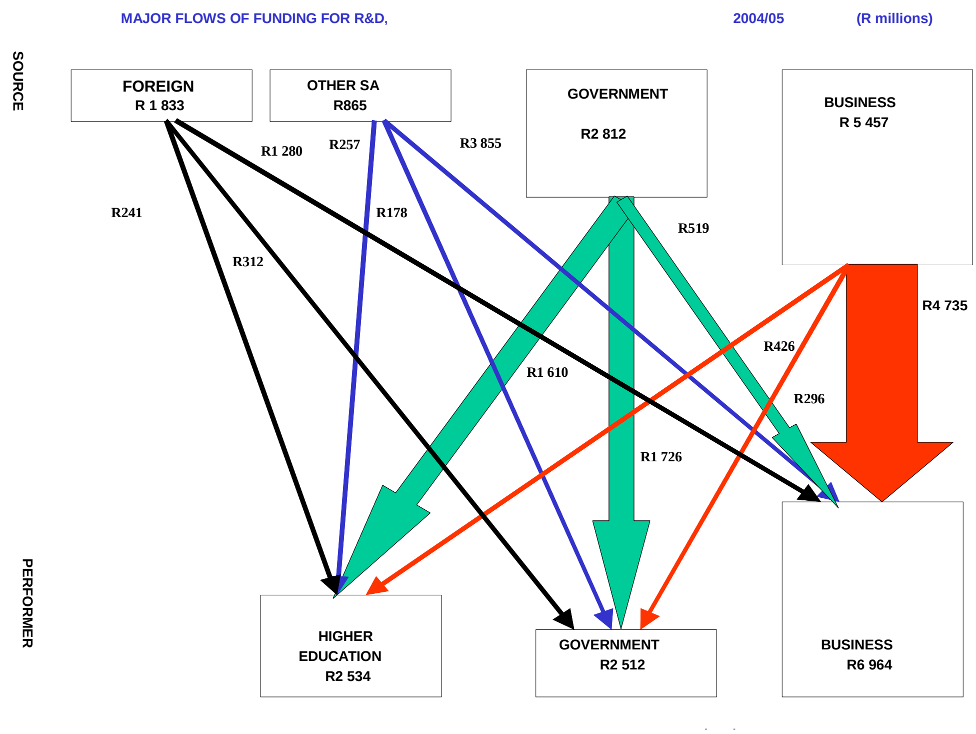


Figure 6. Major flows of funding for R&D (2004/05) (R million)[34]



33 As for 2003 (OECD, 2006).
34 Data obtained from the 2004/05 *National R&D Survey* (DST, 2006c).

Table 13. Major flows of funding for R&D (R million) [35]

		R&D Performer			
		Business	Government	Higher Education	Total
R&D Funder	Business	4 735	296	426	5457 (45.4%)
	Foreign	1 280	312	241	1833 (15.3%)
	Government	520	1 727	1 710	3957 (33.0%)
	Other	430	176	157	763 (9.1%)
	Total	6 965 (58.0%)	2 511 (20.9%)	2 534 (21.1%)	12 010

Major flows of funding for R&D (PPP US$)

		R&D Performer			
		Business	Government	Higher Education	Total
R&D Funder	Business	1 821	114	164	2 099
	Foreign	492	120	93	705
	Government	200	664	658	1 522
	Other	165	68	60	293
	Total	2 679	966	975	4 619

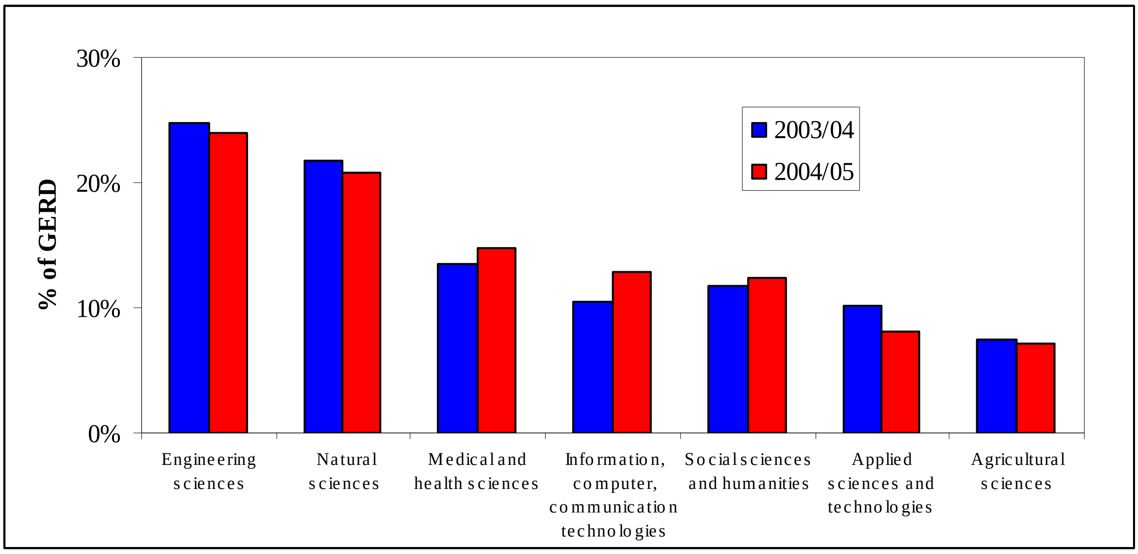
Strong basic research within a national system of innovation is important for a number of reasons, including training new researchers and generating new fundamental knowledge that feeds the subsequent categories of applied research and experimental development. According to the 2004/05 R&D Survey (DST, 2006c), 18.6% of GERD is devoted to basic and strategic basic research. The main sources of this funding are the Focus Area Programmes of the National Research Foundation and the research grants administered by the Department of Education. Historically, much of South Africa's basic research has been in the areas of natural resources and the environment, especially the biological sciences and the exploitation of natural resources (such as mining, fishing and agriculture).

Strong applied research and experimental development are similarly important, since these activities play an essential role in the translation of new knowledge into innovative processes, goods and services that can contribute to economic development and improved quality of life. Further detail on the funding of these categories is presented in subsequent sections.

R&D expenditure by major research field is shown in Figure 7; social sciences and humanities are a relatively small proportion of the total expenditure, whereas the allocation to information, computer and communication technologies is rising.

[35] R&D performers: Government includes science councils; Business includes not-for-profit.
Source of funding: government includes higher education, agency funding and science councils.

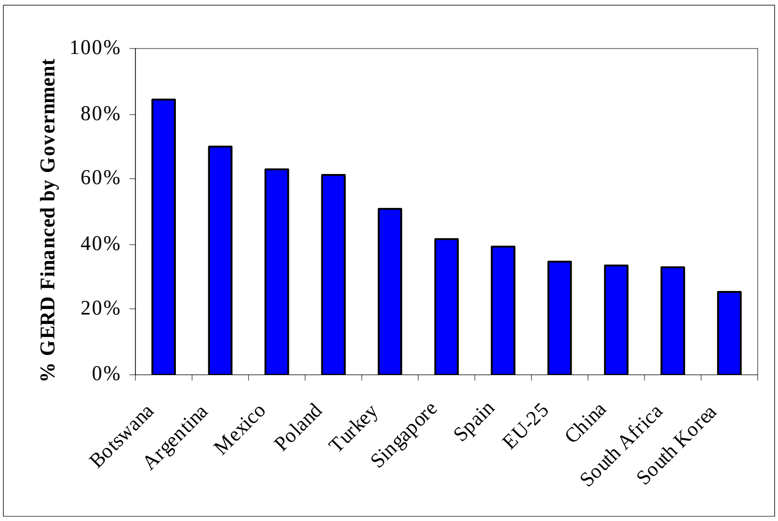
Figure 7. Expenditure on R&D by major research field[36]



4.3 Government R&D Expenditure and Allocation

Government funds 33% of all R&D in South Africa, which is in the lower quartile for developing countries and almost the same as the OECD average (OECD, 2004), as shown in Figure 8.

Figure 8. Government funding of R&D as a percentage of GERD



[36] Data obtained from the 2004/05 *National R&D Survey* (DST, 2006c).

More detail on each funding stream is now provided.

4.3.1 Promotion of R&D in the HEIs

Higher education in South Africa is funded mainly through a grant from the Department of Education (based on performance), fee income from students supplemented by the National Student Financial Aid Scheme and other sources of funding, including income from foundations and contract research. Roughly 50% of the funding of HEIs is from government, but this percentage differs between institutions. The estimate of total expenditure per student is therefore double the figures in Table 14.

It can be seen from Table 14 that government expenditure per FTE student decreased in nominal terms between 1995 and 2001. Government expenditure on higher education as a percentage of GDP has declined, from 0.81% in 1999 to 0.72% in 2003.

Table 14. Government expenditure on higher education (1995 to 2003)[37]

Year	Expenditure per student (PPP US$[38]/FTE student)	Expenditure per student (R/FTE student)	Total expenditure (% of GDP)
1995	6 790	10 847	0.72
1996	n.a.	n.a.	0.82
1997	7 259	13 043	0.78
1998	n.a.	n.a.	0.80
1999	8 484	17 098	0.81
2000	8 311	17 839	0.77
2001	7 683	17 202	0.75
2002	5 917	14 467	0.72
2003	n.a.	n.a.	0.72

Similarly, a comparison with 18 representative countries from all continents shows that higher education in South Africa is relatively under-funded (see Table 15).

Table 15. Higher education expenditure in comparison with other countries[39]

	Higher education expenditure (% of Total)	
Budget item	**South Africa**	**Other countries**
State budget	2.7	3.3
Education budget	20.6	22.1
GDP	0.72	1.1

The principal source of funding for basic research at HEIs is the National Research Foundation, which administers the following programmes (it should be noted that the programmes are often jointly funded and managed):

[37] Data obtained from the Council on Higher Education (2004: Tables 2 and 24).
[38] See Appendix D for conversion rates.
[39] Data obtained from the Council on Higher Education (2004: 195).

- The Research and Innovation Support Programme, which is aimed at supporting self-initiated or proposal-driven research within one of nine Focus Areas, namely Advancing Strategic Knowledge, Distinct South African Research Opportunities, Ecosystems and Biodiversity, Economic Growth, Education and the Challenges for Change, Indigenous Knowledge Systems, Information and Communication Technologies, Socio-political Impact of Globalisation, and Sustainable Livelihoods and the Eradication of Poverty
- The Innovation Fund and the Technology and Human Resources for Industry Programme, which focus on the innovation end of the research and innovation value chain (see Section 4.3.3.1 for further details)
- A selection of other ring-fenced programmes, which the National Research Foundation administers on behalf of the DST, including the Scarce Skills Development Fund, the Indigenous Knowledge Systems Fund, the S&T Agreements Fund (associated with international S&T agreements) and the South African National Antarctic Programme
- The Research Chairs Programme, which supports the establishment and funding of research chairs at universities. The chairs are intended to attract new but experienced researchers into universities by providing suitable incentives. It is anticipated that the programme will also lead to an increase in the production of high quality postgraduates, scientific publications and new discoveries that can be further developed into high-value products and services.
- Centres of Excellence, which are either physical or virtual centres of research, concentrating existing capacity and resources to assist researchers in collaborating across disciplines and institutions on long-term projects. The projects are highly relevant to local needs and are intended to improve both research excellence and capacity development in South Africa.
- Funding of special R&D capacity development programmes for the benefit of historically disadvantaged students.
- Initiating, commissioning and funding public understanding of science and technology projects.

In addition to its funding mandate, the National Research Foundation also governs and manages seven national research facilities, most of which are large facilities containing expensive infrastructure and equipment and are accessible to outside researchers. The existing national research facilities are the South African Astronomical Observatory, the Hartebeesthoek Radio Astronomy Observatory, the Hermanus Magnetic Observatory, the South African Institute of Aquatic Biodiversity, the South African Environmental Observation Network, the National Zoological Gardens and iThemba Laboratories (the latter refers to the reconfigured facilities of the former National Accelerator Centre).

The National Research Foundation is not the only public sector funder of R&D within HEIs. For instance, the DST directly funds and administers the Innovative Post-doctoral Programme, which is aimed at supporting the development of research capacity within HEIs (as well as PRIs). The programme supports outstanding doctoral graduates in obtaining research experience at a university in partnership with a PRI, with the aim of securing a supply of highly qualified South Africans with leading-edge scientific and research skills for South African universities, PRIs, industry and government.

4.3.2 Promotion of R&D in the PRIs

As mentioned in Section 3.5.2.2, the PRIs form a significant component of the public sector performance of R&D. The PRIs and public research funding agencies are funded through both grants and contracts, with parliamentary grant allocations exceeding R1.6 billion (PPP US$ 0.6 billion) and an additional income of over R2.2 billion (PPP US$ 0.87 billion) from contracts, including contracts from the public and business sectors (see Table 16).

Table 16. Grant allocations and contract income to the PRIs and the National Research Foundation (2004/05)[40]

Council	Line Department	Grant Income (R1 000s)	Contract Income (R1 000s)
Council for Scientific and Industrial Research	DST	366 326	674 410
South African Bureau of Standards	Trade and Industry	99 242	334 545
Mintek	Minerals and Energy	88 632	167 160
Council for Geoscience	Minerals and Energy	77 606	43 238
Agricultural Research Council	Agriculture	320 708	237 539
Medical Research Council	Health	155 726	179 452
Human Sciences Research Council	DST	70 562	116 591
National Research Foundation	DST	413 669	500 639
Africa Institute of South Africa	DST	16 325	4 669
Total		**1 608 796**	**2 258 243**

Grant allocations and contract income to the PRIs and the National Research Foundation in PPP US$

Council	Line Department	Grant Income (PPP US$ 1 000s)	Contract Income (PPP US$ 1 000s)
Council for Scientific and Industrial Research	DST	140 818	259 248
South African Bureau of Standards	Trade and Industry	38 149	128 601
Mintek	Minerals and Energy	34 071	64 257
Council for Geoscience	Minerals and Energy	29 832	16 621
Agricultural Research Council	Agriculture	123 282	207
Medical Research Council	Health	59 862	68 983
Human Sciences Research Council	DST	27 125	44 818
National Research Foundation	DST	159 017	192 449
Africa Institute of South Africa	DST	6 275	1 795
Total		**618 432**	**868 083**

4.3.3 Promotion of Business R&D

Three main sets of instruments are available for supporting business R&D, namely funding in direct support of R&D projects (the Innovation Fund, the Technology and Human Resources for Industry Programme and the Biotechnology Regional Innovation Centres), funding for technology transfer and similar initiatives (Godisa

[40] Data from the Key Performance Indicators Reports for the PRIs.

and Tshumisano trusts) and indirect support through tax rebates. These instruments are briefly reviewed in the following sections.

4.3.3.1 Funding in Direct Support of R&D Projects

A summary of government expenditure in direct support of the main R&D funding instruments is given in Table 17. It should be noted that most of these programmes have been introduced only since 1997 (following the adoption of the *White Paper on Science and Technology*). Further details on each scheme, together with information on other instruments, is given in the remainder of this section.

Table 17. R&D funds allocated through government programmes

	Funds Allocated (R million)	
Funding Instrument	**2003/04**	**2004/05**
Technology and Human Resources for Industry Programme	163	135
Innovation Fund	161.5	171.3
Support Programme for Industrial Innovation	83	83
Sector Partnership Fund	15.5	13
Competitiveness Fund	22	30

R&D funds allocated through government programmes in PPP US$

	Funds Allocated (PPP US$ million)	
Funding Instrument	**2003/04**	**2004/05**
Technology and Human Resources for Industry Programme	65.1	51.9
Innovation Fund	64.5	65.8
Support Programme for Industrial Innovation	33.2	31.9
Sector Partnership Fund	6.2	5.0
Competitiveness Fund	8.8	11.5

Innovation Fund

The Innovation Fund was established by the DST in 1998 to give effect to the policy imperative of supporting innovation development (by linking knowledge creation and its subsequent commercialisation). In essence, it caters for applications ranging from the proof-of-concept phase to full commercialisation. It functions on an open-call basis (although it also manages a top-down component), albeit with a preference for topics aligned with the *National R&D Strategy* and *Advanced Manufacturing Technology Strategy*, is open to applications from both private and public sector institutions and is administered by the National Research Foundation on the basis of standard peer review mechanisms. The Innovation Fund has, since its inception in 1998, awarded a total of R714 million (US$ 319 million) to 108 large-scale projects. Its budget for 2006/07 is R128 million (PPP US$ 49 million).

Apart from its funding programmes, the Innovation Fund also manages two downstream services that provide financial and intellectual property support. The first is the Commercialisation Office, which subsidises certain patent and/or commercialisation costs; the other service is the Intellectual Property Management Office, which promotes a culture of intellectual property protection.

Technology and Human Resources for Industry Programme

The Technology and Human Resources for Industry Programme (THRIP) is a joint programme established by the Department of Trade and Industry and the National Research Foundation in 1991. THRIP focuses on technology development by producing highly skilled researchers and technology managers who understand research, technology development and the diffusion of technology from the perspectives of both industry and academia. Specific priorities include increasing the numbers of black and female students, promoting technological know-how in small, medium and micro enterprises (SMMEs) and enhancing the competitiveness of black economic empowerment. Funding is limited to South African HEIs and government science, engineering and technology institutions (SETIs), and industrial partners can leverage funding for projects through partnerships with HEIs and SETIs. The programme supports public–private research collaboration on a cost- and risk-sharing basis on a default R2:R1 basis. The evaluation of applications follows standard peer-review approaches. The budget for the 2006/07 financial year is R151.6 million (PPP US$ 58 million). A review of the programme in 2001 concluded that it could generally be commended for having attained most of its strategic targets.

