Chapter 2

AN INNOVATION SYSTEM IN TRANSITION: MAIN FEATURES AND CURRENT POLICY CHALLENGES

This chapter reviews the transformation of the South African innovation system since the early 1990s. It first recalls key features of the system as it was at the beginning of that decade and which must have seemed at the time to offer very limited prospects for meeting the goals of a radically changed society as it entered an unfamiliar international and rapidly evolving environment. It then turns to the present and highlights the considerable success achieved in broad areas of the system's performance in spite of the unpromising initial conditions. It moves on to describe some of the sources of that success: recent policy developments, the structures developed for policy-making and implementation, and certain features of the main research and innovation performers. It concludes by noting some of the challenges still to be addressed.

2.1. The innovation system in the early 1990s

At the beginning of the 1990s the prospects must have appeared very dim for developing an innovation system able to support rising living standards for all the country's citizens. Such a system would require well-articulated structures able to interact with the outside world from positions of excellence and strength in science and technology (S&T). It was not that important building blocks for such a system were lacking. Indeed, there were strong components of such a system in universities, public research institutes and business enterprises. Moreover, these had clearly been remarkably effective in helping to achieve many of the aims of South Africa's dominant interest groups. For example, a successful defence industry had enabled the country to become self-sufficient in armaments and to capture a substantial export market;[19] technological developments and applications had enabled large-scale agriculture, owned by the white

19. The country was one of the few in the world to have developed a nuclear weapons capability.

population, to ensure self-sufficiency in food supplies (for those able to purchase them); an internationally competitive mining industry was based on leading technologies that had been adapted for the peculiarities of mining in South Africa; the country was the leader in commercial-scale technology for deriving liquid fuels from coal; and high quality medical research supported international standards of health care for the advantaged white community.

However, it was doubtful that the system that had delivered those achievements could be transformed into an innovation system which could help to achieve objectives such as a broad base of internationally competitive economic activity that would generate rising levels of per capita income for the population as a whole. The economic, social and political framework conditions for such a system did not exist nor did the economic basis for it. Following a period of high growth based on inward-looking import substitution until the mid-1970s, the decay of that regime took place over the next two decades. This was a fairly common phenomenon in the international economy after the 1970s, but in South Africa it was uniquely entangled with the apartheid economy, and the country became more completely disconnected from the international economy during the 1980s.

By the early 1990s the economic picture was bleak. After nearly 20 years of low or zero growth in GDP, income per head in 1994 was about the same as it had been in the mid-1960s. Gross fixed capital formation had fallen from around 30% of GDP through the 1960s and 1970s to about 20% in the 1980s and then to roughly 15% in the early 1990s. Consequently the capital stock had become smaller, older and outdated. Yet in spite of the collapse of growth and investment, the rate of inflation had been high since the late 1970s, at rates of around 10-15% a year, largely owing to macroeconomic policies intended to prop up the decaying regime, with rapidly growing public expenditures and a heavy commitment to defence and security. In many respects, therefore, South Africa in the early 1990s had many of the features of the centrally planned economies that had very recently passed through various forms of collapse, usually leading to the decimation of their science, technology and innovation systems.

In addition, job creation had fallen to low levels during the 1980s, except in the apparatus of the apartheid government, and unemployment had reached an extremely high level, although the precise figure was not known. Some estimates suggested it had reached around 40% of the economically active population by 1994, compared to 19% in 1970. This was associated with the world's most unequal income distribution, which was matched by a similarly unequal distribution of basic necessities: food, housing, health care and education. These inequalities were split sharply along racial lines.

At the same time, the economy was largely based on primary production, especially in capital-intensive mining and associated heavy downstream industries, and appeared to hold little potential for escaping this situation through rapid growth and employment creation. Concentration on the primary sectors actually increased during the late 1980s as output and employment in many areas of manufacturing declined.[20]

Nor had the earlier growth phase of import substitution led to the creation of a substantial civilian capital goods manufacturing sector, except in a few areas of machinery and equipment for the mining and related industries. As a result, this important potential locus of innovative activity was very narrow. However, there was considerable production of capital goods for the defence sector, including a very large commitment to the development of nuclear weapons, and a substantial fraction of the country's innovative capability was tied to these areas of production.

It was clear that large swathes of heavily protected (civilian) and heavily subsidised (defence) manufacturing would not be internationally competitive under a more open trade regime. But other routes to income and employment growth faced an obstacle created by a feature of the apartheid economy: the exclusion of the non-white, especially African, population from more than very basic levels of education and training. There was no large pool of skilled (or even semi-skilled) labour to mobilise in the development of a different kind of export-driven economic growth.

Responsibility for the governance of the science, technology and innovation (STI) system was not formally vested in any particular government department but distributed across different sectoral departments. A very large fraction was concentrated in three areas with differing types of government oversight. One component was committed to research, development, engineering and innovation associated with defence objectives and was closely controlled at the heart of government. A second major government commitment was to science and technology for innovation in the mining and related industries, implemented via the public funding of research, the creation of large state enterprises in key areas of technology (*e.g.* Sasol in coal-based fuel and Eskom in electrical power), and the financing of related industrial projects by the Industrial Development Corporation (IDC). A third substantial commitment was to technological support for large-scale and resource-intensive agriculture via the Agricultural Research Council.

20. Not surprisingly, some commentators discussed prospects for a reversion to primary production.

Control and management of the business enterprise segment of the innovation system was very heavily concentrated in a small number of large corporations. In the early 1990s six large and highly diversified business groups controlled more than 80% of the market capitalisation of the Johannesburg Stock Exchange and governed a very large share of all technology development and innovation by private sector business.

Moreover, technology development and innovation by government and business actors were rooted in strong systemic structures. There was intensive innovation-related interaction among a wide range of organisations – funding bodies within government departments; public technology institutes (*e.g.* the science councils); university departments (*e.g.* mining and materials technology at the University of the Witswatersrand); state co-ordinating agencies for technology development and acquisition (*e.g.* the Atomic Energy Commission and Armscor. South Africa's Armaments Corporation); in-house research, development and engineering groups in private enterprises, along with their collaborative research associations (as in the mining industry); state enterprises like Sasol or Eskom; and public organisations to finance large-scale applications of new and acquired technology (*e.g.* the IDC). Further, these closely interacting organisations were embedded in and aligned with a nexus of institutional relationships involving the political alignments of interest groups as well as their influence over the relevant organs of government and the concentrated resources of the business sector.

In other words, although the language was not used at the time, there was a highly articulated, interactive and purposefully shaped science, technology and innovation system. Consequently, if post-1994 South Africa was able to avoid the decimation of its science, technology and innovation system as a result of some combination of economic collapse and social disintegration stemming from extreme, racially defined inequality, it nonetheless faced the challenge of radically transforming that system. This was a much more difficult task than simply reinforcing its existing growth trajectories or marginally reorganising some of its elements. Instead, across a wide range of areas, the directions of scientific, technological and innovative effort would have to be reoriented to support fundamentally different social, economic and political aims in a new context of interaction with the global economic and technological environment. This represented a daunting task precisely because of the system of strongly interconnected actors that were deeply embedded in pervasive social, economic, bureaucratic and political relationships.

2.2. Innovation system performance today

Data on research and development (R&D) are readily available in South Africa, especially since the latest survey undertaken by the Human Sciences Research Council (HSRC) and despite some limitations in their scope. This section draws on the data to describe key aspects of the R&D component of the innovation system across all sectors of the economy. Then innovation survey data, also subject to considerable limitations, are used to illuminate wider aspects of innovation, but only in manufacturing industry.

2.2.1. Overall R&D performance

South Africa's investment in R&D as a proportion of gross domestic product (GDP) is consistent with its status as a middle-income industrialising country, although the national average conceals wide disparities between the first and second economies. It shares with most other countries the desire to become more R&D-intensive. The fact that business expenditure on R&D is a large proportion of the total is an unusual strength. The concentration of much of this R&D in a limited number of large companies provides a strong base upon which to build, although widening the number of companies involved in R&D should clearly be an objective. In order to provide the human capital needed to expand industrial R&D, South Africa will need to invest in more research in the higher education sector.

Race and gender inequalities within the R&D system are narrowing, but the fact that major parts of the industrial and academic R&D system are headed by older white males implies a need to overcome the shortage of suitably qualified people not only to enable growth but also to replace the current leadership as it retires.

South African companies appear to have a high propensity to innovate, but they devote a rather low proportion of sales to wider innovation activities. They are strongly linked with innovation partners outside the country, probably owing to substantial inward technology transfer. These external linkages need to be complemented by stronger national supply-chain relationships if the innovation system is to work well.