Support Programme for Industrial Innovation

The Support Programme for Industrial Innovation (SPII), which is funded by the Department of Trade and Industry and administered by the Industrial Development Corporation, also addresses the innovation end of the research and innovation value chain and is aimed at supporting private sector enterprises to develop competitive products, services and/or processes. The 2004/05 budget for the SPII programme was R81 million (PPP US$ 31 million). Support for innovation activities is provided on a matching grant basis, and about 35% of the current participants are black empowerment companies. On the output side, SPII created/retained 3 145 jobs in 2004/05 and generated sales amounting to R800 million (PPP US$ 308 million), more than half of which were from exports. Companies participating in SPII had an average R&D expenditure of 13% of their sales.

4.3.3.2 Funding for Technology Transfer

The DST is the owner of two structured programmes aimed at funding the technology transfer and commercialisation process, namely the Godisa and Tshumisano trusts.

Godisa Trust and Small Enterprise Development Agency Technology Programme

The Godisa[41] programme, managed as a trust, was originally established in 2000 to create and develop small enterprises (SMMEs) through technology transfer and diffusion by means of technology-focused business centres or incubators. The trust had a budget of about R40 million (PPP US$15 million) per annum, and to date has

[41] *Godisa* means 'to grow'.

been responsible for the creation of 480 small enterprises and about 3 800 jobs. A small and medium enterprise survival rate of 84% has been achieved.

In April 2006, the Small Enterprise Development Agency (SEDA) Technology Programme was born from the merger of the Godisa Trust and the National Technology Transfer Centre. The latter was a special initiative of the Department of Trade and Industry responsible for technology transfer and business incubation. The SEDA Technology Programme seeks to contribute to economic development through the creation and support of technology business centres, which include incubators and technology demonstration centres. These centres will provide a variety of business support services and office accommodation to small enterprises.

Tshumisano Trust

The Tshumisano[42] programme, consisting of several technology stations, was established in 1999 to strengthen and accelerate interaction between universities of technology and SMMEs with regard to technological solutions, services and training. The programme is co-funded by the DST and the German GTZ, with an annual budget of R33 million (PPP US$ 13 million), and currently funds ten technology stations. Current initiatives include a biodiesel project in Limpopo province and a new incubator in the Western Cape.

Incubators of the Industrial Development Corporation

In addition to the above, three technology incubators were established in collaboration with the Industrial Development Corporation, namely the Automotive Industry Development Centre and incubators for base metals and platinum.

Venture capital

Venture capital in South Africa is not a significant source of funding for start-up and high-technology R&D-intensive enterprises, but a number of dedicated high-technology venture capital funds exist, including the South African Intellectual Property Fund (launched in 2005 and managed by Triumph Venture Capital; worth approximately R120 million [PPP US$ 46 million]; around 500 applications have been received to date), Bioventures, three funds administered by the Industrial Development Corporation and the National Empowerment Fund.

Table 18 compares the relative sizes of the private equity markets in South Africa and those in selected other countries (see NACI 2003e). South Africa appears to have a relatively sizeable private equity market (as a percentage of GDP) in comparison with selected European countries. A study currently being finalised by KPMG suggests that only about R1 million (PPP US$ 0.38 million) is actually available as venture capital (from seed funding to company expansion). It should further be noted that there is very little collaboration among venture capital funds, in contrast to, for instance, the USA, where there is clear referral and collaboration among funds.

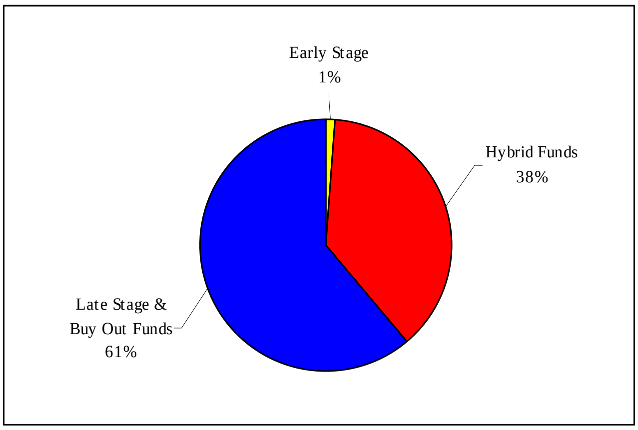
[42] *Tshumisano* means 'cooperation'.

Table 18. International private equity markets (measured by investments)[43]

Country	Amount (US$ billion)	% of GDP
USA	400.0	4.0
UK	34.8	2.5
Netherlands	6.0	1.6
Sweden	5.0	2.2
South Africa	3.7	2.9

Figure 9 shows the distribution of private equity investments for 2002 in terms of the purpose of the funds. Only 1.2% of the total amount was directed for 'early stage' business. 'Early stage' funds in the USA normally constitute between 2% and 4% of the funds disbursed by private equity investors.

Figure 9. Distribution of private equity investment, by purpose of funds (2002)[44]



4.3.3.3 Indirect Funding through R&D Tax Incentives

In addition to technology development and promotion programmes, the government has indicated its commitment to increasing private sector investment in R&D and promoting technological innovation. A study was commissioned in 2005 to assess the suitability of fiscal incentives as tools for encouraging increased private sector levels of expenditure on R&D. The outcomes of the study were presented to the National Treasury in order to motivate the implementation of some form of fiscal incentives for R&D. In the 2006 Parliamentary budget speech, it was announced that companies would be allowed a 150% tax deduction on their R&D expenditure, as opposed to the current level of 100%. The scheme will be implemented once the necessary regulations have been finalised.

4.3.4 Promotion of Linkages between Performing Agencies

The *White Paper on S&T* recognised the advent of Mode 2 knowledge production, and hence the importance of strong inter-institutional linkages. The development of

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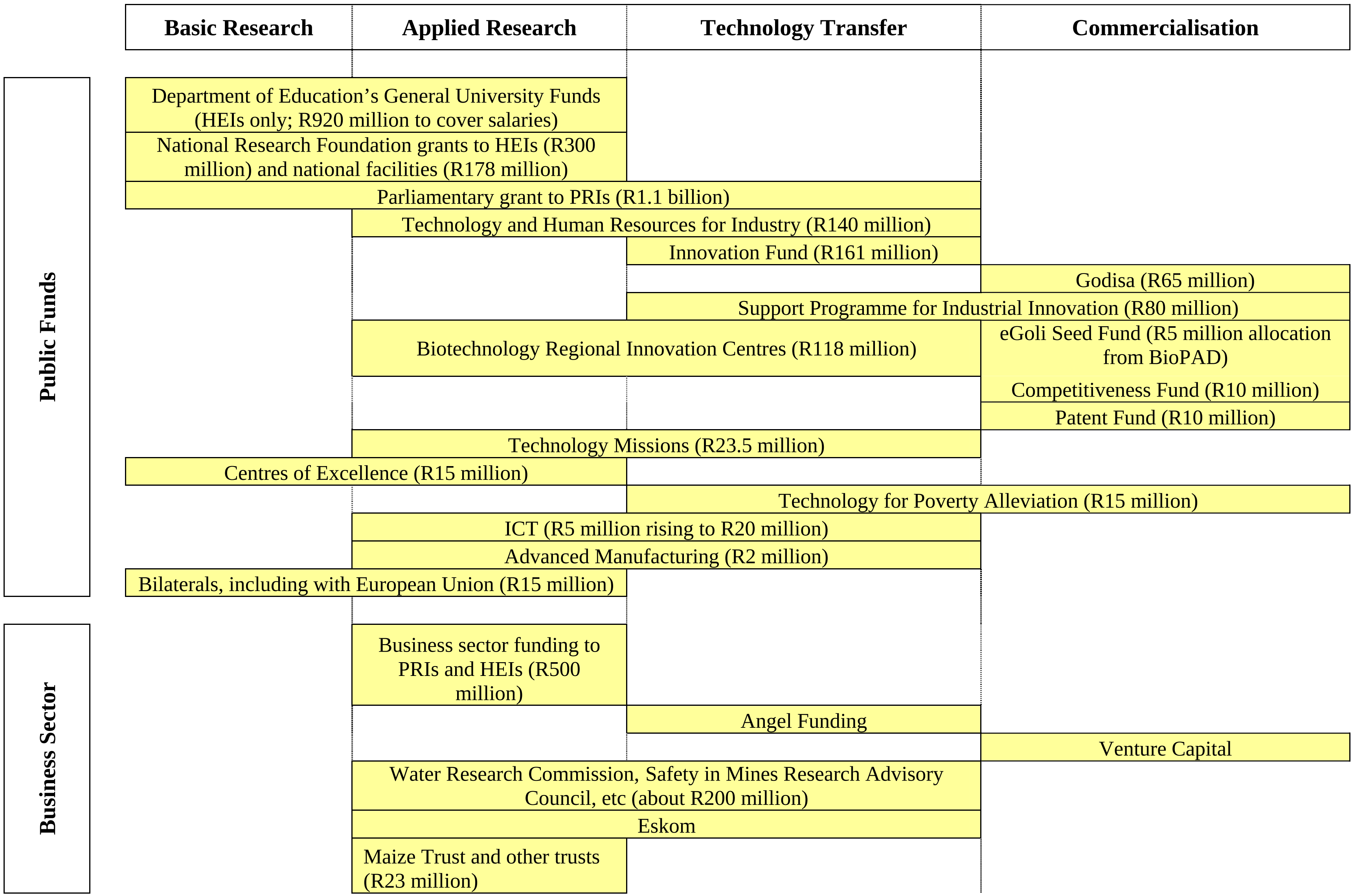
[43] Data from KPMG & SAVC (2003). The South African data are for 2002 and the data for other countries for 2001.

[44] Data from Science Consultancy Enterprises (incorporating data from South African Venture Capital Association and the NSF).

such linkages is thus supported and encouraged through many of the programmes described, including the Technology and Human Resources for Industry Programme and the Innovation Fund. Linkages with the systems of innovation in other countries have been developed through initiatives in terms of bilateral and multilateral agreements.

In concluding this section, a summary of the overall funding for R&D and innovation in South Africa is shown in Figure 10.

Figure 10. Funding for R&D and innovation in South Africa (2003/04)



4.4 Business R&D Expenditure and Allocation

The business sector is the dominant R&D actor in South Africa, funding 45% of all R&D and performing 58%. As in other countries, this R&D is focused on the near-market research categories of applied research and experimental development, which together comprise 90.5% of business R&D (see Table 19). HEIs, however, focus more on basic research, and government and its S&T performing institutions, such as the PRIs, largely play a bridging role between the universities and the private sector. This situation is very similar to that of other countries and reflects the relative roles of these sectors within modern economies.

Table 19. Business R&D expenditure by type of research[45]

Type of Research	Actual Funds (R1 000s)	% of Total
Basic Research	642 302	9.5
Applied Research	2 223 955	32.9
Experimental Development	3 900 103	57.6
Total	**6 766 361**	**100**

Business R&D expenditure by type of research (PPP US$)

Type of Research	Actual Funds (1 000 PPP US$)	% of Total
Pure basic research	246 905	9.5
Applied research	854 903	32.9
Experimental development	1 499 225	57.6
Total	**2 601 033**	**100**

R&D expenditure is heavily concentrated on the manufacturing sector, as may be expected (see Table 20), although the R&D intensity (R&D as a percentage of total value added or turnover) of all sectors is low in international terms. R&D activity is concentrated in only three provinces, namely Gauteng (61%), the Western Cape (14%) and KwaZulu-Natal (9%).

This spatial concentration of R&D may be compared to the spatial GDP contribution. At current prices, GDP rose from R618.0 million in 1996 to R1 386.6 million in 2004, with Gauteng contributing 33.3% to value added, followed by KwaZulu-Natal (16.7%) and the Western Cape (14.4%). It is apparent that R&D expenditure is not a fixed proportion of provincial GDP. Gauteng is double the national average, whereas KwaZulu-Natal is almost half; the Gauteng dominance is explained by the concentration of PRIs in the province.

[45] Data from the 2004/05 *National R&D Survey* (DST, 2006c).

Table 20. Business R&D expenditure by SIC code[46]

SIC Code	Description	R&D Expenditure (R1 000s)	% of Total
10000	Agriculture, Hunting, Forestry and Fishing	**180 008**	**2.7**
20000	Mining and Quarrying	**425 917**	**6.3**
30000	Manufacturing	**2 981 267**	**44.1**
30	Food Products, Beverages and Tobacco Products	145 848	2.2
31	Textiles, Clothing and Leather Goods	14 843	0.2
32	Wood and Products of Wood and Cork, except furniture Articles of Straw and Plaiting Materials Paper and Paper Products Publishing, Printing and Reproduction of Recorded Material	86 214	1.3
33	Refined Petroleum, Coke and Nuclear Fuel Chemicals and Chemical Products (incl. Pharmaceuticals) Rubber and Plastic Products	1 120 622	16.6
34	Non-Metallic Mineral Products	115 461	1.7
35	Basic Metals, Fabricated Metal Products, Machinery & Equipment Office, Accounting and Computing Machinery	428 409	6.3
36	Electrical Machinery and Apparatus	83 582	1.2
37	Radio, Television and Communication Equipment and Apparatus Medical, Precision and Optical Instruments, Watches and Clocks	284 803	4.2
38	Transport Equipment	697 268	10.3
39	Furniture, Recycling, Manufacturing not elsewhere classified	4 218	0.1
40000	Electricity, Gas and Water Supply	270 538	4.0
50000	Construction	483 519	7.1
60000	Wholesale and Retail	23 469	0.3
70000	Transport, Storage and Communication	325 707	4.8
80000	Financial Intermediation, Real Estate and Business Services	1 912 951	28.3
90000	Community, Social and Personal Services	162 986	2.4
	Total	**6 766 361**	**100.0**

Other aspects of note in connection with business R&D are as follows:

- The system of innovation has become increasingly open. Multinational corporations or their subsidiaries currently perform some 20% of business expenditure on R&D (BERD).
- The flow of foreign funds as a proportion of GERD has increased steadily over the last few years from 6% in 2001/02 to 15% in 2004/05. Foreign sources now comprise 18% of BERD.

[46] Data extracted from the 2004/05 *National R&D Survey* (DST, 2006c).

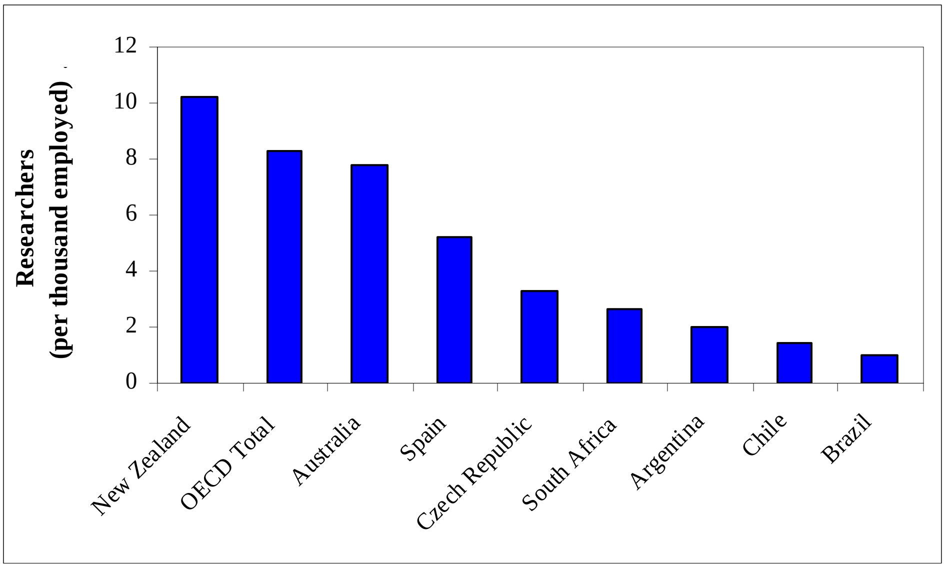
- There is strong investment in the health sciences, manufacturing and ICTs.
- 72% of all R&D takes place in large firms; only 25% takes place in SMMEs.

4.5 The Human Resource Base of the NSI

South Africa has a total of 29 692 FTE R&D personnel, comprising researchers, technicians and other support staff. Of this total, about 60% (or 17 910 FTE) is made up of the researchers or academically qualified people who manage and guide the process of undertaking research (and are classified as researchers).

While South Africa's R&D expenditure is fairly high compared with other developing countries, the total number of researchers, expressed as the number of researchers per thousand total employment, is low relative to developed countries and some of its peer countries (at 2.7 researchers per thousand employees) (see Figure 11), but higher than Chile at 1.4. In comparison, OECD countries such as Japan, Sweden and Finland have 10.2, 10.6 and 15.8 researchers per thousand employed, respectively.

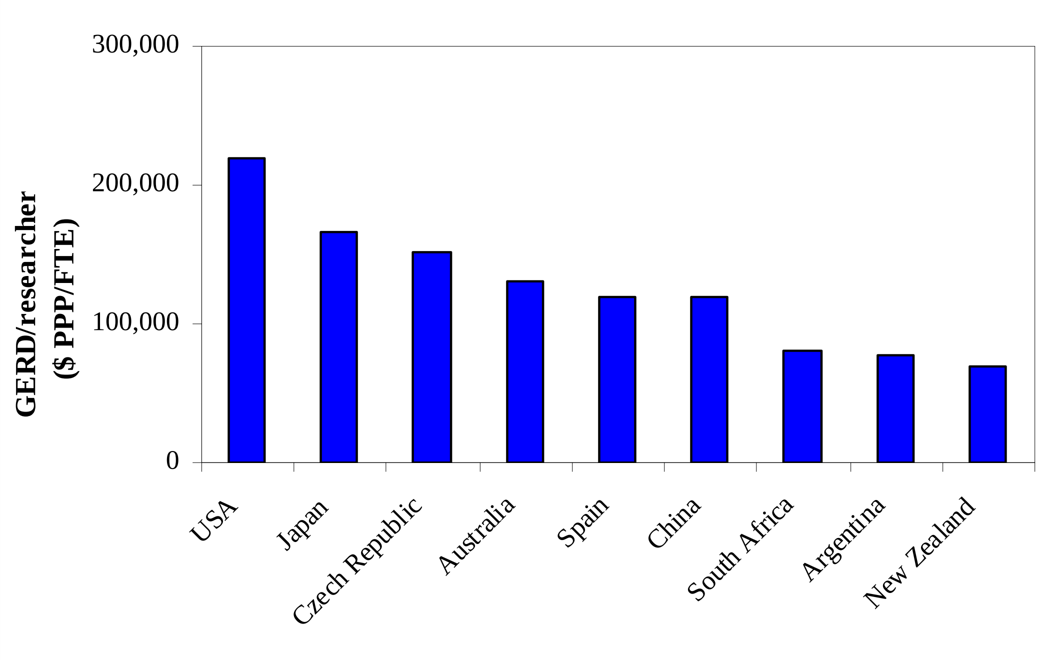
Figure 11. FTE researchers per thousand employed (2003 or latest available figures)[47]



A second aspect of the overall human resource base is the funding per FTE researcher. Using the information from Section 4.2, it is shown that this funding is low in comparison with South Africa's peer countries (see Figure 12). It is clear that South African researchers are relatively poorly funded, and although further work is required to clarify the information, it is likely that the main difference lies not in salaries but in the provision of high-quality, modern R&D infrastructure. The DST is aware of this problem and has allocated further dedicated funding of about R100 million (PPP US$ 38 million) in 2006 in order to upgrade the scientific equipment infrastructure within the country's HEIs and PRIs.

[47] Data obtained from the OECD (2006).

Figure 12. Country comparison of GERD per FTE researcher[48]



The demographic profile of researchers in South Africa is changing slowly but consistently. Women researchers now comprise 38.3% of all researchers, compared to 50.6% in Argentina, 43.3% in Russia, 11.44% in South Korea and 28.4% in Norway. The following three significant problems still remain:

- The age distribution of the R&D population, as measured by the *National R&D Survey*, peaks in the range 35 to 44; however, the average age of university researchers is ten years higher, and the profile is predominantly white male (Kahn & Blankley, 2005; NACI & DST, 2002).
- Progress towards the racial transformation of the human resource base is slow, especially at senior and experienced levels.
- The proportion of the population between the ages of 25 and 64 with a tertiary education was estimated at 4.5% in 2001, which is far below the European Union and OECD average. (Note that the present population between the ages of 25 and 64 is about 20 million.)

These problems are summarised graphically in Figure 13.

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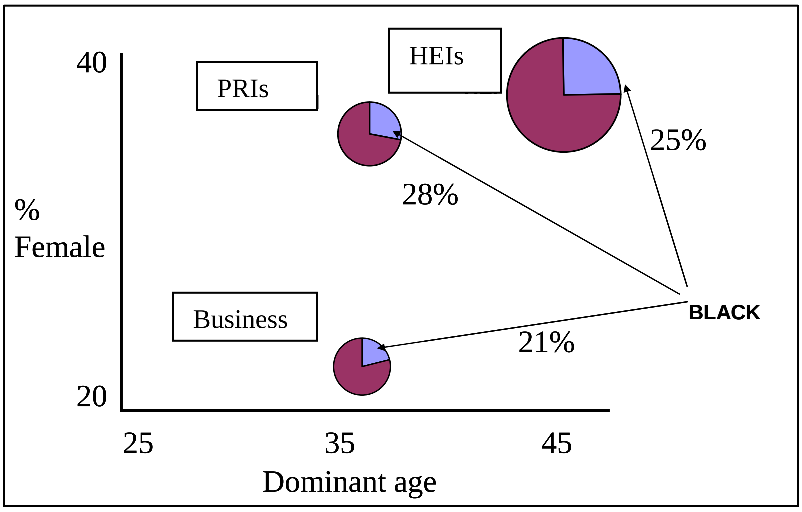
[48] Data obtained from the *OECD's Main Science and Technology Indicators* (OECD, 2004) and the 2003/04 *National R&D Survey* (DST, 2005a).

Figure 13. Demographic profile of South Africa's researchers[49]



Another indicator of the structure of human capital is the growth rate in the number of business researchers, which was 30% over the period 1992 to 2004. This number is much higher than the overall growth rate of 7% (including business, government and higher education). The number of researchers in the business sector has grown by a relatively large percentage, but this is not true for higher education and government (see Table 21). Indeed, the number of researchers in HEIs declined over the 12-year period, in contrast to the growth in the population, the total number of HEI students and the economy as a whole.

Table 21. FTE researchers by sector (1992 to 2004)[50]

Sector	**1992**	**2004**
Business	3 395	4 411
Government	2 428	2 342
Higher education	3 631	3 374
Total	**9 454**	**10 127**

Given the gradual shift of the South African economy to higher-value products and services, it is surprising that the S&T base has remained relatively static as a proportion of total employment. For instance, over the period 2001 to 2005, the number of employed graduates within the economy grew by 8.7%, but the S&T human resource base as a proportion of total employment held approximately constant over the period 1997 to 2002 (see Table 22).

[49] Figure obtained from Kahn (2006).
[50] 2004/05 *National R&D Survey* (DST, 2006c).

Table 22. S&T human resources as a percentage of total employment (1997–2002)[51]

Year	1997	1998	1999	2000	2001	2002
S&T human resources (% of total employed)	17.3	15.9	16.5	13.5	13.8	15.1

South Africa has lost a large number of researchers over the last decade through emigration. Although it is not possible to provide reliable statistics as a result of mismatches between emigration/immigration statistics and the other countries' statistics (indicating possible undercounting on the South African side), it is estimated that annual losses were of the order of 2 500 researchers per annum, while the gains were about 500 (see Table 23). A significant number of the immigrant researchers are mid- to late-career professionals from African countries.

Table 23. Emigration and immigration of the S&T workforce (1994 to 2001) [52]

Year	1994 to 1997	1998 to 2001
Human resources in S&T emigrants	7 534	9 191
Total emigrants	37 614	40 040
Human resources in S&T immigrants	3 295	1 682
Total immigrants	20 972	15 925

In conclusion, it is evident that South Africa has a comparatively low percentage of highly qualified people. The total number of researchers, expressed as the number of researchers per thousand total employment, is low by world standards. Moreover, the proportion of doctorates in science and engineering is lower than in many other developing countries. Human resources capacity building is therefore a top priority in the NSI, with some of the main challenges being:

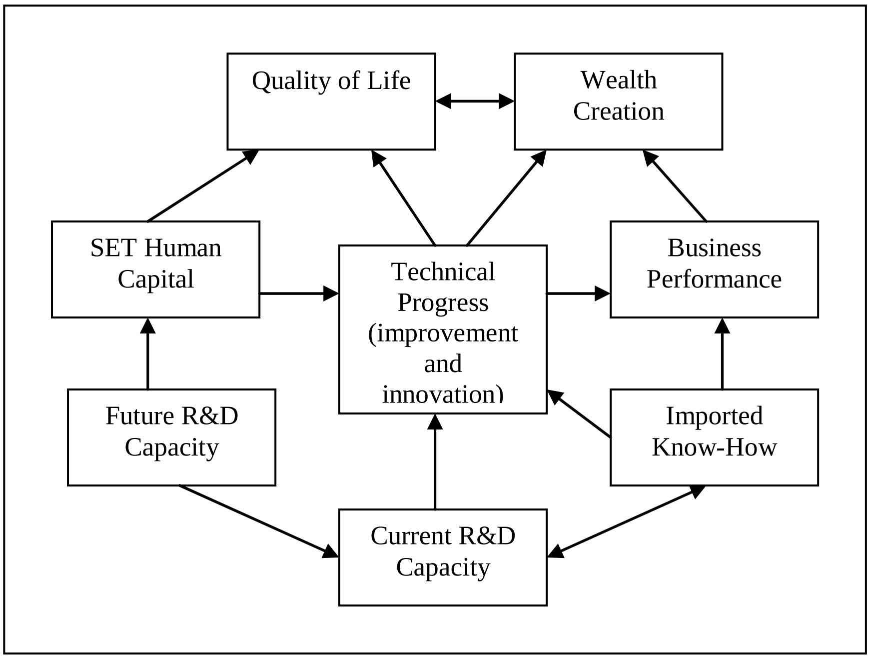
- To increase the number of enrolments in mathematics and science at schools and HEIs
- To improve matriculation pass rates with university entrance exemption, since the current rate is inadequate to meet the future needs of the country
- To increase the employment of permanent researchers at HEIs (for instance, to reverse the ongoing loss of academics with doctorates on permanent staff)
- To broaden the base of the most productive researchers, most of whom are presently either ageing or aged
- To increase the enrolment of masters and doctoral students, following the increases experienced between 2000 and 2003, including the proportion of international students (see also Section 5.2.3).

[51] Data obtained from NACI (2003c).
[52] Data obtained from Statistics South Africa Annual Migration Reports.

Chapter 5: Performance of the NSI

In this section, performance evaluation is in accordance with the evaluation framework outlined in the *National R&D Strategy* (DST, 2002a) (see Figure 14). The strategy identifies a number of indicators that have application at various levels within the system, from measures for current R&D capacity to indicators for 'quality of life'.

Figure 14. Key components and indicators identified by the *National R&D Strategy*



Level	Area	Indicator
Primary	Future R&D capacity	S&T proportion of HEI enrolments S&T postgraduate degrees Matriculants with mathematics and science
	Current R&D capacity	Publications Global share of publications R&D intensity
	Imported know-how	Technology balance of payments Imported high-technology equipment Imported information and communication technologies
Intermediate	Science, engineering and technology human capital	Researchers per 1 000 workforce S&T demography
	Technical progress (improvement and innovation)	Patents, high-technology start-ups Business innovation investment Key technology missions
	Business performance	Technology trade mix Proportion of high-technology firms Sectoral performance
High	Quality of life	Technology Achievement Index
	Wealth creation	Technology-based growth

On the R&D side, much of the information can be drawn from the *National R&D Surveys* (based on the *Frascati Manual*), while indicators for innovation are drawn from the 2001 *Innovation Survey* (based on the OECD's *Oslo Manual* and conducted by the University of Pretoria and its partners).

The two most important outcome indicators suggested by the *National R&D Strategy* will also be considered, namely an indicator for improved quality of life, based on the Technology Achievement Index (TAI) (which takes into account mobile telephone subscriptions, Internet users and electricity consumption per capita), and an indicator for wealth creation, based on the growth of technology-intensive industries.

5.1 Publications

This section reviews South Africa's overall performance (both in absolute terms and compared with the performance of other countries), disciplinary points of gravity, the impact of South African publications and the rating of South African journals.

5.1.1 National Performance

In absolute terms, there has been a steady growth in South Africa's scientific publications (as listed by the Institute for Scientific Information [ISI]), from 2 190 to over 4 000 during the period 1981 to 2003 (see Figure 15). However, in relative terms, South Africa's share of world publications has declined from about 0.70% in 1987 to 0.48% in 2003, with the prospect of a further decline in future years (see also Figure 15). Further analysis of the data by institution reveals that the most productive institution accounted for 18% of the total South African output, and the top five institutions (out of 21) accounted for 62% of the national output. At the other end of the scale, the lowest five accounted for less than 1% of the output (ASSAf, 2006).

Figure 15. Number and proportion of South African publications in the ISI

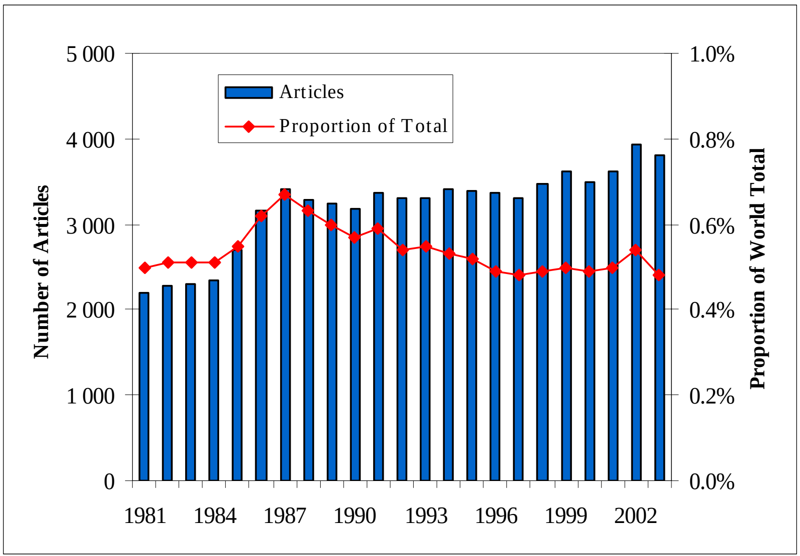
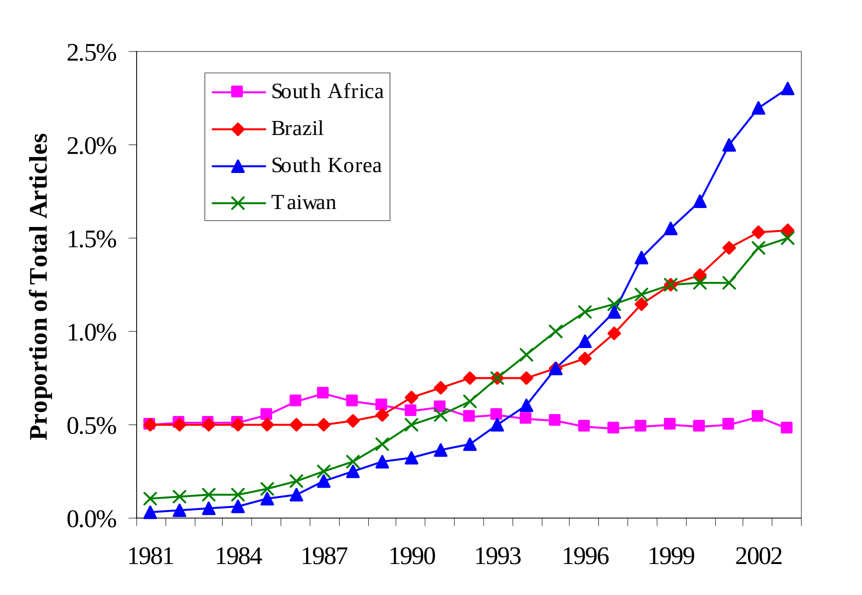


Figure 16 provides comparisons with selected countries, namely Brazil, Taiwan and South Korea. These three countries started from a lower base than South Africa in the early 1980s, but in the early 1990s overtook South Africa at an increasing rate.

Figure 16. Share of world articles: South Africa, Brazil, Taiwan and South Korea (1981–2003)[53]



5.1.2 Quality of Publications

While the number of publications may indicate productivity, citations are used to reflect on quality. A recent comparison of citation rates (King, 2004) showed that South Africa is the only African country among the top 31 countries, ranked according to normalised citation rates per article (see Table 24). In addition, the data indicate a rising citation rate or impact factor associated with South African articles within the global scientific literature, but below the world average of 1.0.

Table 24. Normalised citation rates per article (1993–2002)[54]

Country	Australia	South Africa	Greece	South Korea	Brazil	India	Iran
2002	1.09	0.76	0.70	0.64	0.58	0.48	0.42
1993–2002	1.01	0.61	0.67	0.61	0.62	0.40	0.44

[53] Data obtained from *National Science Indicators*, ISI.
[54] Data obtained from King (2004).

5.1.3 Performance by Discipline

The share of articles published globally and the citation rate of selected South African scientific disciplines for the periods 1989 to 1993 and 1999 to 2003 are shown in Table 25. With regard to the world share, the fields of immunology and education exhibit the highest increases (104.5% and 77.8% respectively), while material sciences and computer sciences exhibit the highest declines (29.3% and 25% respectively). Table 25 further shows that the impact of all South African disciplines was below the world average of 1.0. Mathematics and immunology are closer to the world average, while education, space science and agricultural sciences were above average during the earlier period, but lost some of their impact during the period 1999 to 2003. Overall, the world impact of South African science appears to have improved from 0.54 during the period 1989 to 1993 to 0.66 during 1999 to 2003.

The data reinforce previous studies that have suggested that South African research is characterised by the bio-environmental model (strong in ecology, plant and animal sciences, geosciences and agricultural sciences), with both high activity and relatively high impact. Areas such as materials science and physics are associated with lower activity and impact.