Table 2.1. R&D performed by business enterprises in selected countries ranked by the GERD/GDP ratio

Countries	GDP per capita (2004 PPP USD)	GERD as percentage of GDP (2004)*	% of GERD performed by business enterprises (2004)*
Sweden	29 540	3.95	74.1
Japan	29 291	3.13	75.2
Korea	20 471	2.85	76.7
United States	39 678	2.68	70.1
Denmark	31 914	2.48	68.0
Singapore	28 860	2.25	60.8
Canada	31 263	1.99	54.0
United Kingdom	30 821	1.88	65.7
Netherlands	31 790	1.78	57.8
Norway	38 453	1.61	54.8
Ireland	38 827	1.20	64.5
New Zealand	23 932	1.14	42.5
Spain	24 992	1.07	54.4
South Africa	**11 393**	**0.87**	**56.3**
Portugal	19 629	0.79	33.2
Turkey	7 752	0.66	28.7
Greece	22 205	0.62	30.1
Poland	13.316	0.58	28.7
Argentina	13 302	0.44	29.0
Mexico	9 776	0.43	34.6

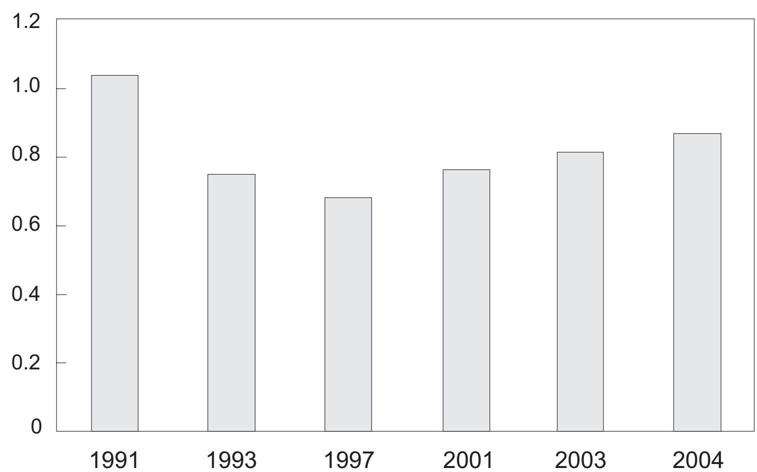
* Or nearest date for which data are available.

GERD = Gross expenditure on R&D.

Sources: GDP per capita 2004 PPP USD) – World Bank, *World Development Indicators*; R&D, South Africa – Centre for Science, Technology and Innovation Indicators, Human Sciences Research Council, *National Survey for Research and Experimental Development (R&D), 2004/05 Fiscal Year*; R&D, other countries – OECD, *Main Science and Technology Indicators 2006 (1).*

According to the 2004/05 survey,[21] South Africa's gross expenditure on R&D (GERD) was ZAR 12 billion or 0.87% of GDP, which represents an increase over the equivalent 2003/04 figure and is part of a longer-term increase from the low of 1997, when expenditures of ZAR 4.1 billion (0.69% of GDP) were recorded (Figure 2.1). The sudden decline in R&D between 1991 and 1993 is explained by the end of the period during which the apartheid government heavily funded the national military-industrial complex in response to South Africa's international isolation. In recent years, the government has sought to reverse the decline in GERD and in 2002 it adopted the National Strategy for Research and Development, which aims to double government investment in science and technology by 2008 and increase the R&D/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 well below the OECD average.

Figure 2.1. GERD as a percentage of GDP

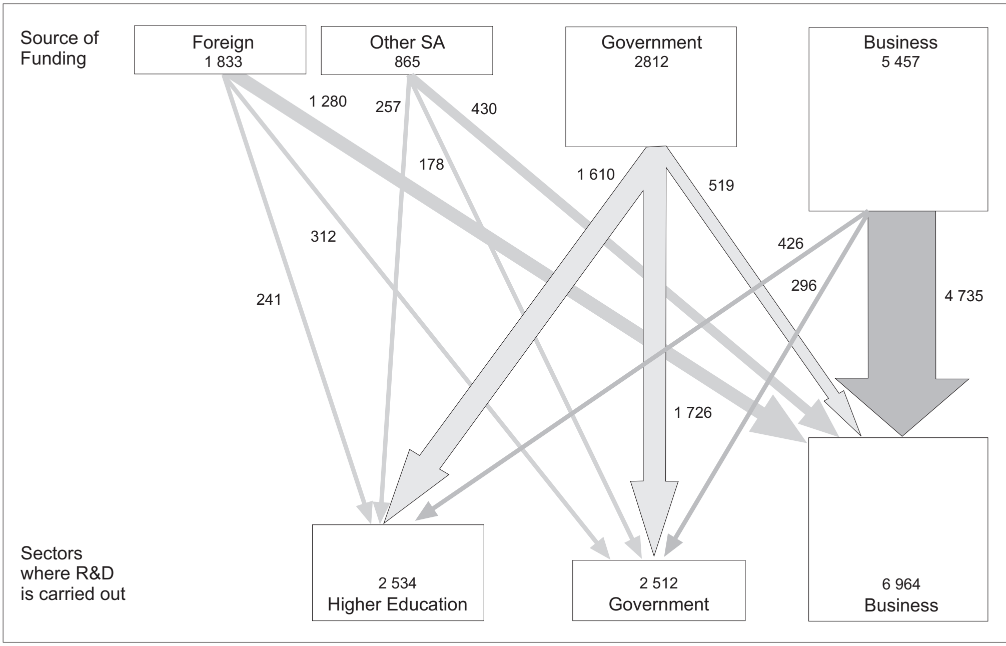


Source: Background report.

21. This was the first survey of R&D in South Africa to be accepted by the OECD. The survey's coverage of business expenditure on R&D (BERD) has probably improved in the past five years, so recent increases may reflect a combination of better measurement and genuine growth in BERD. A second issue is the large (in terms of the number of people involved) "second" or informal economy, a sign that official estimates tend to understate the size of GDP.

Figure 2.2. Major flows of funding for R&D, 2004/05

ZAR millions



Source: Background report.

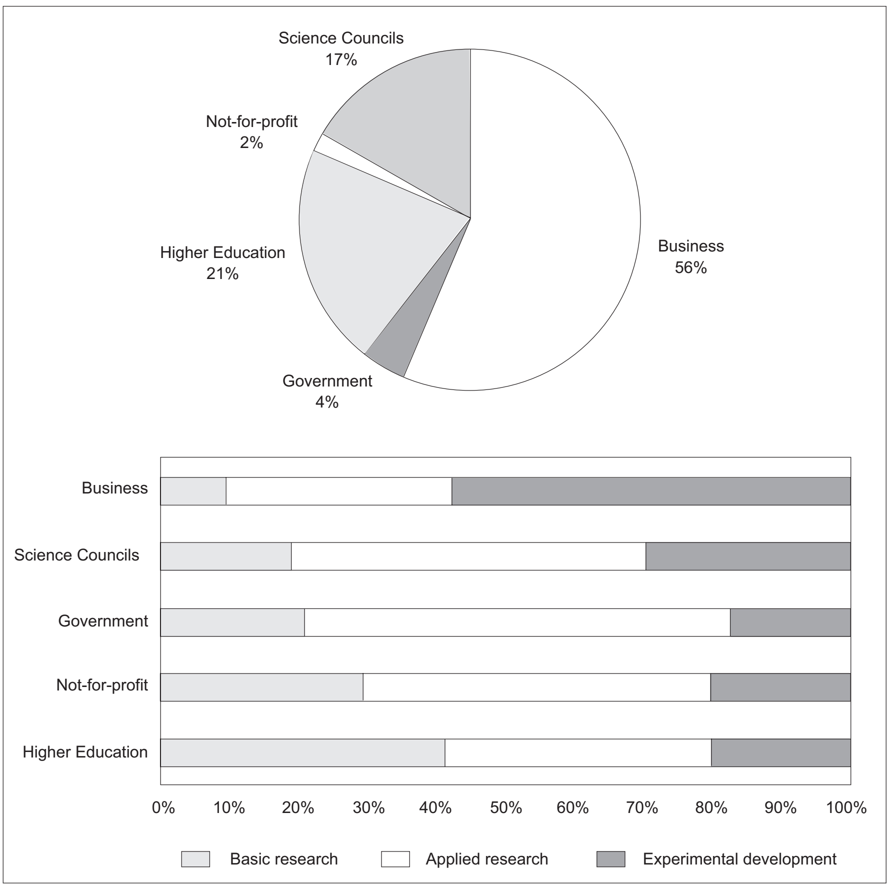
Government funds 33% of South Africa's R&D and performs 21% (Figure 2.2). Insofar as a declining share of government funding is normally taken as an indicator of development, this places South Africa firmly within the OECD funding pattern. The business sector in South Africa funds 45% and performs 58% of total R&D. The higher education sector undertakes 21% of R&D. About 15% of South Africa's R&D is funded by international sources 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 public research institutes (PRIs) and higher education institutions (HEIs) is derived from a number of competitive public funds such as the European Union Framework Programmes, the Ford Foundation, the US National Institutes of Health, various United Nations and World Bank programmes and funding for bilateral and multilateral science and technology agreements managed through the Department of Science and Technology (DST and its counterparts abroad. An important inflow of research funding is associated with HIV/AIDS research, since

South Africa has an advanced research infrastructure compared to other African countries.