Table 25. World share and impact of selected South African scientific disciplines (1989–1993 and 1999–2003)[55]

	Share of Global Articles (%)		**World Impact**	
Scientific field	**1989–1993**	**1999–2003**	**1989–1993**	**1999–2003**
Agricultural sciences	0.42	0.54	1.11	0.81
Biology and Biochemistry	0.35	0.37	0.43	0.62
Chemistry	0.40	0.33	0.80	0.64
Computer science	0.32	0.24	0.69	0.83
Economics and business	0.35	0.45	0.24	0.35
Education	0.54	0.96	1.60	0.62
Engineering	0.31	0.30	0.85	0.72
Geosciences	1.17	1.14	0.81	0.77
Immunology	0.22	0.45	0.65	0.92
Law	0.70	0.06	0.16	0.14
Materials science	0.41	0.29	0.88	0.84
Mathematics	0.42	0.39	0.89	0.95
Microbiology	0.56	0.65	0.62	0.88
Molecular biology and genetics	0.30	0.29	0.43	0.63
Physics	0.27	0.24	0.62	0.75
Plant and Animal science	1.83	1.56	0.55	0.66
Social sciences, general	0.50	0.65	0.68	0.85
Space science	0.96	0.88	1.10	0.76
Total for South Africa	**0.57**	**0.50**	**0.54**	**0.66**

[55] Data obtained from *National Science Indicators*, Thomson Scientific (see (http://scientific.thomson.com/products/nci/).

5.1.4 South African Journals

South Africa has published scholarly journals since as early as the mid 19th century. The political and academic isolation of the country at least partially contributed to official initiatives in the 1960s to stimulate scholarly journals, when the government through the Bureau of Scientific Publications launched a strategy that included the publication of a series of national scholarly journals and subsidies for smaller ones. The policy and its outcomes have been reviewed on at least two occasions, firstly by Pouris & Richter (1998) and most recently by the Academy of Science of South Africa (ASSAf, 2006). This section gives a brief overview of the current policy and landscape, and the impact of South African journals.

On the basis of a review commissioned by the DST (then still the Department of Arts, Culture, Science and Technology) in 1999, the government disengaged from direct involvement in the publication of journals, and journals are currently independent of direct government involvement and support. However, the Department of Education continues to support the publication of articles in selected/recognised journals. Currently the subsidy is just over R84 000 (PPP US$ 32 300)[56] per article. The recognised journals include 23 indexed by the Institute for Scientific Information (ISI) and/or the International Bibliography of Social Sciences (IBSS) and 232 in an additional list developed by the Department of Education. In addition, at least 200 other scholarly journals that are not internationally indexed are published in the country.

The Science Citation Index indexes 17 South African scientific journals (see Table 26). This number is equal to or larger than the number of journals published in countries that are substantially more research intensive than South Africa (such as Sweden, Finland and Greece).

Table 26. ISI-indexed journals and GERD/GDP in selected countries

	Australia	Spain	Ireland	South Africa	Sweden	Belgium	Finland
Journals in ISI	64	26	18	17	17	13	11
GERD/GDP	1.55	0.96	1.17	0.76	4.27	2.17	3.42

The three most productive scientific disciplines in South Africa, as reflected in ISI-indexed local journals over the period 2000 to 2004, were plant sciences (2 182), animal sciences (2 108) and environment/ecology (1 187). Not all productive South African research fields are catered for by South African journals, however, for example, physics, microbiology and space science.

An analysis of impact factors shows that four South African journals are above the median in their disciplinary group, namely the *South African Journal of Science*, *South African Journal of Geology*, *South African Medical Journal* and *Social Dynamics*.

[56] The Rand-equivalent US dollar amount is presented to indicate purchasing power parity (PPP).

An analysis of more than 200 non-ISI-indexed South African journals (producing an estimated 1 000 articles annually) showed that some of the journals compared relatively favourably (in terms of a composite extended journal impact factors ranging between 0.25 and 0.50) with ISI-indexed journals (Mouton, Boshoff & Tijssen). As elsewhere in the world, however, a number of local journals seem to be monopolised (in terms of article content) by authors of a particular institution, which is often the publishing institution. The majority of social scientists (77% of articles) and researchers in the arts and humanities (90% of articles) publish in local non-ISI-indexed journals, in contrast to the more than 60% of science and engineering researchers who publish in ISI-indexed journals (both international and South African).

5.2 Human Capital Development

The training of the necessary human capital to drive innovation is a fundamental requirement within any NSI. The performance of the NSI in this regard is now discussed in more detail with respect to the three categories of secondary, tertiary and vocational education (see also Section 6.2.1).

5.2.1 Output of the Secondary School System

A major issue affecting the ability of all the educational institutions is the number of school leavers with the required qualifications to enter a career in S&T. For instance, the number of school leavers with mathematics seems to have stabilised at around 20 000 per annum over the period 1997 to 2003 (see Table 27). Although this problem has been addressed through the Dinaledi programme, which sought to increase mathematics and science participation at school level and targeted 102 high schools, such interventions have generally not been sufficiently broad based to achieve a major impact.

Table 27. Mathematics higher grade passes (1 000s) (1997–2003)[57]

Year	1997	1998	1999	2000	2001	2002	2003
Wrote	68.5	60.3	50.1	38.5	34.9	35.5	35.4
Passed	22.8	20.3	19.9	19.3	19.5	20.5	23.4

5.2.2 Supply of Artisans

Since the mid-1980s, South Africa has experienced a drastic decrease in the number of people trained as artisans in both public and private sector training centres, accompanied by a drop in the number of apprenticeship contracts registered with the Department of Labour. The result has been that serious labour shortages have emerged in the engineering, welding and power engineering fields. Existing industry-based training facilities were utilised at only about 70% of their capacity of 18 000 artisans per annum in 2003. The shortfall between the supply of and the demand for skilled artisans was estimated at 7 000 in 2004 (NACI, 2003b).

The Department of Labour is attempting to address this skills shortage through the work of the Sector Education and Training Authorities and its own learnership

[57] Data obtained from DST (2005d).

programme. The total budget for these initiatives is in excess of R2.5 billion (PPP US$ 0.96 billion) per annum. (The Sector Education and Training Authorities are funded through a 1% levy on all payrolls; the system has recently been revised in the interests of small businesses.)

5.2.3 Graduates in Science and Engineering

The total production of doctoral and masters level graduates (in all disciplines) by the HEIs has grown slowly but consistently over the last ten years. For instance, the average annual growth in doctoral graduations over the period 1992 to 2001 has been about 3% in universities and 37% in technikons (now called universities of technology). It should be noted that the latter growth was from the very low base of one doctorate in 1992.

Within universities, the growth in masters degrees has outstripped other qualifications (with an average annual growth of 7.4% over the same period), with the result that the ratio of doctoral to masters graduates has increased from 1:5 in 1992 to 1:8 in 2001. Although the number of doctoral enrolments has increased sharply, this has not yet improved the annual qualification numbers, and it seems that many students either leave the system after attaining a masters degree or enrol for doctoral studies without eventually graduating.

The numbers of black and women graduates as a proportion of all graduates have grown consistently over the last 14 years (see Table 28). The proportions are slowly approaching national demographic profiles (with the exception of women graduates as a percentage of total qualifications, which is already in excess of the demographic target).

Table 28. Black and women graduates (percentage of total graduations)

Category	**Blacks (% of total)**		**Women (% of total)**	
	1992	**2001**	**1992**	**2001**
All qualifications	33.8	59.9	28.5	56.0
Doctorates	9.1	30.2	28.5	37.4
Natural sciences	23.8	53.7	45.0	49.6
Engineering	15.8	52.0	13.9	23.1

The generally strong growth in undergraduate numbers and qualifications (3.6%) has not been evident in engineering and the natural sciences, in which the average annual growth (for all qualifications) has been 1.4% and 2.4% respectively over the period 1992 to 2001. A further factor is the generally low average pass rate at HEIs, particularly in science and engineering disciplines.

Table 29 gives the number of graduations in 2001, categorised in terms of the National Qualifications Framework level and field of study. Twenty per cent of all graduates (totalling 16 451) were in science and engineering, which is still far below the target of 30% set by the Department of Education for the proportion of science and engineering enrolments by headcount. A total of 1 609 new science and engineering masters and doctoral level graduates (levels 8 and 9) entered the system in 2001. The proportion of masters and doctoral graduations in science and engineering is 10% of all science and engineering graduations. A similar proportion applies to other fields of study.

Table 29. Total graduations, by field of study and National Qualifications Framework level (2001)

Field of study	National Qualifications Framework level			
	Up to honours (or equivalent)	**Masters (or equivalent)**	**Doctorate (or equivalent)**	**Total**
Science and Engineering	14 842	1 326	283	16 451 (20.38%)
Other	58 773	4 970	518	64 261 (79.62%)
Total	73 615 (91.21%)	6 296 (7.80%)	801 (0.99%)	80 712

A good indicator of the current imbalance between supply and demand can be obtained from the employment prospects for university graduates, which continue to be robust. Graduates from most disciplines (with the exception of the fields of law, humanities and arts) find employment within six months of graduation (see Table 30). The data are derived from a follow-up postal survey of 2 672 university graduates in South Africa (Moleke, 2006).

Table 30. Period before finding employment, by field of study (percentage of graduates)

Field of Study	Immediately (%)	1–6 months (%)	7–12 months (%)	1–2 years (%)	More than 2 years (%)	Total
Natural sciences	55.0	38.8	3.8	2.1	0.3	100
Engineering	77.2	18.3	3.0	1.0	0.5	100
Agriculture	61.6	31.4	5.8	1.2	0.0	100
Medical sciences	79.3	18.5	2.2	0.0	0.0	100
Humanities and Arts	46.8	33.1	8.5	7.3	4.3	100
Education	57.0	33.8	3.9	4.4	0.9	100
Law	49.6	30.2	8.6	7.2	4.4	100
Economic and Management sciences	65.4	23.3	6.2	3.7	1.4	100
Total	**59.5**	**28.4**	**5.9**	**4.2**	**2.0**	**100**

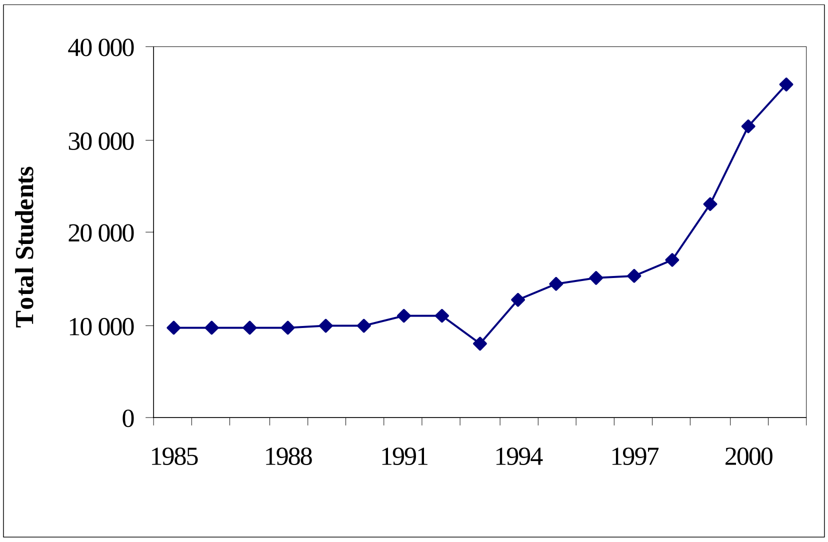
A final aspect covered in this section with respect to HEI output performance is the rising number of foreign students. South African HEIs play an important role in the training of international students, particularly students from the rest of Africa (see Table 31 and Figure 17). The majority of foreign students studying at South African HEIs are from countries of the Southern African Development Community (SADC) (66%)[58], and almost 22% of foreign enrolments in 2001 were at postgraduate level. A total of 3% of foreign enrolments were at doctoral level.

[58] The member countries of the Southern African Development Community are Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

Table 31. Foreign student enrolments at South African universities (1995–2002)[59]

Year	Foreign enrolments (% of total)
1995	3.7
2001	9.1
2002	8.4

Figure 17. Enrolment of foreign students at South African universities[60]



Enrolments of foreign students are also high in comparative terms (see Table 32). It is considered that these numbers could be further increased and that South Africa could play a much more significant role in building the human resource base of other sub-Saharan African countries. Foreign students benefit the South African research base; many are highly motivated to obtain advanced degrees, build their careers and make a contribution to the R&D output of the country's institutions.

[59] Data obtained from the Council on Higher Education (2004: Table 32).
[60] Data obtained from NACI (2003c).

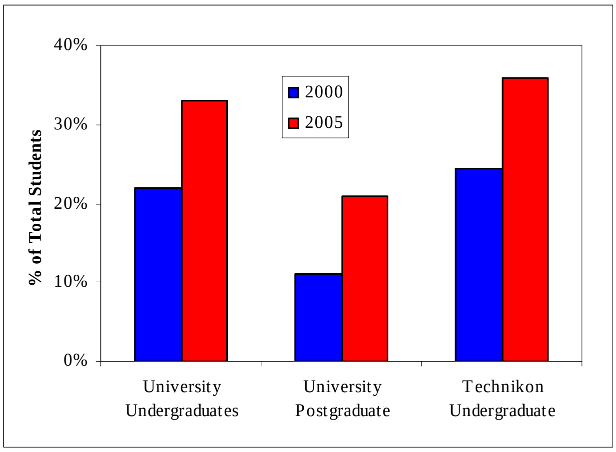
Table 32. International statistics on foreign student enrolments (2000)

Nation	Total National Population[61]	Number of Foreign Students in HEIs[62]	Foreign Students (% of Total HEI Enrolment)[63]
Australia	19 138 000	105 764	12.5
United Kingdom	59 415 000	222 936	11.0
South Africa	43 309 000	31 149	5.3
United States	283 230 000	475 169	3.6
Turkey	66 668 000	17 654	1.7
Tunisia	9 459 000	2 756	1.5
Malaysia	22 218 000	3 508	0.7
Argentina	37 032 000	3 181	0.2
Korea	46 740 000	3 373	0.1
Mexico	98 872 000	2 430	0.1

5.2.4 The Impact of HIV/AIDS on Human Resource Development

Projections of demand and supply of human resources in the NSI are all subject to the potential influence of HIV/AIDS. Given that the proportion of South Africans infected with HIV is one of the highest in the world, it follows that the effects of the pandemic have to be accounted for in supply and demand projections as well as capacity development plans. Figure 18 shows the estimates of HIV infection among the student population, which provides the next generation of NSI workers. (The Higher Education Association of South Africa recently launched an internationally funded programme worth €20 million to address HIV in the higher education sector.)

Figure 18. Estimated HIV infection rates among students[64]



5.3 Patents, Royalties and Licences

South Africa's performance in the area of intellectual property protection and exploitation started from a weak base and has weakened further over the last ten

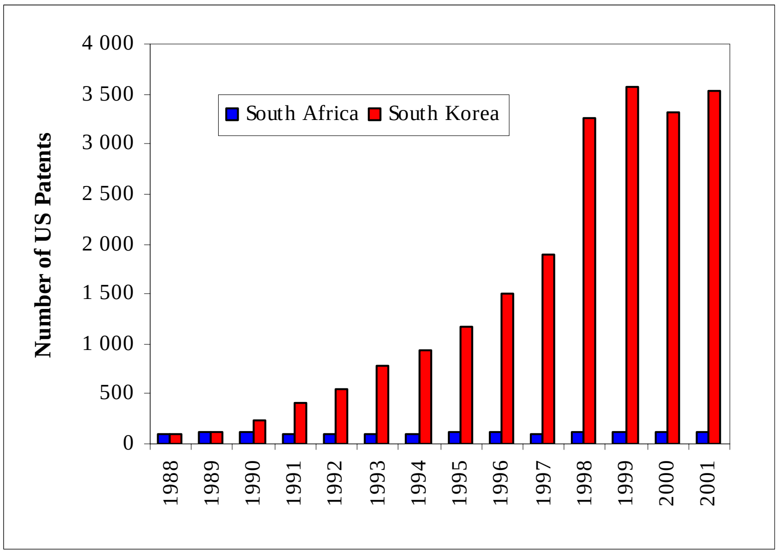
[61] Data obtained from the Medium Population data of the United Nations Population Division (2001).
[62] Data obtained from the OECD Education database and the South African Department of Education Higher Education Management System (HEMIS) database.
[63] Data obtained from the OECD (2004) and South African Department of Education.
[64] Data obtained from the South African Universities Vice-Chancellors' Association (2000).

years. For instance, during the period 1990 to 2001, the number of patents registered in the US Patent Office by South African inventors has remained almost unchanged (114 in 1990 and 120 in 2001). Over the same period, other countries fared significantly better. For instance, Ireland increased its patents in the US Patent Office from 54 to 143, Spain from 130 to 269 and South Korea from 225 to 3 538 in 2001 (see Table 33 and Figure 19).

Table 33. Numbers of patents granted by the US Patent Office to selected countries (1994 to 2004)[65]

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
South Korea	943	1161	1493	1891	3259	3562	3314	3538	3786	3944	4428
Spain	141	148	157	177	248	222	270	269	303	309	264
South Africa	101	123	111	101	115	110	111	120	113	112	100
Ireland	48	47	77	71	71	90	121	141	127	163	186
India	27	37	35	47	85	112	131	178	249	341	363

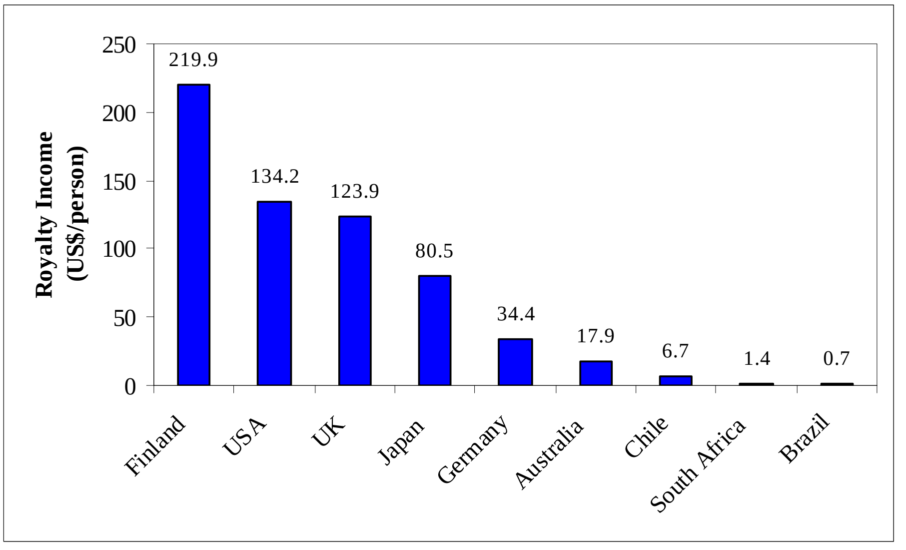
Figure 19. Differential growth in the number of US-registered patents between South Africa and South Korea (1988–2001)



Furthermore, income from royalties and licence fees has been almost negligible (see Figure 20), and South Africa has a significant negative balance of payments with respect to intellectual property (hence the description of South Africa as a ‘technology colony’).

[65] Data obtained directly from the US Patent Office.

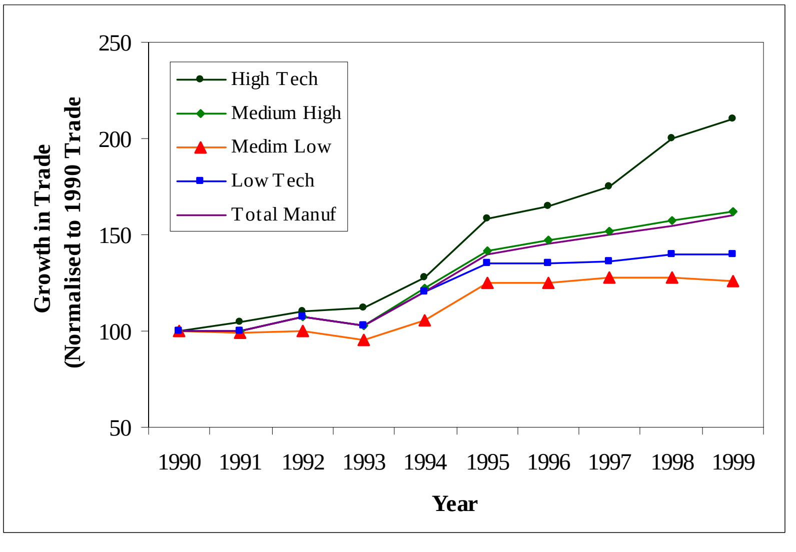
Figure 20. Royalty and licence fees[66]



5.4 Exports of High Technology Products

High-technology and medium-high technology industries dominate international trade (see Figure 21). In 1999 they constituted 64% of all trade (research commissioned by NACI to Science Consultancy Enterprises in 2006). The three industries with the highest growth rates in OECD manufacturing trade during the last decade are all classified as high-technology industries, namely pharmaceuticals, radio, television and communication equipment, and computers.

Figure 21. International trade of high-technology goods (1990–2000)

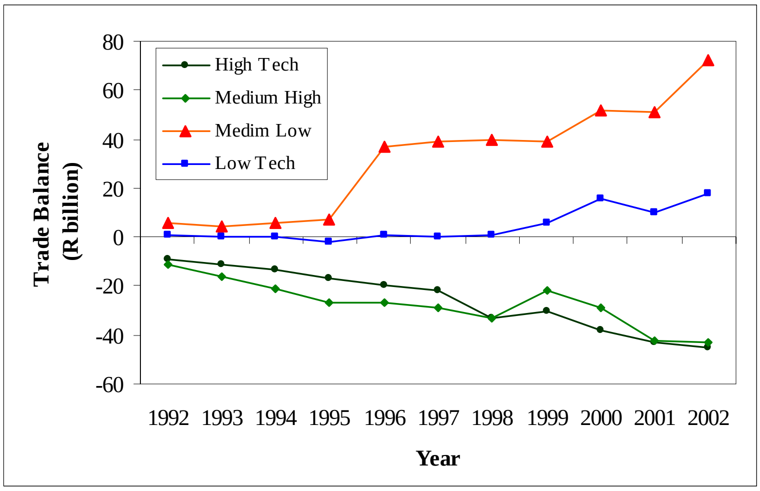


[66] Data obtained from UNDP, 2004.

By comparison, South Africa's international trade is skewed towards the export of primary products and resource-based manufactures, with relatively low levels of high-technology exports. A study conducted by Kaplan (2004b) concluded that over the period 1992 to 2002, primary products and resource-based manufactures constituted a far more significant share of South African exports than for the world or for developing countries; low-technology manufactured exports constituted a much smaller share of South African exports than for the world and for developing countries; medium-technology manufactures represented a higher share of South African exports than for developing countries and were similar to the world level; and the share of high-technology products in South Africa's export basket was very low by comparison with the world and developing countries.

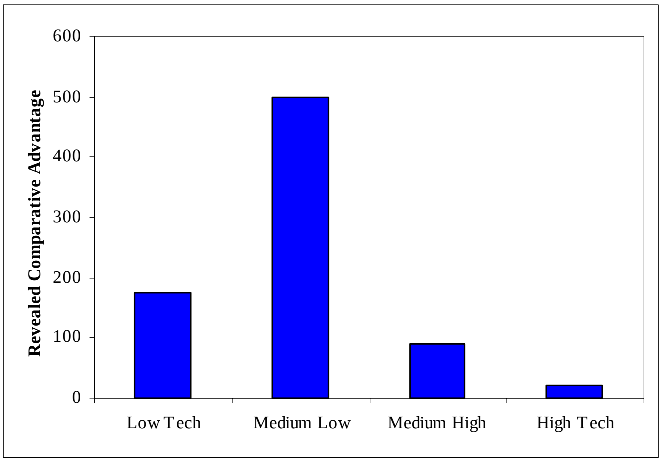
South African trade lags behind the world trend in this regard (see Figure 22, which shows South Africa's trade balance of payments [exports less imports], according to research intensity, for various industries for the period 1992 to 2002) (research commissioned to Science Consultancy Enterprises). South Africa shows a substantial deficit in high technology and medium-high technology and a surplus in the trade of medium-low technology products.

Figure 22. South African trade balance of payments (1992–2003)



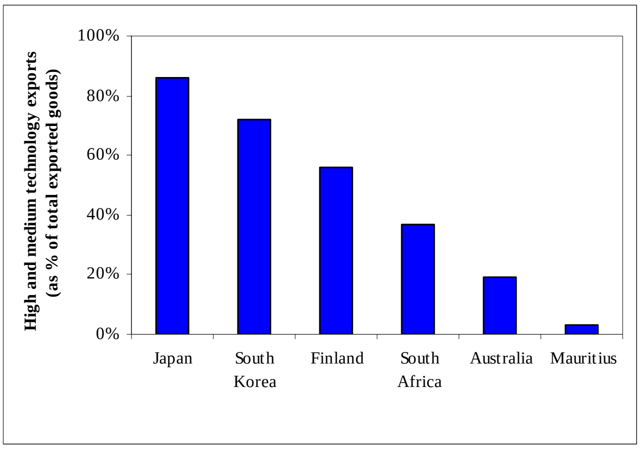
The revealed comparative advantage or export specialisation (see Figure 23) shows the extent to which a country's exports are specialised in a particular industry grouping relative to the OECD average. Values greater than 100 indicate that the country's exports are relatively specialised in that industry. It can be concluded that over the past decade, South Africa possessed a comparative advantage in the medium-low industries, followed by the low-technology industries.

Figure 23. Revealed comparative advantage of South Africa compared with the OECD average (2001)



Even though South African performance in high and medium technology is weak (and has a value below 100 in both cases), South Africa performs better than countries such as Australia and Mauritius (see Figure 24). To improve South Africa's performance in this area, aggressive investment would have to be made in the R&D sector as well as in the development of our human capital in that sector. This is also an area in which China is performing very well, and South Africa can expect even more aggressive competition in the next decade.

Figure 24. High and medium technology exports (as percentage of total goods exported)[67]



5.5 Innovation Performance

Innovation is the process of transforming an idea, generally generated through R&D, into a new or improved service, product, process or approach that relates to the real needs of society and involves scientific, technological, organisational or commercial activities. The key to this definition is the fact that the innovation process is only complete once a defined product, process or system with some tangible benefit has been implemented.

[67] Data obtained from the United Nations Industrial Development Organisation.

Throughout the *White Paper on Science and Technology*, the theme of innovation, as opposed to S&T itself, is central to the determination of policy and strategy. This is a crucial focus, since excellence in S&T does not necessarily translate into innovation. The transformation of new ideas into commercial success, which is so important to the nation's ability to achieve economic growth, employment creation and competitiveness, requires attention not only to R&D and technological factors of innovation but also to social, institutional and market factors such as the adoption, diffusion and transfer of technology.

In certain areas, South African firms (and individuals) have established a strong culture of R&D and innovation. Examples of local innovation are well documented in the two publications *The Leading Edge* and *The Hidden Edge* (Addison, 2000a & b); for instance, Sasol has an internationally competitive position in coal-to-liquid (or gas-to-liquid) fuels technology, De Beers is a leading producer of synthetic (and natural) diamonds, and Aubrey Kruger, a South African inventor, developed the 'dolos' which is used globally in harbour construction.[68] Many South African firms are now large international organisations with strong local R&D and highly developed technology (including SAB-Miller, Eskom, AngloGold and Sasol).

A more general view of this sector can be obtained from the 2001 *Innovation Survey*, undertaken by the University of Pretoria (Buys, Oerlemans, Pretorius, & Rooks, 2003) in accordance with the *Oslo Manual* (which defines innovation as the introduction of a new or substantially improved service, product or process to the firm), covering the period 1998 to 2000. The results of this survey are presented in the following sections.

5.5.1 Innovation Intensity

According to the 2001 *Innovation Survey* (SAIS 2001), a large number of South African firms (585) were reported to be innovative, but only 1.8% of sales income was spent on innovation activities (see Figures 25 and 26). Total innovation costs include R&D as well as non-R&D investments such as the purchase of machinery, equipment or computer hardware, outsourced research, industrial design and innovation implementation, licences/advices, and marketing and training costs that were specifically incurred for innovation purposes.

The three most important reasons for not being innovative are costs that are too high, a lack of time to spend on R&D and a shortage of R&D financing. These reasons may be indicative of three critical underlying factors, namely insufficient supply of venture capital for innovative activities; lack of networking and collaboration (with universities and universities of technology, for instance) and of government support for innovation (such as tax breaks); and lack of qualified personnel to undertake innovation processes.

The importance of tacit and specialised knowledge calls for greater attention to investment in human capital, since humans are central as holders of important knowledge assets.

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[68] Further information on South African innovations available at http://news.bbc.co.uk/1/shared/spl/hi/picture_gallery/04/africa_south_african_innovators/html/1.stm.

The R&D effort was also found to be low. About 51% of firms had no R&D effort. The mean R&D effort in persons was only 1.8%, and 1.55% of total sales were allocated to R&D-related innovation activities. Firms spent about 1% of total sales on non-R&D innovation activities, such as the purchase of machinery and equipment, outsourcing research, innovation implementation, licences, innovation-related marketing and training.

Figure 25. Percentage of innovating firms [69]

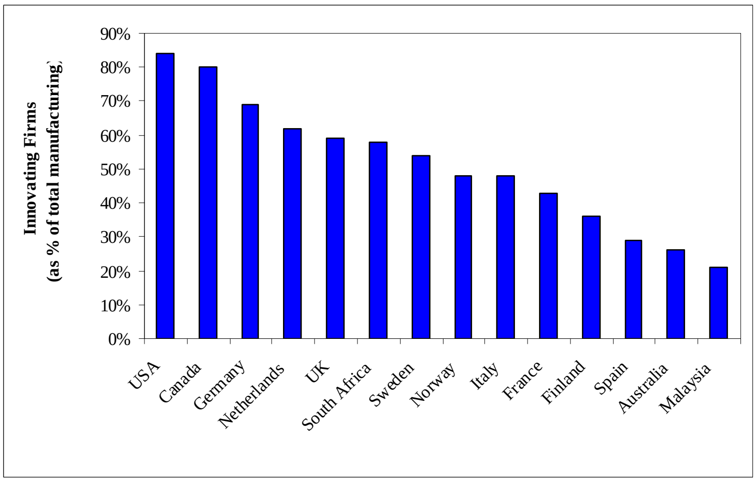
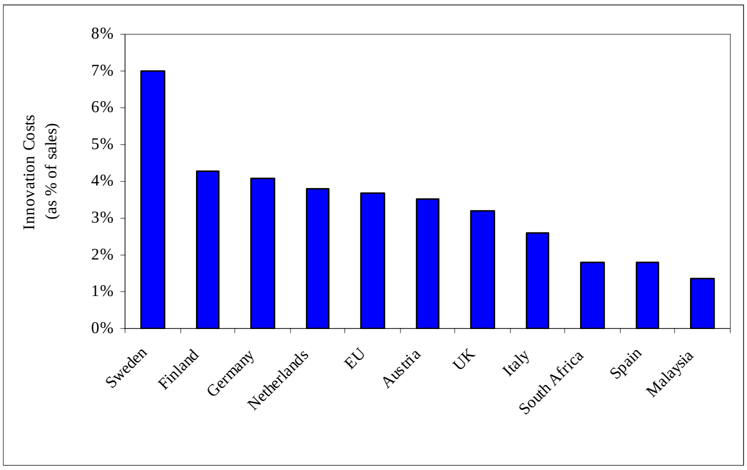


Figure 26. Innovation costs as a percentage of sales[70]

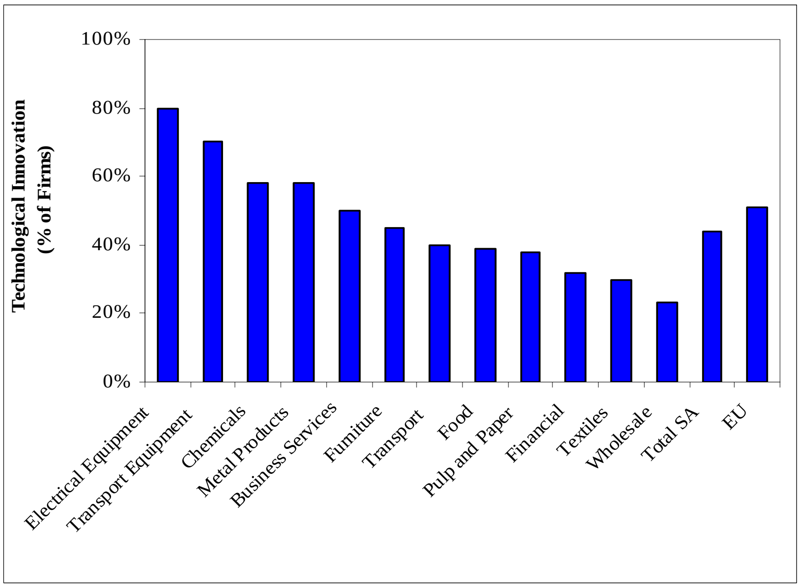


[69] Information from 2001 *South African Innovation Survey*.
[70] Data obtained from 2001 *South African Innovation Survey*.

5.5.2 Innovation Partnerships

The 2001 *Innovation Survey* revealed that approximately 44% of South African firms had technological innovations in the period 1998 to 2000 (see Figure 27). This proportion is considered to be high, as it is comparable to that of many developed countries in Europe. The survey further revealed that a relatively large part of the development of new or improved products and/or services was done by, or together with, a third party (32%), indicating strong links with external knowledge and contributions.

Figure 27. Innovation rate in firms



Using Table 34 as well as the results from the 2001 *Innovation Survey* report, the following observations were made:

- Among South African innovators, there is a strong orientation towards Europe, especially the partners of the own enterprise group, buyers and suppliers located there.
- There is some orientation towards partners located in North America, but this mostly takes the form of innovative collaboration with suppliers.
- Levels of partnering are very low with players in African countries outside the Southern African Development Community (SADC) or in South America and Asia/Australia.

It is clear that South African firms collaborate more strongly with European firms than with firms in any other region. This result confirms that South African firms have weak links with local firms and tend not to use intellectual resources that are locally available. Besides “the legacies of the past, other reasons for the relatively strong dependence of South African innovators on foreign partners could be a lack of suitable and knowledgeable domestic partners and local resources (limited local R&D) on the one hand, and a policy of foreign direct investors in South Africa to concentrate their R&D efforts in European countries on the other” (Buys et al., 2001). It is also important to note that the majority of innovation activities performed by

South African firms were incremental, and that larger firms had higher innovation rates than smaller firms.