Figure 2.3 shows how GERD splits among the different R&D-performing institutions in South Africa and the type of R&D done by each. Business naturally focuses most on experimental development, while the higher education sector has the highest share of basic research. The science councils have an intermediate profile that should equip them to relate more directly than universities to industry.

Figure 2.3. Type of R&D by performing sector, 2004/05



Source: R&D Survey, 2004/05.

Overall, R&D activity is most heavily concentrated in the engineering and natural sciences. Life sciences are also important, and information and communication technology (ICT) appears to be growing (driven mainly by industrial expenditure). Table 2.2 shows that there are big differences among the classes of R&D performers in terms of the proportion of effort they devote to different fields. Business focuses most on engineering and applied sciences but also makes a significant effort in health. Government takes responsibility for agriculture, while the higher education sector focuses especially on medical and health sciences and engineering. Here, too, the profile of the science councils is more industry-like than that of the higher education sector.

Table 2.2. Proportions of R&D expenditures by performer and field,* 2004/05

	Business	Govern-ment	Higher education	Science councils	Total
Mathematical sciences	1%	4%	5%	1%	2%
Physical sciences	3%	2%	6%	3%	4%
Chemical sciences	7%	2%	6%	2%	6%
Earth sciences	1%	7%	6%	5%	3%
Information, computer and communication	20%	3%	6%	8%	15%
Applied sciences and technologies	13%	1%	3%	3%	9%
Engineering sciences	32%	2%	19%	25%	27%
Biological sciences	2%	12%	12%	11%	6%
Agricultural sciences	3%	39%	6%	22%	8%
Medical and health sciences	15%	19%	27%	13%	17%
Environmental sciences	1%	4%	2%	3%	2%
Material sciences	1%	0%	2%	4%	2%
Marine sciences	0%	5%	1%	1%	1%

*Excluding social sciences.

Source: R&D Survey, 2004/05.

Table 2.3. Distribution of R&D workers, 2004/05

	Business enterprise	Government	Higher education*	Not-for-profit	Science councils	Total	%
Headcount							
Researchers	6 575	692	27 603	285	1 846	37 001	65.5
Technicians	3 724	494	2 801	40	1 582	8 641	15.3
Other personnel	4 038	1 125	2 722	184	2 742	10 811	19.2
Total	14 337	2 311	33 126	509	6 170	56 453	100
%	25.4	4.1	58.7	0.9	10.9	100	
FTEs							
Researchers	5 300.66	491.05	10 339.79	234.18	1 548.83	17 915	60.3
Technicians	2 856.53	376.25	568.1	30.69	1 344.13	5 175.7	17.4
Other personnel	3 138.8	800.02	473.04	97.81	2 096.6	6 606.3	22.2
Total	11 295.99	1 667.32	11 380.93	362.68	4 989.56	29 696	100
%	38	5.6	38.3	1.2	16.8	100	

FTE = full-time equivalent.

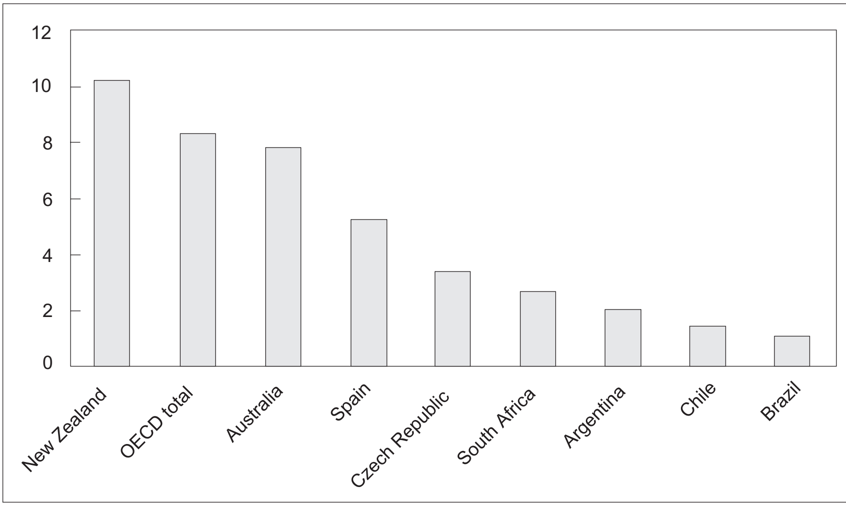
*Includes PhD students.

Source: R&D Survey, 2004/05.

South Africa has a total of 29 696 full-time equivalent (FTE) R&D personnel, comprising researchers, technicians and other support staff (Table 2.3). Of this total, about 60% are researchers or academically qualified people who manage and guide the research process. The OECD statistical convention is to include PhD students among academic researchers. This, together with the difficulty of getting reliable estimates of how academics actually spend their time, tends to inflate the higher education numbers somewhat.

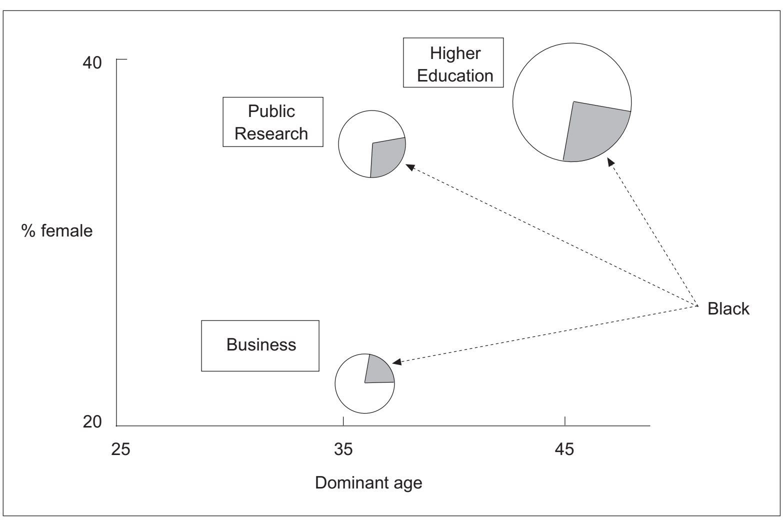
While South Africa's R&D expenditure is fairly high compared with other developing countries, the number of researchers, at 2.7 per thousand employees is low relative to developed countries and some of its peer countries (Figure 2.4), but higher than Chile at 1.4. Very R&D-intensive OECD countries such as Japan, Sweden and Finland have 10.2, 10.6 and 15.8 researchers per thousand employees, respectively.

Figure 2.4. FTE researchers per thousand employees, 2003



Source: Background report.

Figure 2.5. Demographic profile of South African researchers



Source: Michael Kahn.

Funding per FTE researcher appears to be modest compared with other countries. There is a significant investment backlog in parts of the South African research system. The picture is complicated by the comparatively high wages that R&D workers are said to be able to command, especially those in senior positions in government.

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, 11.4% in South Korea and 28.4% in Norway. However, significant problems remain.

- The age distribution of the R&D population, as measured by the National R&D Survey, peaks in the range 35 to 44 years; however, the average age of university researchers is ten years more, and the profile is predominantly white male (Figure 2.5).
- 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, far below the European Union and OECD average. (The present population between the ages of 25 and 64 is about 20 million.)

Available statistics suggest that there has been little change in the overall number of researchers active in South Africa over the past decade (Table 2.4). There has been some growth in the business sector but a decline in higher education. Available data suggest that during this period there has been net emigration of as many as 2 000 members of the scientific work-force yearly, with an annual outflow of 2 500 and an inflow (mainly from other African countries) of 500 or so. Data sources are weak and inconsistent in this area. Brrain drain issue nonetheless appears to be a significant issue.

Table 2.4. FTE researchers by sector, 1992-2004

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

Source: Background report.

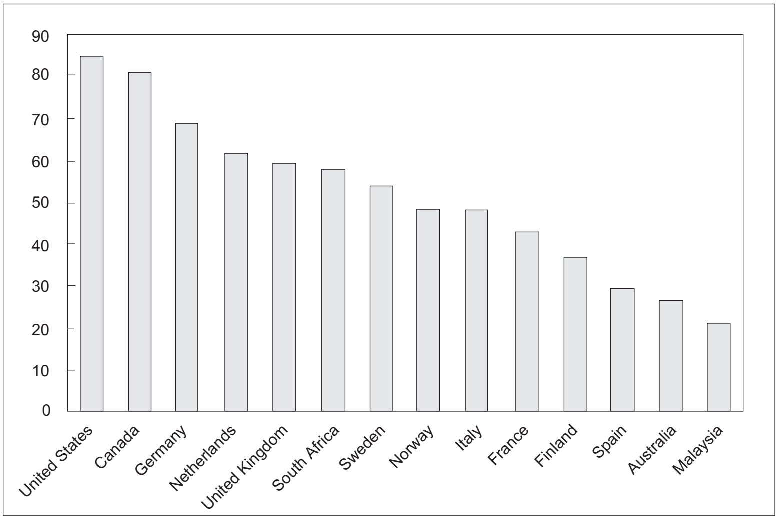
Against this background, the government has made human resource development in science and technology a high priority. Major challenges identified include:

- To increase the number of enrolments in mathematics and science at schools and higher education institutions (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 the permanent staff).
- To broaden the base of the most productive researchers, most of whom are ageing.
- To increase the enrolment of Master's and PhD students, following the increases experienced between 2000 and 2003, including the proportion of international students.

2.2.2. Industrial innovation

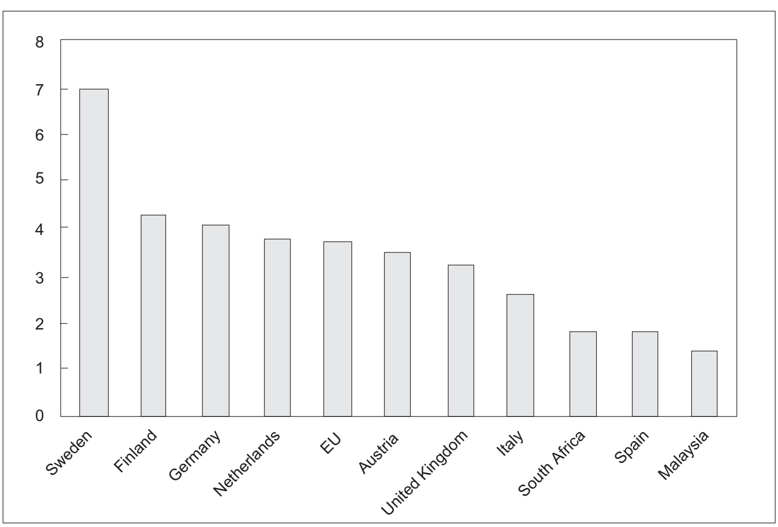
Innovation in industry is much harder to characterise than R&D. The first innovation survey, modelled on the European Union (EU) Community Innovation Survey (CIS), was done in 2001 and covered the period 1998-2000 (Oerlemans *et al*., 2003). Such surveys are in their infancy, and there are significant problems of comparability between countries. Two issues are especially important. First, however strictly innovation is defined in questionnaires, the word itself means different things in different places. Second, the unit of analysis in these surveys is the firm and responses are not weighted by the size or importance of the responding companies. As a result, CIS-like surveys are effectively studies of the SMEs that dominate the response. They do not give an accurate picture of the sources of innovation in the large-firm category.

Figure 2.6. Percentage of innovating firms, 1998-2000



Source: Background report.

Figure 2.7. Innovation costs as a percentage of sales



Source: Background report.

Provided their limitations are understood, however, CIS-like surveys can nonetheless provide policy-useful information. The South African survey suggested that South African firms have quite a high propensity for technological innovation, compared with firms in many other countries (Figure 2.6).

However, they devote very few resources to innovation activities, only some 2.6% of sales (Figure 2.7); this suggests that much innovation is incremental. Innovation capacity in the small, medium and micro enterprise (SME) sector is poor on average. Firms in the size range 50-250 spent only 1.1% of sales on innovation.

A key thrust of the last 20 years of innovation research has been that successful innovators tend not to innovate alone. Partnerships often help companies take more significant innovation risks, for example by providing them with an initial customer or a "Beta-test partner" for an innovation. The degree to which firms innovate in partnership with other companies is an indicator of the extent to which they are embedded in supply chains. South African innovators responding to the 2001 survey, however, had domestic company partners in only 18% of cases (compared with 26% in the EU), but had foreign partners in 26%. This reinforces the impression that much technology is acquired from abroad. It suggests scope for increasing the number and quality of inter-firm linkages within as well as outside South Africa.

Table 2.5 shows where innovating firms obtained information they needed for innovation, and is a very typical result of innovation surveys. It shows that the commonest information sources are those with which firms are in constant touch, notably customers and suppliers, and that recruiting people with useful knowledge is fairly important. It also shows that universities and institutes are not common sources of information for innovation. When international surveys question companies that perform in-house R&D (not done in the South African innovation survey), the importance of links to research institutes and universities is normally found to be very great. Such links are therefore much more important where more technologically advanced types of innovation are involved than in the run-of-the-mill incremental work that requires most of industry's innovation effort and is, in many cases, all that smaller firms are able to do. Policy therefore needs to activate both inter-firm networking and networking between the business sector and the research infrastructure in order to meet the needs of different types of companies. Different types of policy instrument are of course generally needed to achieve these two objectives.

Table 2.5. Innovators' use of external information sources

Percentage of respondents

External source	Source not used	Used, but of little importance	Used and important	Used and very important
Competitors	32	18	41	9
Exhibitions	35	18	40	7
Suppliers	36	21	29	14
Professional literature	38	17	38	7
Buyers	43	20	27	10
New personnel	57	14	23	5
Consultants	58	17	16	8
Electronic info	61	18	16	5
Group	65	10	10	14
Sector institutes	74	14	9	4
Universities	75	12	11	2
Research labs	78	13	6	3
Patents	79	13	5	3
Innovation centres	86	9	4	1

Source: Innovation Survey, 2001.

Another particularly interesting issue is why many firms fail to innovate. The responses to the South African survey are again in some ways stereotypical (Table 2.6). Small firms are always short of money, though many South African firms may be particularly so. Small firms are normally under pressure and lack the capacity to devote even to urgent projects. However, the lack of capacity suggested by the "shortage of staff" responses points to a need to raise the number and proportion of innovation-capable people in the population of predominantly small firms responding.

Table 2.6. Obstacles to technological innovation, 1998-2000

Reasons for not innovating	% of respondents
Costs too high	52
Short of staff	38
No time	46
Time to market	15
Short of finance	45
Demand risks	40

Source: Innovation Survey, 2001.

2.3. Policy developments in the transition and current state organisation

2.3.1. Policy developments

Following the formation of the new government in 1994, the public missions of the apartheid era such as defence, energy and food self-sufficiency were largely abandoned. Since then, government has sought to rationalise structures and actors in the R&D funding and performance system and to realign priorities to address South Africa's overall social and economic development needs. To some degree, this has brought the country closer to international priorities and it has involved a significant reversal of the research community's comparative isolation. It has involved an effort to transform the human resource base to resemble more closely the nation's overall demographic profile, while at the same time trying to exploit the strong points in the system left from apartheid.

Recognising the importance of a more co-ordinated view of the science and technology function the government upgraded it to Ministry and Department level in 1994, with the formation of the Department of Arts, Culture, Science and Technology (DACST). This was split in 2002, so that science and technology had its own ministry. The Department of Science and Technology (DST) became an independent department in 2004.

The 1996 White Paper on Science and Technology (DACST, 1996) provided a considered statement of the new government's priorities. It introduced the idea of a national innovation system as distinct from the narrower idea that policy should focus only on science and technology. It aimed to trigger a more holistic approach to R&D across government, tackling the need to (re)build human capacity, to increase the innovation effort in the private sector, to increase government interaction with private-sector innovation through new funding schemes and greater involvement by the public research institutes (PRIs), and to increase the importance both of longer-term thinking in policy making for research and innovation and the use of the ideas of the new public management movement.

South Africa followed the international trend and ran a foresight exercise at the end of the 1990s (DACST, 1999). As is normal with many such exercises, it served more to analyse context and to increase dialogue among stakeholders in the research and innovation policy system than to trigger new policies. Key observations of the foresight report which cut across the ten areas of technology and society that were the exercise's main focus were:

- Internal rich-poor tension and the need for rural development.
- External North-South tensions, standards regimes and regulatory barriers.
- Opportunities and threats of globalisation.
- Sustainable development as a fundamental principle.
- Raising living standards while protecting the environment.
- HIV/AIDS and its impact on the social fabric and economy.
- Knowledge/information society imperatives.
- Human resource development both as constraint and necessity.
- Skills loss and reduced capability to absorb new technology.
- Public safety and morals and their impact on the social fabric and economy.
- South Africa's position in the South African Development Community (SADC) and the African Renaissance.
- Lack of investment in R&D by multinationals in South Africa.