Table 34. Innovation in partnership (foreign partners, percentages per type of partner)[71]

Type of partner	Not a partner	A partner and located in					
		SADC	Other African countries	Europe	North America	South America	Asia/ Australia
Own group	32	2	1	53	8	2	2
Buyers	43	12	4	31	6	0	4
Suppliers	32	8	0	32	19	3	5
Competitors	61	18	0	15	1	0	4
Consultants	52	24	0	18	2	0	4
Research institutes	85	4	0	6	2	0	2
Universities	79	10	0	6	4	0	1
Other partners	75	1	0	15	5	0	3

With regard to the 56% of firms not innovating, the main reasons given were a lack of resources in terms of money, staff and time for innovation projects. The innovation activities of innovating firms were hampered by the same factors. About 40% of innovating firms experienced seriously delayed innovation projects due to a lack of qualified personnel, information about and familiarity with technologies, high costs, economic risks, shortage of finance, and time to market problems.

It can thus be concluded that South African industry can be characterised as being predominantly engaged in the improvement of products and processes using foreign technology. South Africa can therefore be characterised as a type of 'technology colony', with industries that are dependent on foreign technology for the improvement of their products and processes. The primary mode of innovation seems to be imitation rather than invention.

The discussion shows that South African firms cited lack of funds as one of the main factors inhibiting innovation activities. The next section discusses the extent to which firms utilise innovation funds and subsidies made available by the South African government.

5.5.3 Use of Innovation Funds

To stimulate firms to engage in risky innovation projects, governments made subsidies and innovation funds available, and South Africa is no exception in this regard. According to the 2001 *Innovation Survey*, however, relatively few South African innovating firms actually make use of innovation subsidies and funds (see Table 35). By comparison, 21% of innovating firms in the European Union made use of subsidies or funds available from their governments over the same period. The perceived reason for firms' relatively low use of funds from such schemes is that government funds had very limited budgets.

[71] Data obtained from 2001 *South African Innovation Survey*.

According to the report, the budget for the 1999 innovation funds was allocated as follows: Technology and Human Resources for Industry Programme (industry/academia cooperation) – R50 million (PPP US$ 25 million); Innovation Fund (industry/PRI/academia cooperation) – R30 million (PPP US$ 15 million); Support Programme for Industrial Innovation (trade and industry) – R95 million (PPP US$ 47 million); Competitive Fund (industry) – R600 000 (PPP US$ 298 thousand). Although the size of the funds has grown since 1999, they are perceived to be relatively small to have an impact on the innovation activities of local firms.

Table 35. Proportion of innovating firms using a specific type of innovation fund[72]

Name of Fund	**Responsible Line Department**	**% of innovating firms**
Technology and Human Resources for Industry Programme	Department of Trade and Industry	18
Innovation Fund	Department of Science and Technology/Department of Trade and Industry	46
Support Programme for Industrial Innovation	Department of Trade and Industry	46
Sector Partnership Fund	Department of Trade and Industry	12
Competitive Fund	Department of Trade and Industry	63
Venture capital	Individuals, venture capital organisations	8
Development capital	Banks, Industrial Development Corporation	24
Research cooperation	PRIs	10
Other funds		2

From this information, it is clear that innovating South African firms make little use of innovation funds, venture capital and development capital.

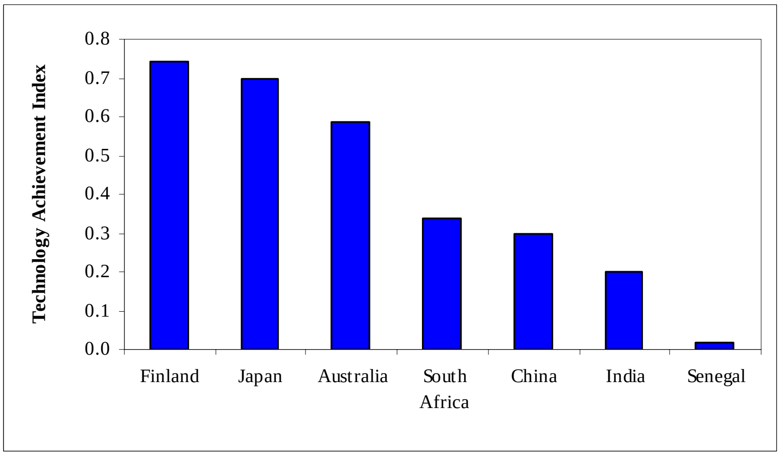
5.6 Improvement in Quality of Life and Wealth Creation

In the final section of this chapter, the performance of the NSI with respect to the high-level parameters (improved quality of life and wealth creation) is discussed. As mentioned in the chapter introduction, the *National R&D Strategy* proposes the use of the Technology Achievement Index as an indicator of impact at this high level.

[72] Data obtained from 2001 *South African Innovation Survey*.

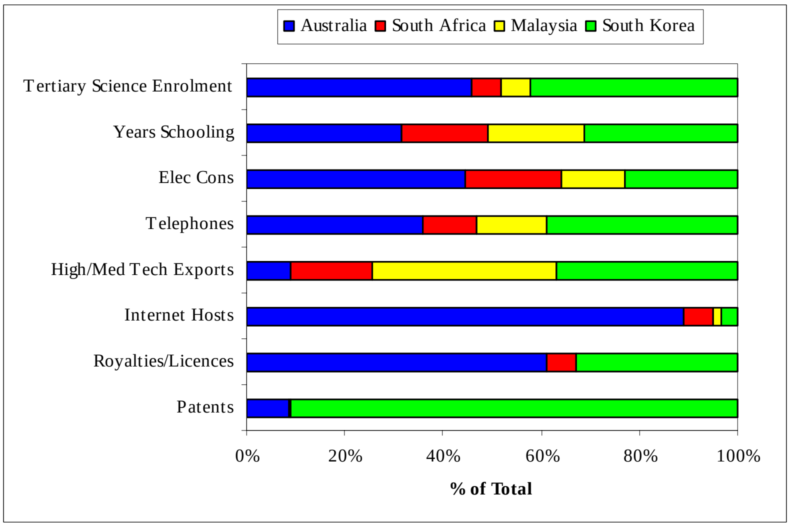
In terms of the Technology Achievement Index, South Africa compares favourably with comparator countries such as Malaysia, Chile, and Brazil (not shown in the graph), but less favourably than comparators such as South Korea and Australia (see Figure 28).

Figure 28. Country comparison using the Technology Achievement Index (2002)



South Africa's Technology Achievement Index was 0.34 in 2000, which was lower than countries such as South Korea (0.666), Australia (0.587) and Malaysia (0.396). The relatively low value of South Africa's index is due a poor performance in the areas of patents, royalties, Internet hosts and tertiary education (see Figure 29). The latter reinforces the need to develop South Africa's human capital in order to achieve economic progress and consequently an improved quality of life for all.

Figure 29. Relative performance for components of the Technology Achievement Index



Chapter 6: Assessment of Weaknesses and Strengths

6.1 Introduction

There is some debate about the applicability of the innovation systems approach in a developing country context in general, and specifically in South Africa (Muchie, 2003). For instance, the most important levers for economic and social development within developing countries may not include a focus on R&D or innovation. Notwithstanding this criticism, the application of the systems approach in South Africa has been extremely valuable in tackling a number of historical legacies and in providing stronger leadership and policies in support of innovation.

Such benefit has been particularly obvious in identifying disjuncture and weaknesses within the policy environment, and hence in obtaining overall coordination within government in addressing such problems. For instance, immigration policy should link closely with human capital needs, and trade policy should link with industrial policy. In this chapter, several important weaknesses that continue to hinder the further development of the NSI are presented, along with some of the strengths of the system.

6.2 Weaknesses of the NSI

The overviews presented in the previous chapters suggest a number of important weaknesses that will have to be addressed if the high expectations of contributions by the NSI to the country are to be realised. The following weaknesses are regarded as significantly inhibiting the system from functioning optimally, yet are factors over which role-players in the NSI have control and should therefore address:

- The provision of human resources
- Rigidities in financing
- Rigidities in the domains of knowledge production
- The role of S&T in poverty reduction.

These weaknesses are now discussed in more detail. It is noted that the Accelerated and Shared Growth Initiative for South Africa (ASGISA)[73] defines a much broader set of constraints that need to be addressed before the economy can attain a sustained 6% growth rate. These constraints include the volatility of the currency, the cost of logistics, the shortages of skilled labour, limits to competition and deficiencies in state organisation. The Joint Initiative for Priority Skills Acquisition is the first intervention launched to address the skills shortages.

6.2.1 The Human Capital Pipeline

According to the 2001 *Innovation Survey* (Buys et al., 2003), "highly trained specialists and employees educated on tertiary level are required in industry to develop technology, design and develop products and processes, and implement or commercialise them … the shortage of skilled labour appears to be a major stumbling block for firms to be more innovative".

[73] For more information on this initiative, see South African Presidency (2006).

Furthermore, the current strong growth in the economy has created a number of shortages in human capital in science, engineering and technology. For instance, it is estimated that the target of 1% GERD/GDP will require an additional 7 000 researchers. These shortages include, but are not limited to, technically skilled artisans (welders, machinists, electronics and electrical artisans and the like), graduate engineers, young researchers and full-time researchers at HEIs.

The response of the education and training system to this shortage has been limited. During the last ten years, science and engineering graduates grew at a slower rate than business and commerce graduates and social science graduates, and the in-house training of artisans for technically skilled occupations by large companies has been seriously eroded (NACI, 2003b). Although there has been a steady increase in the number of enrolments at universities and universities of technology (with average annual growth in headcount enrolments between 2000 and 2003 of 6.7%), the ultimate delivery of science and engineering graduates has been too slow to meet the demands of the system (see also Section 5.2). The interventions that have been made at different stages of the pipeline have been fragmented and have often not achieved a critical mass scale. For example, the DST pilot programmes for post-doctoral fellowships and early career support for young researchers have also not yet been increased to significant levels, and these programmes are therefore having only limited impact.

Another aspect of the human capital pipeline is the lack of suitable opportunities for training young public sector researchers (mostly at a post-masters or post-doctoral level). A key input into current and future R&D activities is the extent of public funding; at 28% of GERD (see Figure 6 in Section 4.2), South Africa's government expenditure is low relative to most developing countries and even a significant number of developed economies. While the overall level of R&D funding has been growing, the proportion of public funding is shrinking, with the major growth in sources of finance being the international sector. This creates a situation in which young researchers struggle to establish themselves and make a career in research seem unattractive (especially the early years of such a career). A key indicator of this effect is the static level of FTE researchers in the NSI between 2001 and 2004 (see Table 21 in Section 4.5) and the reduction in time spent on research by university researchers over the same period. The number of permanent academic staff with a doctorate at HEIs was essentially static over the same period.

In summary, the NSI faces serious short- to medium-term shortages with respect to three key inputs, namely future R&D preparedness, current public R&D activity and the stock of human capital in science, engineering and technology.

6.2.2 Ongoing Rigidities in Financing Research and Innovation

One of the key functions of the public investment in the system is to stimulate knowledge production in new areas and to ensure linkages with technical improvement and innovation. Global trends that are not mirrored in South Africa include growth in the number of patents secured from publicly funded research, incentives to develop larger multidisciplinary and transdisciplinary research groups, and the availability of mechanisms such as incubators, early stage venture capital and entrepreneurial support measures.

The primary granting mechanisms that have traditionally been used are based on historical assessment of the research productivity of individual researchers. Although newer mechanisms, such as a national centres of excellence programmes, have recently been established, the researcher-centred approach tends to reward investment in individual research careers. Although relevance-based criteria have become more important, significant targeted research money in new areas of research, supported by infrastructure investment, is not yet a pervasive feature of the system.

The incentives to patent new inventions have remained low, and universities and research councils have limited capacity (and indeed finances) to establish and maintain quality technology licensing and commercialisation offices. No national policy has yet been established to ensure common approaches and practices in this regard. One of the impacts of this is the very high transaction costs in the negotiating phase of commercial arrangements with inventors, entrepreneurs and licensors. Established relationships with large research-intensive firms have been retained, or have grown during this period, but these often depend on the university or PRI effectively subsidising the research. This is compounded by the absence of standards on overhead cost recovery within research institutions, and by research contracts being based on marginal cost rather than full cost. Similar practices are developing with respect to international grants that enter South Africa.

From the perspective of researchers, the number of research-financing instruments has grown, but such instruments have varying and sometimes contradictory grant conditions. The overheads experienced by researchers in preparing funding applications, conducting peer review and ensuring compliance with reporting requirements has increased much faster than the success rates of applications, leading to serious concerns about participation by top researchers in the publicly funded system.

Some progress has been made in developing a system of support in the form of incubators and technology stations, but early stage venture capital financing (both public and private) is still largely absent. This means that the primary uptake of research postgraduates remains the large traditional employers. The number of technology-based small start-ups remains small.

Aspects of the financing system could be made more transparent, and institutional and other sources of finance could be redesigned to give greater incentives to the larger-scale organisation of relevance-based longer-term research initiatives, more focus on the support of technology-based start-ups and more integration of different financing instruments.

6.2.3 Ongoing Rigidities in Domains of S&T

These dynamics in the financing system have tended to favour areas of knowledge production that are well established, as well as mature researchers who have mastered the 'art' of securing grants. The result is a system that lacks the ability to enter new fields and domains of knowledge production. The absence, until very recently, of capital financing for equipment and new infrastructure has tended to reinforce this pattern. Emerging areas of research of significant innovation potential have therefore not been addressed with coherent and targeted activities on any significant scale (with the exception of astronomy and biotechnology through public funding, and nuclear technologies associated with the Pebble Bed Modular Reactor).

This pattern is changing, with considerable new funding, but the danger exists that there will be further multiplication of funding instruments, programmes and approaches without coherence. This pattern of investing in established fields means that a number of areas of importance have never developed as research and innovation areas, including microelectronics, display devices, semi-conductors and electrical goods.

6.2.4 S&T and Poverty Reduction

South Africa's history has left a legacy of marginalisation and poverty for large numbers of the population. This legacy has also meant that the inherited S&T system was designed and has evolved to serve only five million people out of South Africa's population of 45 million. The system therefore displays many features of a mature national system of innovation but lacks capacity to serve South African society more broadly. For instance, the capacity to develop solutions to diseases such as HIV/AIDS, malaria and tuberculosis is low. Similarly, rural energy supply, effective agricultural extension for small-scale farmers, rural communications infrastructure, facilities for science education and the like are under pressure to deliver without an entrenched or effective history of technology development and technology transfer assisting this process.

As a result, the accumulation of learning on good practices and the adoption of effective technological solutions have been slow, and S&T for poverty reduction remains a significant challenge.

6.3 Strengths of the NSI

This section of the report is not intended to be exhaustive; at various points in the text, strong features of the NSI have already been highlighted. Several additional strengths are now discussed.

6.3.1 Regular Institution and Programme Evaluations

An outstanding characteristic of the NSI over the past decade has been the fact that almost all aspects are reviewed on a regular basis and following standard international practice – explicit terms of reference approved by the particular organisation, a panel of international and local experts, extensive documentation, interviews with stakeholders and site visits. The reports of such reviews are eventually released into the public domain. The following summaries offer a selection of the reviews undertaken since the publication of the *White Paper on S&T* in 1996 and the introduction of a new higher education policy in 1997 (Appendix C offers a selective list of institutional and programme evaluations).

6.3.1.1 Policy Implementation Review

The first systematic evidence-based evaluation of the implementation of the *White Paper on S&T* was commissioned by NACI in 2002 (NACI, 2003d). The review looked, among other things, at the appropriateness of the policy, the resourcing of the system, implementation, and interim outcomes of the radical changes introduced by the *White Paper on S&T*. At an overarching level, the review concluded that the DST (then still the Department of Arts, Culture, Science and Technology) was serving as an effective vehicle for a wide range of initiatives to enable the implementation of the NSI. It further concluded that the *White Paper on S&T* had been accepted by all relevant sectors as an excellent policy framework for driving the NSI.

Other positive developments noted in the report included increasing multidisciplinary and multi-institutional linkages; the development of strategies ranging from biotechnology to the *National R&D Strategy*; and new instruments such as the Innovation Fund and the Technology and Human Resources for Industry Programme. The constraints and challenges mentioned in the report included intellectual capital inefficiencies; failure in the transformation of the business sector; the need for role clarification between the DST and some of the institutions; and the transaction costs of the proposed reconfiguration of the higher education system. The report concluded that "there is sufficient energy and health in the S&T system which, coupled with improved implementation capacity, should bode well for the future of the system and the country's social and economic development".

6.3.1.2 Cross-Institutional Reviews

The first institutional reviews of government science, engineering and technology institutions (including the PRIs) took place in 1997. Generic issues such as the following were investigated: independence, alignment, transparency and accountability, planning, funding, internationalisation and strategic alliances.

Apart from institution-specific recommendations, a number of system-wide recommendations were made as follows:

- The need for substantial increases in funding and linking public financial support to specific functions
- The introduction of key performance indicators for each institution
- Implementation of a human resource redress and equity strategy.

A follow-up evaluation, initiated by NACI in 2003, concluded that those recommendations that were still relevant had been implemented.

A second cross-institutional review took place in 2006 with essentially similar terms of reference as the 1997 review. The final report of the review (DST, 2006b) is expected in the latter half of 2006, but initial indications are that the review will comment on:

- A clarification of the definitions, positions and roles of the different categories of institutions in the system
- Mechanisms for encouraging inter-institutional collaboration
- The need to increase the levels of innovation and knowledge production
- The inclusion of transformation targets and monitoring systems in institutional resource strategies
- The need for a balance between second economy and first economy initiatives in institutional priority setting
- The autonomy of research councils in the execution of research and in the development of evidence-based policy advice.