In general, the panels saw South African technological development as lying between the levels of developing and developed countries. Human resources were the key constraint, followed by the lack of money to address the problem. The foresight exercise was followed by specific national strategies for biotechnology and advanced manufacturing.

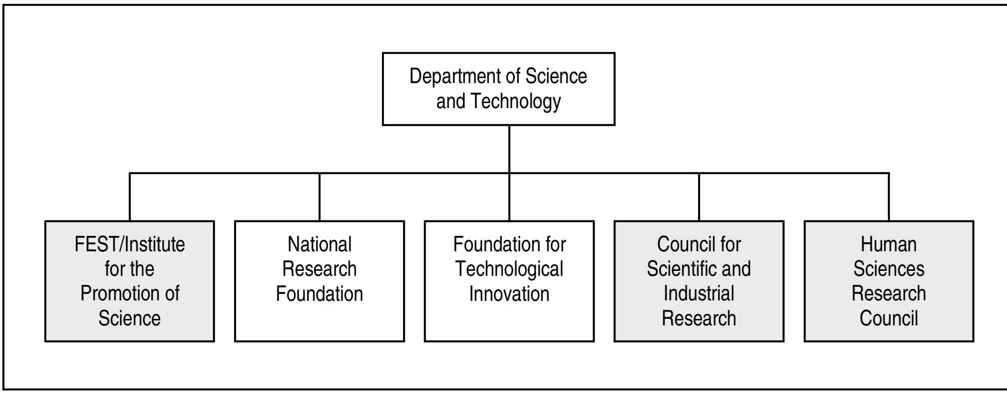
In 2002, the government endorsed the DST’s national R&D strategy (DST, 2002) which made some of the institutional and governance proposals of the earlier White Paper more explicit. It identified six key weaknesses in the national innovation system:

- The dramatic drop in GERD, which fell from 1.1% of GDP in 1990 to 0.7% in 1994, and which had only slowly been recovering.
- The need to maintain a super-critical R&D community, in support of strategic needs and to generate national absorptive capacity.
- Failure to renew human resources for science and technology, as the predominantly white male research community was ageing and not being replaced in sufficient numbers.
- Declining investments in formal R&D by South African companies, which the strategy document connected with globalisation.

- An inadequate infrastructure and legal system to handle intellectual property (IP).
- Fragmented governance structures in research and innovation funding.
- The strategy involved three lines of action.
- A cluster of innovation programmes, particularly in biotechnology, information technology, manufacturing technology and technology for poverty reduction:
- Strengthening and refocusing state-funded science, engineering and technology research on areas in which South Africa had an advantage (for example, in astronomy, palaeontology and indigenous knowledge) and on strategic basic research in areas that fit areas of industrial and social need. This would replace the focus created by the national missions during the period of South Africa's isolation.
- Creating the basis for a more holistic R&D policy by creating a clear distinction between the roles of sectoral departments (such as Agriculture and Health) and the DST, which should play an integrative role across the whole of government.

In effect, the strategy proposed that DST should, over time, have five agencies (Figure 2.8). It would share responsibility for basic research. The Department of Education (DoE) would provide one component of the binary funding of research in the universities through the General University Fund while the DST would provide the other component through the National Research Foundation (NRF) and some of the programmes of the Foundation for Technological Innovation. Ultimately, the Foundation for Education, Science and Technology (FEST) function was moved into the NRF and the Foundation was not created. As a result, South Africa *de facto* has chosen, like Norway and Iceland, to organise much research and innovation funding under a single agency.

Figure 2.8. DST and agencies proposed in the National Strategy for R&D



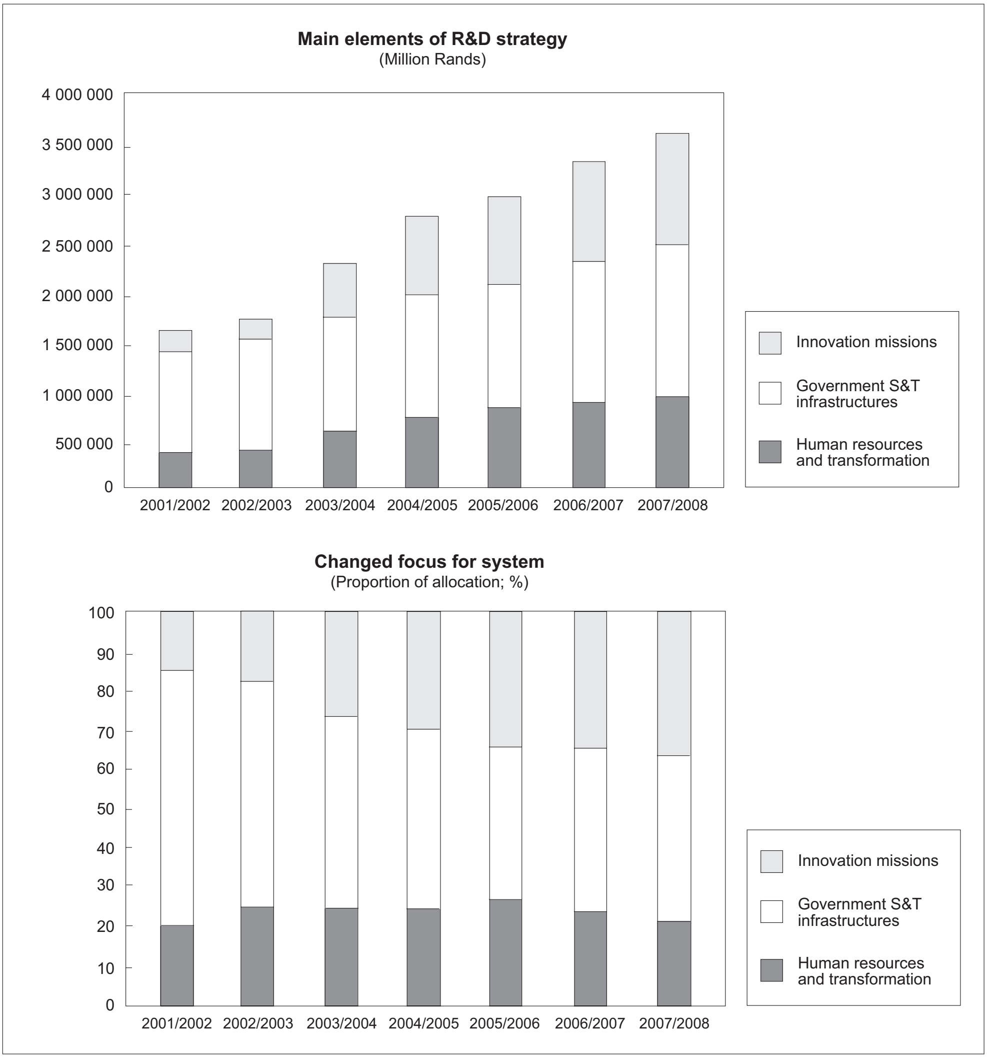
Note: Shaded agencies are research performers. The others are funding organisations.

The other, crucial element of the strategy was to use the bulk of a growing budget for the innovation mission rather than for expanding fundamental research, because of the urgency of economic development (Figure 2.9). However, it appears that this part of the strategy has not been fully implemented. Neither the Technology and Innovation for Poverty Reduction Programme nor the Programme for Resource-based Industries has been implemented. The latter was apparently sidelined because it is low-technology. These failures in implementation appear to involve significant missed opportunities to use research and innovation to support central social and economic development objectives of the new government.

2.3.2. The overall structure of the state system

The current structure of government R&D performance and innovation support is shown in Figure 2.10. There is no high-level body responsible for deciding, or for advising the government as a whole, about the entire spectrum of research and innovation policy. Figure 2.11 shows the main streams of public funds for different stages of the innovation process which are channelled through this institutional framework.

Figure 2.9. Intended refocusing of R&D towards innovation



Source: National R&D Strategy, 2002.