6.3.1.3 Programme Reviews

Programmes and initiatives within the NSI are evaluated about every five years. Examples of programmes evaluated are the Innovation Fund in 2002 and the Technology and Human Resources for Industry Programme in 1997 and 2002. The implementation of recommendations is the responsibility of the governing bodies of the programmes.

National reviews of disciplines or fields of knowledge production are also undertaken; for example, a review of the discipline of physics (reported on in *Shaping the Future of Physics* [DST, NRF & South African Institute of Physics, 2004]) and a review of biotechnology, both of which were managed by the National Research Foundation.

Finally, it is important to mention that selected higher education programmes are also regularly reviewed by the Council on Higher Education's Higher Education Quality Committee and that a negative outcome could jeopardise the future of such a programme.

6.3.2 Strengths in Leadership and Governance

Despite the urgency of other social priorities for public funds, including the need to develop the second economy, the provision of basic services in low-income areas and the demand for housing and health services, the political leadership in South Africa has shown a strong commitment to increasing government support for R&D and to ensuring that matters of S&T receive attention at the highest level. The growth in GERD and the formation of a dedicated S&T department in government (the DST) have previously been mentioned. In addition, senior government officials are often on record emphasising the contribution that S&T makes, and will continue to make, to the economy and the quality of life of all South Africans.

This leadership of S&T is not only evident in national politics, but is also apparent in the major role that South Africa plays in promoting the importance of S&T on the continent. For instance, it has been highly instrumental in the formation of the Ministerial Conference on S&T within NEPAD, which has now set long-term goals for all African countries in many areas of science policy, including GERD. South

Africa also has observer status at the OECD and has played a role in the development of new initiatives such as the focus on International S&T Cooperation for Sustainable Development.

In terms of governance in the post-1994 period, South Africa has instituted and maintained a strong consultative and democratic culture. New policies are required to proceed through an inclusive process of debate and discussion. While the final adoption of policy remains the prerogative of the ruling party, its formulation is developed through consultation with other parts of government, members of business, civil society and other stakeholders. For instance, the National Biotechnology Strategy and other strategies developed by the Department of Science and Technology were the result of both government initiative and public feedback.

The introduction of these new strategies and policies has considerably strengthened the overall policy framework of the NSI. As already mentioned, prior to 1994, South Africa did not have any formal S&T policy and certainly did not possess a coordinated policy framework or S&T system. The post-1994 government was required to start from a 'blank slate', and although this was in itself a challenge, it facilitated the introduction of a modern S&T governance approach. For instance, South Africa was the first country in the world to adopt the concept of a national system of innovation as a basis for policy. In certain respects, it was able to leapfrog the systems of other countries, which were forced to undergo painful and complicated transformations in order to implement such a policy approach.

6.3.2 Strengths in the Business Sector

In many areas, South African industry has a strong and innovative technological base (see Section 5.5), which to a large extent has been developed in response to the economic and technological challenges facing local companies. For instance, the challenges of extracting minerals at extreme depths, of converting coal to liquid fuels, of competing in remote international markets, and of producing food within severe environmental conditions have together stimulated the development of technologies that in certain areas are unique to the country. As a result, South Africa can be classified as a rapid adopter of new technologies; global advances in fields such as communications, health, engineering, financial services and manufacturing are quickly absorbed into the operations of local companies.

In addition, many South African companies have become major global players within their fields. For instance, SAB Miller (formerly South African Breweries) is the second-largest beer-brewing company in the world; Sasol is the world's leading company in the conversion of coal and gas to liquid fuels; BHP Billiton (formally Billiton) is a major player in the mining sector; De Beers and Anglo American (together with its associated companies of AngloGold and AngloPlat) are also major international mining companies. This global reach has helped to maintain strong technology links with the global community and hence ensure that local companies use advanced technologies.

A further important strength both of and for local industry is the competitive pricing of R&D services. South Africa's research institutions typically operate in a lower cost environment than similar institutions in developed countries. As a result, the FTE researchers rate is between 60% and 70% of the rate within countries such as the USA and the United Kingdom. Although this is changing as a result of the international mobility of researchers and the need to provide competitive local salaries, South African institutions still provide a lower cost and attractive environment for the R&D activities of international companies.

6.3.3 Other Strengths

Linkages within the NSI. Although there is still a need for further improvement, the linkages within the NSI are strong and growing. As a consequence of the *White Paper on Science and Technology,* several policy initiatives were implemented that have resulted in joint projects and collaborations between industry and universities (such as THRIP and the Innovation Fund), between local and international universities, between government and the PRIs, and between small businesses and the research institutions (such as GODISA). The main weaknesses of the system do not arise from poor networks between existing actors, but are due to the absence of certain actors such as strong clusters of entrepreneurs and venture capitalists.

Research in the Higher Education Sector. In several areas of science, South African universities have played, and continue to play, leading international roles. For example, the country has strong research expertise in cardiology, immunology and aspects of environmental science (see Section 5.1.3). Graduates from South African universities are highly considered in other parts of the world and are able to make major contributions within the research institutions of other countries. There are, for instance, many South Africans in the world's leading universities, including the Universities of Harvard, Cambridge, Oxford, Stanford and the Massachusetts Institute of Technology. Apart from the four Nobel Prize winners in Peace, three South Africans have won the Nobel Prize for Medicine, one for Chemistry and two for Literature.[74]

Definition of the NSI. In comparison with many developing countries, the NSI in South Africa is well defined. The existence and roles of all the various institutions within the system are well understood; there is a clear separation between governance, funding and performance agencies; there is an annual R&D survey that provides an good basis upon which to develop new policies and policy instruments; and there is a set of national statistics covering aspects ranging from household income to industry manufacturing outputs and national accounts.

Many unique features of the NSI. This last comment perhaps falls in the category of opportunity rather than strength, but it is important nonetheless. South Africa is fortunate to possess many unique features that prompt and stimulate R&D and its conversion to innovation. For instance, the region has a huge biodiversity, with unique plants, animals and micro-organisms that have already revealed novel natural products for use in healthcare, manufacturing and other areas and will continue to do so. The geological formations in the region, characterised by a stable but high altitude interior plateau surrounded by regions of fold mountains and a low coastal belt, provide many unique opportunities to geoscientists interested in the geological history of the Earth and the formation of certain materials such as diamond. The clear

[74] See http://www.sahistory.org.za/pages/people/great-safricans/nobel-prize-winners.htm.

southern skies, in some areas also free of non-natural radiation, have drawn the attention of astronomers and cosmologists and resulted in the construction of local observatories and array telescopes. There are many fascinating archaeological sites containing evidence of life going back billions of years, but especially important to the studies of human evolution and the emergence of *Homo sapiens*. These natural strengths are helping South African researchers to build international networks, and hence gain from the experience of working with the world's best scientists, engineers and technologists. In many cases, our teams cannot offer their global partners state-of-the-art research tools and knowledge; however, these teams are able to offer the knowledge of local research opportunities that can be jointly tackled.

In summary, there are many strong features of the NSI, and the country can be justifiably proud of its achievements in the areas of innovation, novel technologies, the management of R&D and national systems, and the generation of knowledge through R&D. However, it is unfortunate that the benefits of a life enriched by economic progress and technology are restricted to so few. Some would characterise South Africa as two countries, one rich and developed, the other poor and undeveloped; the challenge for the NSI is to extend the privilege of development to the entire country.

Chapter 7: Specific Issues

The dramatic political changes of the 1990s brought to the surface a number of important issues for the NSI that had previously been neglected, or where progress had simply not been possible. In this chapter, four such issues are discussed in some detail, namely the internationalisation of S&T (which was necessary after years of isolation under apartheid), new sectoral policies, indigenous knowledge and the social dimensions of innovation. It should be noted that progress in all these domains is now evident, despite the long lead times in some areas, such as achieving widespread race and gender equity.

7.1 Internationalisation of S&T

7.1.1 European Union S&T Projects

South Africa and the European Union concluded a scientific and technological cooperation agreement in 1996. South African researchers have subsequently participated in more than 180 projects, cooperating with European partners in project consortia funded under the European Union's Fourth, Fifth and Sixth Framework Programmes (including the most recent calls under the Sixth Framework Top-up Programme).

South Africa is currently preparing to participate in the Seventh Framework Programme, to be launched late in 2006. The European Commission has estimated that during the Fifth Framework Programme, South African researchers participated in over 100 R&D projects, which received a total European Commission investment of close to €40 million. Statistics for the Sixth Framework Programme are currently being developed.

7.1.2 Africa Bilateral Relations

The key drivers of South Africa’s bilateral programme are to:

- Support programmes of the Southern African Development Community (see Section 7.1.3) and the New Partnership for Africa’s Development (see Section 7.1.4)
- Contribute to political and economic regional integration
- Harness strategic research partnerships to address common development priorities
- Market R&D products and services from indigenous communities.

African countries with which South Africa has bilateral programmes include Algeria, Egypt, Nigeria, Mali, Botswana, Namibia, Lesotho and Kenya. Examples of joint projects include:

- Potato tissue culture (Lesotho)
- Radioisotope production (Algeria)
- Indigenous medicinal plants and foods (Namibia)
- Nanotechnology for solar energy and rural applications (Senegal)
- Karoo Basin geological survey (Namibia and Botswana)

- Search for S&T content in the Timbuktu manuscripts (Mali).

7.1.3 Southern African Development Community

The African Cooperation Unit within the DST is responsible for engaging with partners in the Southern African Development Community to develop and strengthen national systems of innovation so as to provide scientific and technological solutions for sustainable socio-economic development and poverty eradication. The DST strategy is in line with the SADC Regional Indicative Strategic Plan, which recognises the importance of S&T in stimulating economic development, increasing the competitiveness of local industry and achieving regional economic integration.

The DST has engaged in a number of projects over the past few years to achieve these objectives. The projects have mainly targeted the following key areas:

- Policy development
- Capacity development
- Developing a legal framework for science and technology.

7.1.4 NEPAD S&T Projects

Following the adoption of the New Partnership for Africa's Development (NEPAD) as a development plan for Africa in August 2001, the *Plan of Action for Science and Technology* was developed and adopted in November 2003 by the African Ministerial Council for Science and Technology. This plan outlined priority areas of intervention in scientific research and technology to further the NEPAD social and economic goals.

Since then, the *Plan of Action* has been further developed into specific projects and timeframes through an interactive consultative process, which involved workshops held in all five regions in Africa. As a result, the *Consolidated African Science and Technology Plan of Action* was adopted during the second meeting of the African Ministerial Council for Science and Technology in Senegal in September 2005.

Projects already being implemented include:

- The African Laser Centre, which is a virtual network of laser research laboratories across the continent. This network was launched in November 2003 and has grown to include 18 participating institutions. The current programme involves more than ten funded research and capacity building projects. The South African government has provided financial support to the African Laser Centre since 2003.
- The African Biosciences Initiative is already in operation through focal points in all regions of the continent. The hub for southern Africa is hosted at the Council for Scientific and Industrial Research (CSIR) in South Africa. This network of biotechnology nodes in the region has put together programmes of cooperation in the life sciences and biotechnology, with an emphasis on agriculture, health, the environment and industrial manufacturing.
- The African Institute for Mathematical Sciences is already in its third academic year and has graduated its second cohort of students from all parts of the

continent. Plans are at an advanced stage to establish a network of similar institutions across all regions of Africa.

7.2 Infrastructure Investment and Sector Strategies

The government has already begun to increase public sector investment, which fell below 4% of GDP, but has risen above 6% of GDP in recent years. In order to reduce the backlog in the public infrastructure sector, public sector investment is planned to rise to a level of around 8% of GDP (equivalent to about R370 billion or PPP US$ 142 billion)[75] over three years.[76] Of this, about 40% will be spent by public enterprises, mostly Eskom (R84 billion or PPP US$ 32 billion) and Transnet (R47 billion or PPP US$ 18 billion), mostly on power generation, power distribution, rail transport, harbours and an oil pipeline. The general purpose is to improve the availability and reliability of infrastructure services in response to rapidly growing demand.

Electronic communications also constitute a key commercial and social infrastructure, and plans for implementation include:

- The implementation of a strategy to increase South Africa's broadband network
- The implementation of a plan to reduce telephony costs more rapidly
- The completion of a submarine cable project that will provide competitive and reliable international access, especially to Africa and Asia
- The provision of subsidies to encourage the establishment of telecommunications and labour-intensive business in poor areas.

Apart from infrastructure investment, sector strategies have been, or are being, prepared to promote private sector investment. Some of these are already being implemented. These initiatives are mostly managed and owned by the Department of Trade and Industry, which has recently prepared a *National Industrial Policy Framework*. (It is expected that this document will be adopted by Cabinet during 2006.) This framework covers a number of important sectoral issues including:

- Broad-based Black Economic Empowerment (see box) and small business development
- Specific initiatives for several sectors of the economy, including chemicals, metals beneficiation and capital goods, the creative industries (crafts, film, television and music), clothing and textiles, durable consumer goods, wood products, and pulp and paper.

The Department of Trade and Industry is also addressing several cross-cutting industrial policy challenges including:

- Low domestic competition and import parity pricing
- Limited capacity for trade negotiations
- Poor overall coordination of the *Africa Development Strategy*

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[75] The Rand-equivalent US dollar amount is presented to indicate purchasing power parity (PPP).
[76] See also www.info.gov.za/asgisa/.

- Better use of Broad-based Black Economic Empowerment to encourage industry transformation beyond the transfer of equity (see box).

Broad-based Black Economic Empowerment

One of the main objectives of the South African government is to create an economy that can meet the needs of all South Africans citizens in a sustainable way, including access to employment, opportunities for business ownership, the development of the necessary capacities and skills for full economic participation, efficient government services and high-quality infrastructure.

Broad-based Black Economic Empowerment has emerged as an inclusive approach to empowerment, aimed at narrowing the gap between the first and second economies. It is defined as an integrated and coherent socio-economic process that will directly contribute to the economic transformation of South Africa and bring about significant increases in the number of black people who manage, own and control the country's economy, as well as significant decreases in income inequalities.

In its endeavour to promote Broad-based Black Economic Empowerment, the government has released three critically important documents giving clear guidance on the measurement and implementation of Broad-based Black Economic Empowerment, namely the *Strategy for Broad-based Black Economic Empowerment* (issued in March 2003), the Broad-based Black Economic Empowerment Act (Act No. 53 of 2003), and the *Code of Good Practice on Broad-based Black Economic Empowerment*, which gives a detailed explanation of the approach adopted by the government in its measurement of Broad-based Black Economic Empowerment compliance.

It should be noted that the system is being implemented through a scorecard approach with seven elements, namely ownership, management, employment equity, skills development, preferential procurement, enterprise development and a residual element.

7.3 Indigenous Knowledge

7.3.1 Background

Two main developments have led to indigenous knowledge and indigenous knowledge systems (IKS) becoming an important item on the South African science, technology and innovation (STI) agenda. Firstly, the democratisation of the country in 1994 made salient and promoted the agenda (perspectives, traditions, needs and priorities) of the black population, who did not have political rights before 1994. Indigenous knowledge is an important component of the NSI and is covered in a range of contexts within the *National R&D Strategy* (see, for instance, indigenous knowledge and intellectual property (pp 67 and 68[77]); defining indigenous knowledge as a natural or competitive knowledge advantage (pp 16 and 52); the relationship between biotechnology, biodiversity and indigenous knowledge (pp 22); therapeutic regimes (p 43); agriculture (p 49); and poverty reduction (p 44). Secondly, the 'rediscovery' of indigenous knowledge systems in social science literature in the last decades of the 20th century also helped draw local attention to this field, especially since South Africa was aligning itself strongly with international best practice.

[77] Page number references are to the *National R&D Strategy*.

7.3.2 Indigenous Knowledge Systems Policy

An *Indigenous Knowledge Systems Policy* was approved in 2005 as "an enabling framework to stimulate and strengthen the contribution of indigenous knowledge to social and economic development in South Africa" (DST, 2005). The drivers of the policy include the affirmation of African cultural values, the development of indigenous knowledge services and interfaces with other knowledge systems. Functions and structures required for the implementation of the policy include development, the recording of indigenous knowledge and practitioners, networking and the protection of indigenous knowledge-based intellectual property. The IKS policy proposes the establishment of an IKS Fund that would provide grants and incentives, project financing, venture capital and targeted investment.

The policy is being implemented by a division of the DST, and attention is currently being given, firstly, to recording indigenous knowledge and, secondly, to the necessary governance and administrative structures.

7.3.3 R&D in Indigenous Knowledge

IKS is one of the nine Focus Area Programmes of the National Research Foundation (NRF) (see Section 4.3.1), which runs the programme on an agency basis for the DST. For this purpose, the NRF has an annual ring-fenced budget of R10 million or PPP US$ 3.8 million, and it reports separately on the outputs and outcomes of the programme. The purpose of the programme is "to support research and human resource development in the field of indigenous knowledge" (NRF, 2006: 33). To date, the programme has supported 109 projects, covering a broad spectrum of scientific disciplines, from history, religion and intellectual property rights to archaeology, tourism and marketing, biotechnology and medicine. Apart from the support for IKS research through the National Research Foundation, many of the PRIs also manage research projects in the field of IKS, and NACI is tasked with advising the Minister of Science and Technology on IKS.