Figure 2.10. Institutional structure of the South African government research and innovation funding system

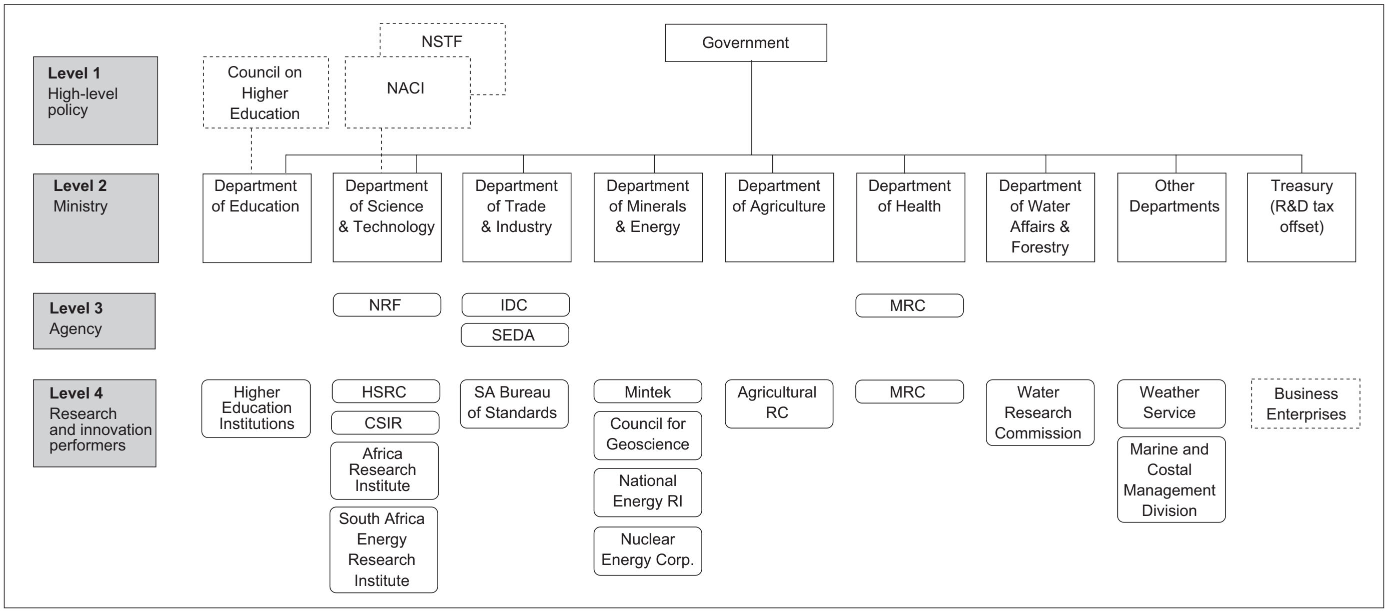
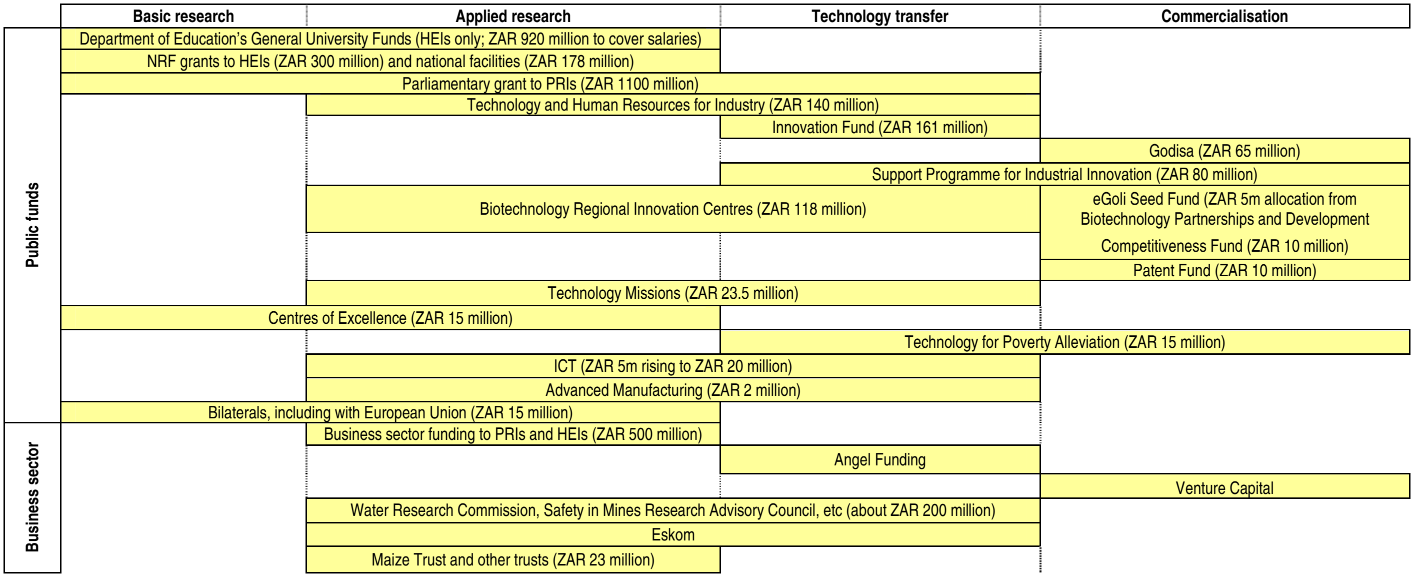


Figure 2.11. Funding for R&D and innovation in South Africa (2003/04)



At the highest level (Level 1), the Parliamentary Portfolio Committee for S&T (comprising members of Parliament) oversees the activities of the DST. The Minister of Education is advised by a group of stakeholders in the Council on Higher Education. The Minister of Science and Technology is advised both by the National Advisory Council on Innovation (NACI) and the larger group of stakeholders involved with the National Science and Technology Forum (NSTF). There is an independent South African Academy of Sciences, and it is intended to create an Engineering Academy in 2007, but these do not appear to have a significant influence on government policy.

At Levels 2 and 3, research councils (actually, research institutes) are widespread. They typically receive a substantial grant from the responsible ministry and have a mandate both to set priorities for individual projects and to perform research. The Medical Research Council (MRC) has a mixed function; it sets internal priorities and performs research, on the one hand, and acts as a funding agency for external contractors (primarily in the higher education system), on the other. As a result, the small number of agencies (Level 2) is striking compared with current dominant OECD practice, in which the research and innovation funding function has generally been separated from project performance.

Most of the research-performing institutions are formally controlled by their parent ministries. The universities, however, have their own charters and the Ministry of Education cannot instruct them directly.

There is a general procedure for horizontal co-ordination at Level 2. The South African ministries organise a number of policy clusters to deal with problems that affect several ministries' responsibilities. Those listed in Table 2.7 are of particular relevance to this report. At the level of ministers they operate as forums at which new draft policies, strategies and high-level initiatives are discussed. They are mirrored at director-general level so that implementation issues can be tackled. One may wonder whether these clusters are efficient co-ordination mechanisms.

Table 2.7. Some research and innovation-related clusters

Cluster	Departments involved
Economics 1	Environmental Affairs and Tourism
	Public Enterprise
	Trade and Industry
	Transport
Economics 2	Science and Technology
	Minerals and Energy
	Communications
Social 2	Education
	Labour
	Arts and Culture
	Sport and Recreation

In addition to the general cluster approach, the DST has a number of special responsibilities for horizontal co-ordination. It has a cross-cutting and steering function for areas such as S&T liaison across departmental line functions and sectors and large-scale, broad-scope new S&T platforms and challenges (such as astronomy, human palaeontology and indigenous knowledge). It also has system-wide oversight functions, including establishing and maintaining a common governance framework, priority setting, and performance and budgetary monitoring systems. In 2005, DST representatives were appointed to the boards of a number of research councils and the Nuclear Energy Council of South Africa (NECSA).

2.3.3. Research and innovation funders

2.3.3.1. Department of Trade and Industry and its agencies

The Department of Trade and Industry (DTI) is a significant funder of technology and research, via other agents. In 2004/05, among its large-scale technology-related transfers to agencies and companies (which totalled ZAR 2.8 billion) were significant payments to the NRF, the Council for Scientific and Industrial Research (CSIR) and the Pebble Beach Modular Reactor (PBMR) company.

Table 2.8. DTI major transfers to agents, 2004/05

Agent	Amount transferred (ZAR millions)
South African Bureau of Standards	98
National Empowerment Fund	160
NRF Technology and Human Research for Technology	139
Export Credit Insurance Corporation	100
CSIR Research Contribution	348
Enterprise Development	498
Export Market and Investment Assistance	103
Pebble Bed Modular Reactor	600

Source: DTI Annual Report, 2004/05. This table lists all transfers of ca. ZAR 100 million or more.

The programmes contained within DTI's Innovation and Technology mission are:

- Technology and Human Resources for Industry (THRIP), discussed under NRF, which operates the programme on the DTI's behalf.
- The Support Programme for Industrial Innovation (SPII).
- The National Technology Transfer Centre (recently transferred from CSRI to the Small Enterprise Development Agency –SEDA) and the National Fibre, Textile and Clothing Centre (NFTCC).
- The Godisa Trust, co-funded with the European Union (now merged with SEDA).
- A small collection of incubators and training centres.
- The Mpumalanga Stainless Initiative, which teaches basic business skills to groups of 16 entrepreneurs in stainless steel sheet fabrication.
- Down Stream Aluminium Centre for Technology, which operates similarly in aluminium casting with funding from KwaZulu-Natal and the EU.
- Furntech, a Swedish-funded training centre for furniture-making and entrepreneurial skills.
- The Venture Fund.