The importance of indigenous knowledge and IKS has already been recognised in a number of ways. For instance, IKS has become established as a legitimate topic of research in a range of disciplines; it is covered in certain scholarly journals, especially in the social sciences; it attracts funding in a limited number of countries; and it is recognised as a priority in an even smaller number of national STI policies. As a result, support for R&D in the field of indigenous knowledge and IKS can be expected to remain a salient item on the national agenda (and therefore also on institutional and programmatic agendas) for many years.

7.4 Social Dimensions of Innovation: Addressing Inequity

7.4.1 Background

The NSI is marked by a range of skewed social distributions that require priority attention in public STI policy. From the perspective of this background document, the two primary issues are, firstly, the overlap between poverty and race in the country, and secondly, the disproportionately low representation of previously disadvantaged individuals (black Africans and women) in the NSI. The skewed distributions are clear from the data provided in Chapter 5 of this report, and only selected data are offered in this section in order to underscore the basic thesis of inequality and the justification for redress as expressed in various policies.

7.4.2 Race and Socio-Economic Development

South Africa has one of the highest Gini coefficients in the world, namely 0.59. Many factors co-produce this disparity, one of which is the urban–rural divide. The country consists of an urbanised industrial first world component (56% of the total population) at the one extreme and a deep-rural, mostly black African, developing third world component (44% of the population) at the other extreme. These contrasts are reflected in the data presented in Tables 36 and 37.

Table 36. Education status of South Africans (adults over 20 years of age) (data expressed as a percentage of the total)

Region	No formal education	Some primary	Primary completed	Some secondary	Secondary completed	Higher education
Rural	32.5	21	6.6	24.9	11.4	3.6
Urban	9.3	13.1	6.2	34.4	25.8	11.2

Table 37. Employment status of South Africans (15–65 years old) (data expressed as a percentage of the total)

Region	**Employed**	**Unemployed**	**Not economically active**
Rural	23	22.4	54.6
Urban	40.5	25	34.5

As a result of these disparities, the development of the disadvantaged people of South Africa has become a national priority. The recently launched Accelerated and Shared Growth Initiative for South Africa, for instance, sets the target at halving unemployment and poverty by 2014.[78] Likewise, public entities such as the DST (through poverty eradication initiatives), the Department of Education (by upgrading under-qualified teachers), the Department of Trade and Industry (by supporting SMMEs), PRIs and NACI are all committed to contributing to this priority. A range of programmes have been developed with the aim of utilising STI for development, rather than only for achieving the usual international criteria of excellence, frontier breakthroughs and competitiveness. Other consequences of this duality in the functions of STI are, for instance, that innovation is regarded, at least in part, as a social/political process and product, rather than merely a technological one, and that IKS is included in most of the strategic plans at national, sectoral and institutional levels.

[78] See www.info.gov.za/asgisa/.

7.4.3 Redressing Inequities Based on Race

A second set of social factors impacting on the NSI is the skewed racial distribution at all levels of the NSI. Africans are significantly under-represented. A range of initiatives is being followed to redress this situation including the following.

Firstly, the number of Africans passing the final secondary school examination in mathematics and science at a level that complies with university entrance requirements for science, engineering, medical and related studies at university low in comparison to their demographic proportion (see Tables 38 and 39). Furthermore, a white or Indian pupil is eight times more likely to meet the university entrance requirements for mathematics and science, than a black pupil.

Table 38. Number of passes in mathematics (higher grade) in the Senior Certificate examination by race and gender (2005)

	Male	**Female**	**Total**
Black	3 780	2 091	5 871
Coloured	814	772	1 586
Indian	1 486	1 609	3 095
White	5 955	5 546	11 501
Other	53	80	133
Total	**12 088**	**10 098**	**22 186**

Various programmes and instruments are being implemented to accelerate the flow of African students into graduate schools. These efforts take place against the background of noticeable shifts at first-degree level, where the percentages of Africans and whites shifted from 39% Africans compared with 53% whites in 1995, to 50% Africans compared with 35% whites in 2002. The need to address this priority is made more salient by factors such as the target annual economic growth rate of 6% and the low proportion of R&D workers in the population.

Table 39. Number of passes in physical sciences (higher grade) in the Senior Certificate examination by race and gender (2005)

	Male	**Female**	**Total**
Black	4 292	2 639	6 931
Coloured	847	716	1 563
Indian	1 694	1 763	3 457
White	6 380	4 733	11 113
Other	59	81	140
Total	**13 272**	**9 932**	**23 204**

Another level at which racial disparities are manifest is the under-representation of Africans in scientific posts in higher education and PRIs. The latest available data, for instance, show that Africans represent 36% of academic and research staff at HEIs. The importance with which this aspect of the NSI is regarded is illustrated by the fact that the redress of past inequalities is a performance indicator for all public STI institutions.

Publication trends also represent a set of racial disparities. Publication trends for the period 1990 to 2002 show that white researchers were responsible for about 98% of all publications, with some variation depending on the category (see Table 40) (Mouton, Boshoff & Tijssen, 2006).

Table 40. Publications by black researchers (percentage of total publications) (1990 to 2002)

Year	South African ISI journals %	International ISI journals %	SA non-ISI journals %
1990	0.5	0.4	0.8
2002	2.1	3.0	3.2

These data show that while black researchers are increasing, their numbers still lag far behind those of their white colleagues.

7.4.4 Redressing Inequities Based on Gender

Achieving gender equity is one of the principles of South Africa’s constitution, and some progress has been made in this regard. For instance, 37% of Parliamentary representatives and 46% of Cabinet ministers are women. Gender equity is also one of the objectives of the NSI, but one that has not yet been realised (South African Reference Group on Women in S&T, 2004). For instance, women account for about 64% of undergraduate registrations, but only 43% of masters and doctoral graduates. Women are also in the minority in enrolments for doctoral degrees in science, engineering and technology (31% compared with 69% for men). The proportion of women in permanent academic or research positions at universities and PRIs is steadily increasing (see Table 41) but a smaller proportion of women than men occupy chairs (7% of women academics, compared with 26% for men).

Table 41. Women in permanent academic and research staff positions (percentage of total)

Year	1992	1996	2001
Higher education	30%	n.a.	40%
Science councils	n.a.	35%	42%

In view of such disparities, gender equity can be expected to remain on the NSI agenda for some years to come.

Chapter 8: Main Conclusions and Way Forward

This chapter offers a summary of the main conclusions emerging from an overview of the NSI and offers a limited set of suggestions on likely future developments over the medium term. The chapter first characterises immediate past developments and challenges. It then offers an assessment of the current situation and an identification of immediate challenges before concluding with a select set of probable future developments.

8.1 Looking Back

Dynamics of the first decade of the NSI

The NSI has undergone far-reaching changes over the past ten years. These changes were driven by the overarching policy imperative of instituting an equitable system to replace the legacy of apartheid, and at the same time bringing the NSI in line with international thinking and best practice. The changes took place within the context of intense competition for resources between various national priorities, making the transition and its progress even more remarkable. At the base of this competition is the duality of the country's economy, namely the fact of a first world economy that is able to compete internationally, and the existence of a second economy marked by isolation, extensive poverty and limited life opportunities. The end product of the transformation process will be a new system that at least conceptually reflects international thinking while addressing local realities (Marais, 2000: 161).

Assessment of the transformation process

Policy analyses, review studies and qualitative evaluations of the transformation process and its outcome, of which there have been several in recent years, suggest that the country has succeeded in developing an extensive set of appropriate policies and strategies, and that it has made significant progress in their implementation, although the resource requirements have not increased in direct proportion to the extent of the changes.

The unintended consequences of some of these changes have not been formally assessed, but it is suggested that some of the new policies, strategies and initiatives within and between sectors may raise problems such as duplication, inconsistent outcomes, elimination of effects, renewed fragmentation and even inefficiencies. One example is the potential effects of the HEI mergers on the S&T productivity of researchers. Another example is the possible influence of human resource shortages on strategies, such as the Centres of Excellence initiative and the Research Chairs programme.

8.2 The Current Situation

The following comments offer a first order, and therefore somewhat abstract, characterisation of the current NSI:

- Notwithstanding the wide range of serious developmental challenges faced by the country, S&T and R&D are being promoted and supported by the South

African government as important priorities. The government recognises that investment in R&D is essential to economic growth and wealth creation and has put measures in place to increase its investment in innovation activities, as well the investment of the business sector.

- The NSI is a dynamic and relatively complex system, which, although characterised by continuous transformation and some areas of overlap, does not show serious signs of instability. It is a fairly strong system with respect to the diversity and size of institutions, but its further growth will be severely inhibited by human capital and skills shortages.

- Against the historical background of a relatively long history of S&T activity in the country, dating back to the 19^{th} century, the past ten years have seen far-reaching transformation, including new missions, new governance and management structures and new approaches to institutional configurations.

- The changes have led to improvements in many areas, including increased cohesion, a stronger focus on innovation, rising R&D expenditure by the business sector and stronger links both within the NSI and with international systems. About 10% of South Africa's R&D is financed from abroad, with the bulk of foreign funding for local business R&D coming from the parent or associated international company. It is clear that South Africa is beginning to take part in the global economy.

- The system is marked by relatively strong steering by central government. S&T priorities are inferred from national imperatives, and in some cases these are taken relatively far into implementation stages by organs of central government, while the role of intermediary bodies is limited largely to the end stages of the process, such as implementation. Central government uses a range of instruments to steer the system, including financial instruments and organisational restructuring.

- A reasonable amount of indicator-type information on the performance of the NSI is available. The inevitable time lag between the implementation of new policies (and associated instruments) and the manifestation of their effects and impact make it very difficult to evaluate the effects of the new policies at this stage. However, it can be concluded that the country's performance in absolute terms has remained stable or has grown slightly, but that in relative or comparative terms, the South African NSI has fallen behind progress in other countries at similar levels of economic development.

- The business sector accounts for more than half of the country's R&D activity, followed by the higher education sector, with the PRI sector close behind. There are several examples of world-class companies with extensive R&D activities, which will continue to be the backbone of innovation within the NSI. The HEIs are mostly under financial pressure, with the result that there are clear signs of mission creep in this sector (as institutions attempt to access other sources of income).

- Components of the NSI are subject to regular reviews, including international reviews, at programme, institutional and sectoral levels, and the outcomes of such reviews are used as the basis for medium-term planning.

- The innovation chasm between upstream R&D and downstream innovation appears to remain relatively stable at an unsatisfactory level. A range of funding instruments is available to the private sector, although optimal use is not being made of them.

8.3 Looking Ahead

In the light of the discussion in the previous chapters of this report, a number of predictions can be made with respect to possible future changes in the policies and in resourcing the NSI. These predictions, which are not exhaustive and are not made in order to pre-empt the conclusions of the OECD review, but in order to establish some points of further discussion, now follow:

Stabilisation of inter-institutional relationships

It can be expected that the intended and unintended (if any) effects of the mergers of higher education institutions will manifest themselves in the course of the next two years and that issues such as the following will have to receive attention:

- Instruments to guide the primary roles (such as the training of high-level human resources for the NSI and the nature of research portfolios) of the HEIs and their S&T productivity
- Mission creep between institutions in the different sectors of the NSI.

Optimising the contribution of S&T to national programmes

The government has recently launched several country-wide programmes to ensure that the country attains and sustains a 6% annual economic growth rate, namely the Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative for Priority Skills Acquisition (see Section 5.2). Already, a list of priority skills has been issued; it is now incumbent on the HEIs and the PRIs to respond to this list by adding their collective weight to the training and acquisition of the required human capital.

Skills development will not be the only role that the NSI can play in these two programmes; the system has other roles, including ensuring the provision of the necessary infrastructure and providing new knowledge that can be incorporated into the growing economy.

Narrowing the innovation chasm

A substantial part of South African S&T policy is aimed at promoting innovation, yet data presented in Chapter 4 indicate that the chasm between R&D and innovation has not narrowed sufficiently. Given the primary importance of this national systems goal, issues such as the following require serious attention:

- More effective support for the innovation activities within SMMEs and the broader business sector through the launch of new programmes and policies to optimise the resources of these important sectors in developing new products, services and processes, especially in areas of national strategic relevance such as advanced manufacturing and biotechnology
- Development of a model for, and hence a greater understanding of, the innovative firm, in order to ensure that new instruments are better aligned with the needs of such firms
- Adjustment of existing instruments and the development of additional ones to narrow the innovation chasm significantly
- Development of new modes of knowledge production and the resourcing thereof, which would help narrow the innovation gap.

Provision of appropriate human resources

Various sections of this background report have highlighted the critical shortages of appropriate human resources, given the historical distortions in the system on the one hand, and the national goal of attaining a 6% economic growth rate on the other. As a matter of fact, the current shortages of skills set an upper limit to the economic growth of the country. The following generic issues are likely to remain on the national agenda over the next few years:

- Innovative strategies to address the skills shortages at all levels of the system
- The development of a balanced and dynamic policy to retain locally grown skills, facilitate the recruitment of skills abroad and optimise skills transfer between the latter and South African talent.

Appendix A: Selected Literature List

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Appendix B: List of Acronyms and Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
Armscor	Armaments Corporation of South Africa
ASGISA	Accelerated and Shared Growth Initiative for South Africa
ASSAf	Academy of Science of South Africa
BERD	Business expenditure on R&D
BioPAD	Biotechnology Partnerships and Development
CSIR	Council for Scientific and Industrial Research
DST	Department of Science and Technology
dti	Department of Trade and Industry
Eskom	Electricity Supply Commission
EU	European Union
FDI	Foreign direct investment
FTE	Full- time equivalent
GDP	Gross domestic product
GEAR	Growth, Employment and Redistribution Strategy
GERD	Gross expenditure on research and development
HDI	Human Development Index
HIV	Human immunodeficiency virus
IBSS	International Bibliography of Social Sciences
ICT	Information and communications technology
IKS	Indigenous Knowledge System
ISI	Institute for Scientific Information, Philadelphia
Mintek	Council for Mineral Technologies
MVA	Manufacturing value added
NACI	National Advisory Council on Innovation
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental organisation
NRF	National Research Foundation
NSF	National Science Foundation
NSI	National System of Innovation
NSI	South African National System of Innovation
OECD	Organisation for Economic Cooperation and Development
PPP	Purchasing price parity
PRI	Public research institution
R	Rand
R&D	Research and development
RDP	Reconstruction and Development Programme
S&T	Science and technology
SA	South Africa
SADC	Southern African Development Community
SAIS	South African Innovation Survey
SEDA	Small Enterprise Development Agency
SMMEs	Small, Medium and Micro Enterprises
SPII	Support Programme for Industrial Innovation
STI	Science, technology and innovation
TAI	Technology Achievement Index
TEA	Total Early-stage Activity TEA
THRIP	Technology and Human Resources for Industry Programme

ToR	Terms of reference
UK	United Kingdom
US/USA	United States of America

Appendix C: Institutional and Programme Reviews Undertaken since 2000

Institution or Programme Reviewed	Commissioned by	Date	Reference
Former Centre for Science Development and Foundation for Research Development	National Research Foundation (NRF)	April 2000	NRF website
Agrarian Research Development Programme (ARDP)	The Royal Society/National Research Foundation	November 2000	NRF website
The Royal Society/National Research Foundation (NRF) SET programme evaluation report (1996 to 2001)	The Royal Society/National Research Foundation	April 2001	NRF website
National Research Foundation (NRF) Programmes directed at research and research capacity development at technikons	NRF	August 2001	NRF website
NRF programmes directed at research and research capacity development at historically black universities (HBUs)	NRF	September 2001	NRF website
Medical Research Council	DST	2001	DST
Travelling Institute for Music Research in South Africa (TIMR)	NRF	March 2002	NRF website
Technology and Human Resources for Industry Programme (THRIP) evaluation report	dti and NRF	June 2002	NRF website
Council for Geoscience	DST	2003	DST
Council for Scientific and Industrial Research	DST	2003	DST
Human Sciences Research Council	DST	2003	DST
Africa Institute of South Africa	DST	2004	DST
Agricultural Research Council	DST	2004	DST
Mintek	DST	2004	DST
Physics in South Africa	DST, NRF, South African Institute of Physics	April 2004	NRF website
South African Institute for Aquatic Biodiversity (SAIAB)	NRF	September 2004	NRF website
iThemba Laboratory for Accelerator Based Science	NRF	November 2004	NRF website
NRF Institutional Review, incl. national facilities	NRF at the request of DST	February 2005	NRF website
National Laser Centre Rental Pool Programme Review	NRF at the request of DST	2005	NRF website (ToR)
African Coelacanth Ecosystem Programme	NRF at the request of DST	November 2005	DST

Appendix D: Rand to PPP US$ conversion rates

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
PPP US$	1.6	1.69	1.80	1.91	2.02	2.15	2.24	2.44	2.50	2.60

Appendix E: Relevant Websites

Body	**Website**
1. Academy of Science of South Africa	www.assaf.org.za
2. Council of Higher Education	www.che.ac.za
3. Department of Education	www.education.gov.za
4. Department of Labour	www.labour.gov.za
5. Department of Science and Technology	www.dst.gov.za
6. Government Communications Information System	www.gcis.gov.za
7. Higher Education South Africa	www.hesa.ac.za
8. Human Sciences Research Council of South Africa	www.hsrc.ac.za/RnDSurvey/
9. National Advisory Council on Innovation	www.naci.org.za
10. National Treasury	www.treasury.gov.za
11. South African Government	www.gov.za
12. South African Qualifications Authority	www.saqa.org.za
13. South African Reserve Bank	www.resbank.co.za
14. Statistics South Africa	www.statssa.gov.za
15. Trade and Industrial Policy Strategies	www.tips.org.za