The DTI's responsibilities include aspects of technology-related innovation and entrepreneurship, often on a shared basis with DST. It uses SEDA, set up in 2004, to create a national delivery network to help existing and potential entrepreneurs establish, manage and improve their businesses by providing them with information. The more active training measures seen in some countries (such as FRAM in Norway, see Box 2.1) do not yet seem to part of the agency's repertoire. However, it does incubate a small number of firms in the biological and life sciences, medical devices, bio-diesel, essential oils, chemicals, construction, floriculture, furniture, ICT, small-scale mining, stainless steel, aluminium, platinum and metal beneficiation sectors through the SEDA Technology Programme.

Box 2.1. The Norwegian FRAM programme

FRAM is funded by Innovation Norway, the Norwegian innovation and business development agency and regional development bank. FRAM aims to improve the survival and success rate of micro-firms by improving their managerial and strategic capabilities. FRAM (which means "forward") was the name of the ship sailed by the Norwegian polar explorer Nansen. In the programme it is an acronym for "Understood, Realistic, Accepted and Measurable". In micro-firms management is generally very deeply engaged in the day-to-day running of the business. FRAM aims to increase value creation by educating entrepreneurs. Experience shows that a structured analysis of the business using simple tools, making management aware of its situation and coupling this understanding to goal-oriented development work is a good basis for increased value creation and profitability. FRAM helps companies reach a position at which they can develop themselves further, in effect, creating a virtuous circle of company development by introducing the needed managerial and strategic skills.

The goal for the companies involved is to increase their return on sales by 5 percentage points. About 80% of the participating firms achieve this. Other sub-goals are:

- Adding external members to the Board of Directors.
- Devoting more time to management of strategy and change.
- Increased national and international collaboration.
- Increased technological and organisational innovation.

The programme was originally operated by the Norwegian Institute of Technology (*Teknologisk Institutt*), which provided methodological support and trained and accredited FRAM consultants. As a result, there is now a cadre of business consultants skilled at supporting SMEs. Between 12 and 20 companies in a region do a situation analysis/diagnostic, which is managed by an external consultant and takes two days. Based on the analyses, the eight companies with the best development prospects are selected to go forward into FRAM. Training is done through a mixture of classroom teaching, discussions, exchange of experience and group work. Individual consultants support project participants between classroom sessions. Projects last three to four months and result in a business plan. Follow-up meetings are held two and six months after the end of the project. Evaluations show the programme increases firm performance and survival rates.

In 2006, the Godisa Trust, the National Technology Transfer Centre (NTTC) and the Technology Advisory Centre were merged into SEDA to form the SEDA Technology Programme. Historically, Godisa (which was set up in 2001, with financial support from the EU) has incubated high-technology companies and provided management support in areas such as IP. It had 11 incubators across the country (intended to reach 18 by the end of 2006) and claimed to have launched 103 companies by the time of the merger. Key problems experienced by the trust included a lack of innovation-based firms, especially black-owned, to serve as role models. With the emergence of two black millionaires and the maturing of the first generation of companies from the centres, this problem began to ease. The other issue was the low level of entrepreneurship focus in the universities, especially the historically black universities (HBUs), which meant that people were slow to identify entrepreneurship opportunities. Again, the Trust's work can provide an important demonstration effect, but needs to be backed up by more explicit commercialisation policies and entrepreneurship focus in the universities.

The NTTC is an initiative to help people in the second economy improve their technologies. It makes 100% grants, up to a maximum of ZAR 0.5 million, available to black-owned businesses. However, the total budget of NTTC is only ZAR 12 million, so the number of firms that can be helped is small.

The NTTC helps small businesses apply appropriate technology to their production processes to enhance productivity and quality. The Technology Advisory Centre was formed to help entrepreneurs and inventors navigate South Africa's tangled web of services, funds and support. The government is following the trend towards one-stop shop delivery of business support services that was popular in Europe during the 1990s. As in OECD countries, perception that such services need to be delivered geographically close to their beneficiaries has led to a decision to increase SEDA's regional presence from 36 to 164 branches.

Box 2.2. Examples of regional delivery of business support

There is an established consensus that SMEs tend to find it hard to navigate their way through complex innovation and business support services systems, and that such services need to be delivered close to the beneficiaries. Several countries have therefore established regional networks of offices that help companies find the support they need and/or deliver these services locally.

- The UK Business Links are the closest to being pure brokerages. They are staffed by business and innovation advisors who can perform initial diagnoses of firm needs and refer them on to organisations in the public and private sectors that can provide relevant support. Other countries, including the following, tend to have networks of regional offices of national support organisations. (There is no such organisation in the United Kingdom.)
- Enterprise Ireland has eight regional offices, where client executives take responsibility for individual “accounts”. Where beneficiaries appear promising, they are guided through a process of company development, with a mix of advice, training and subsidy schemes tailored to individual company development needs.
- Innovation Norway has over 20 regional offices, roughly one in every county. It acts as a regional development bank and runs many advice, training and subsidy schemes (including FRAM, see Box 2.1). Some of the funding available is co-ordinated with individual county development plans and county representatives sit on the board of their local office. These offices also “retail” the R&D- and innovation-orientated schemes of the Research Council of Norway.
- In Finland the TE-Keskus were established in 1997. They are joint regional service centres of the Ministries of Trade and Industry, Labour, and Agriculture and Forestry. They provide and broker services in company development, human resources, labour force, rural areas, technology and exports. The main tasks of the centres are i) to promote entrepreneurship, ii) to support and advise SMEs, iii) to further the technological development of companies and assist them with export and internationalisation issues, iv) to implement regional employment policy, v) to find new business opportunities and create new jobs, vi) to design and organise adult training, vii) to promote agricultural and rural businesses; and viii) to develop fisheries. For a time they also retailed the services of TEKES, the Finnish innovation agency, but these were recentralised in order to provide companies higher levels of expertise.

The Support Programme for Industrial Innovation is funded by the Department of Trade and Industry and administered by the Industrial Development Corporation. It supports private-sector enterprises by providing investment capital to develop products, services and/or processes. The 2004/05 budget for the SPII programme was ZAR 81 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 claims to have created/retained 3 145 jobs in 2004/05 and generated sales amounting to ZAR 800 million, more than half from exports. Companies participating in SPII had an average R&D expenditure of 13% of sales.

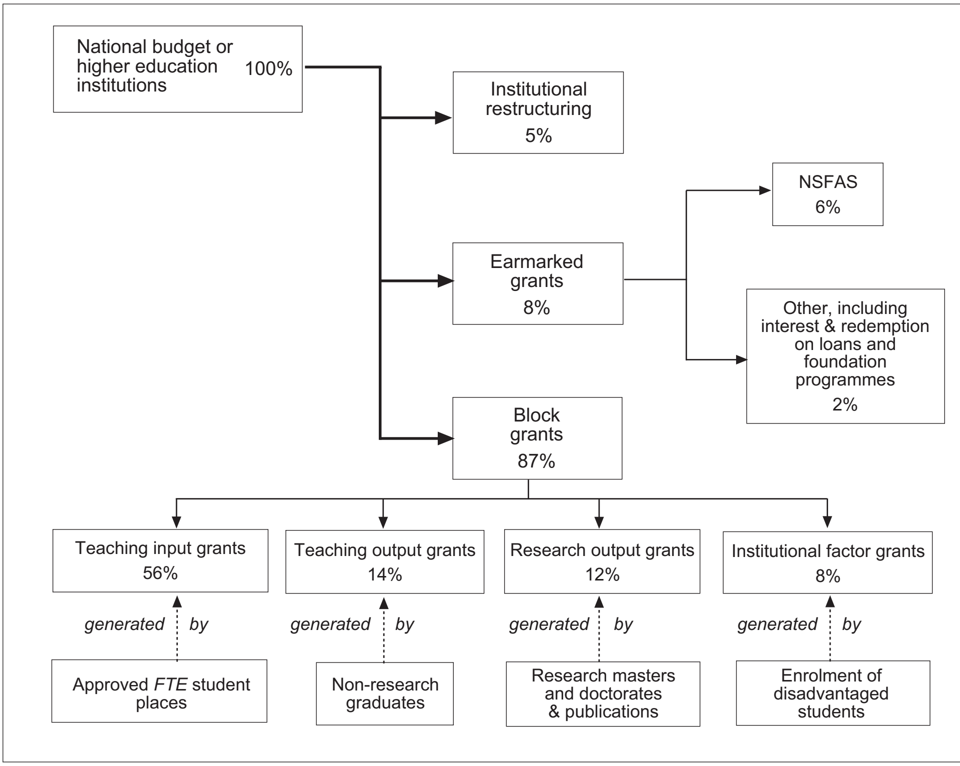
SPII has three sub-schemes, two of which involve grants. One, aimed at larger companies, is based on the idea of co-investment, repayable with interest. Here, SPII aims for a 19% internal rate of return, building the financial capability to recycle funds into new investments over time.

2.3.3.2. The Department of Education in higher education funding

The DoE expects universities to be funded approximately 50% through the grants that it provides, 25% from tuition fees charged to the students and a further 25% from other sources, including research grants from national funding organisations (*e.g.* NRF), programmes (*e.g.* THRIP) and private domestic and foreign sources.

From 2004/05, the DoE has applied a new funding formula to higher education (Figure 2.12), which effectively specifies how the General University Fund is allocated at the institutional level. A proportion is allocated to restructuring costs in the universities and to the National Student Financial Aid Scheme, which allows universities to subsidise the tuition fees of economically disadvantaged students. As is normal in such funding schemes, however, student numbers drive the biggest part via a Teaching Input Grant. This grant is calculated by setting a target number of students per institution. Recognising that some courses (including postgraduate courses) are more expensive to deliver than others, the Department differentiates the grants according to the proportion of students in each of four different groups of subjects.

Figure 2.12. Division of government budget between grant categories, 2004/07



Note: NSAF is the National Student Financial Aid Scheme.

Source: Ministry of Education, A New Funding Framework: How Government Grants are Allocated to Public Higher Education Institutions, Pretoria: Department of Education, 2004.

The number of graduations produced drives the Teaching Output Grant. Postgraduate degrees are weighted more heavily than Bachelor degrees, which in turn have a greater weight than diplomas and certificates. During a transitional period[22] any shortfall in the number of students graduated compared with the plan, will be ignored, and the corresponding money treated as a teaching development grant. Research output grants are provided based on:

22. Which is not predefined, but whose termination will be announced by the department at some point in the future.

- The number and type of research degree graduates produced.
- The number of publications per member of academic staff per year in "approved" journals.

In the past, such journals have had to be on a list approved by the DoE. Currently, the department accepts any Institute for Scientific Information (ISI)-indexed journal as meeting the required quality standard. The formula implies an expectation that faculty will produce at least 1.25 such publications per person a year. It does not differentiate among subjects, despite wide differences in publication propensity and behaviour among fields. As with the teaching output grants, shortfalls against the plan in historically disadvantaged universities are currently treated as research development grants for an undefined transitional period.

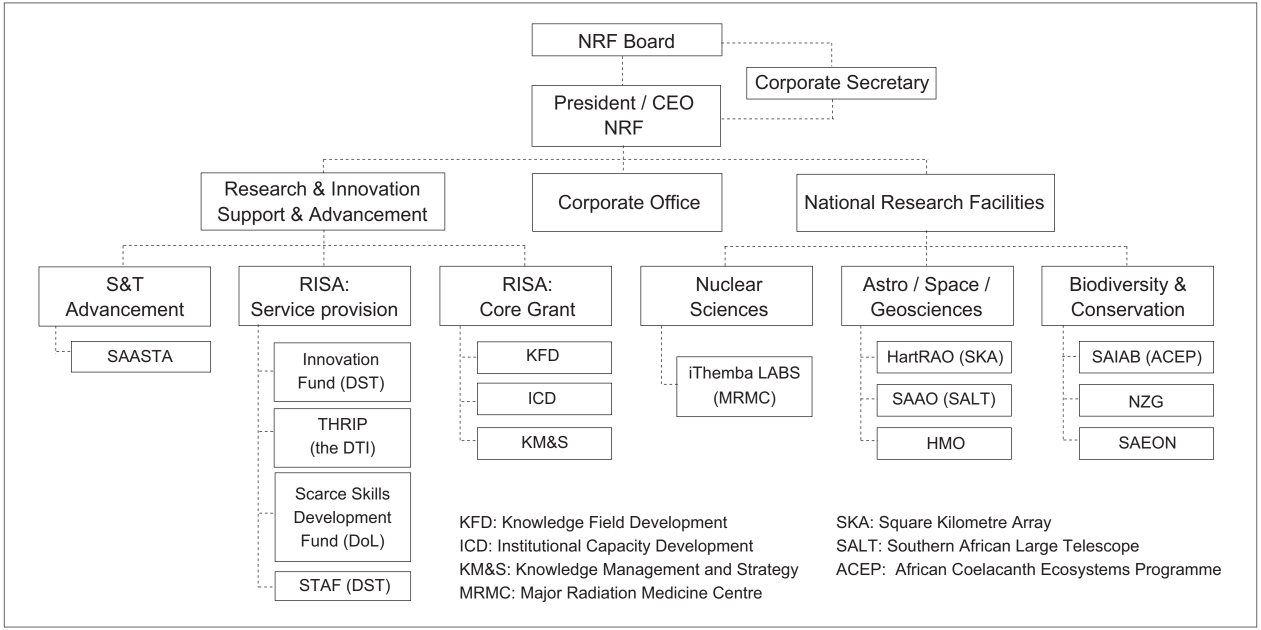
There is a separate category of grants for institutions with a large proportion of disadvantaged students. It is added to the Teaching Input Grant and is based on the proportion of disadvantaged students and the size of the institution, with small universities getting more per disadvantaged student than large ones.

In order to cope with the transition, institutions producing less than the expected numbers of first degrees and research outputs are not penalised in the early years. Over time, the funding formulae will allow the department to encourage more competition among universities. The research publications formula is, for the time being, a rather blunt instrument. Its failure to differentiate among subjects means that universities have incentives to focus on fields with a high propensity to publish, such as some natural and social sciences, rather than on applied research and engineering, where publication behaviour gives more weight to reaching practitioners through conferences and other channels not catalogued by the ISI.

2.3.3.3. National Research Foundation

The NRF is an agency of the Department of Science and Technology. It receives about half its income in the form of a core grant from DST, and the balance via service contracts with DST, the department of Trade and Industry (for THRIP), the Department of Labour (for the Scarce Skills Development Fund) and the department of Environmental Affairs and Tourism (for marine research).

Figure 2.13. Organisational structure of the NRF



Source: NRF Annual Report, 2004/05.

NRF has two major divisions: Research and Innovation Support and Advancement (RISA) and National Research Facilities (Figure 2.13). RISA accounted for ZAR 685 million (75%) of the Foundation's expenditure in 2004/05 and the Facilities division for ZAR 230 million (25%). It is therefore similar to the UK research councils, in providing a mixture of research funding and facilities management.

Table 2.9. NRF income, 2004/05

NRF Income 2004/05	ZAR millions	ZAR million
RISA	*701*	
RISA Core grant + ring-fenced resources		251
RISA Contracts, sundry and other		54
DTI - THRIP		131
Dept. of Labour - Scarce Skills Development Fund		24
DST - Innovation Fund		210
DEAT - Marine and Coastal Programmes		4
South African Agency for Science and Technology Advancement		27
National Research Facilities	*204*	
iThemba Labs for Accelerator Based Sciences		104
S. African Astronomical Observatory		29
Hertebeesthoek Radio Astronomy Observatory		14
South African institute for Aquatic Biodiversity		5
Hermanus Magnetic Observatory		7
National Zoological Gardens		45
NRF Total	905	

DEAT: Department of Environmental Affairs and Tourism.

Source: NRF Annual Report, 2004/05

Table 2.9 shows NRF's sources of income. Some ZAR 159 million (18%) come from sources other than the DST, principally the DTI for THRIP. The core grants are used to fund research, primarily in the higher education sector. Unlike many OECD research councils, which allocate a major part of their budget to fully response-mode bottom-up funding, NRF funds mostly within nine broadly defined focus areas which are primarily thematic rather than disciplinary in nature and emphasise the link to social and economic application of results:

- Unlocking the Future: Advancing and Strengthening Strategic Knowledge.
- Distinct South African Research Opportunities.
- Conservation and Management of Ecosystems and Biodiversity.
- Economic Growth and International Competitiveness.
- Education and the Challenges for Indigenous Knowledge Systems (IKS).
- Information and Communication Technology and the Information.
- Society in South Africa.
- Socio-political Impact of Globalisation: The Challenge for South Africa.
- Sustainable Livelihoods: The Eradication of Poverty.

These focus areas contain a mix of traditional research grants, funding for six Centres of Excellence and a small amount of staff development funding (about ZAR 12.5 million, funding just under 300 people) aimed at upgrading the research capabilities of faculty in the restructured university centres. The Centres of Excellence are intended to have a budget of about ZAR 5 million a year for up to ten years. All six were awarded to senior white male principal investigators.

Using a mixture of the core grant and an extra ZAR 23 million from the Department of Labour's Scarce Skills Fund, NRF supports 1 100 doctoral students (some ZAR 115 million) and 210 postdoctoral fellows. These are a mixture of free-standing grants and grants attached to faculty research projects.

At the time of the last Annual Report, NRF was discussing DTI support for:

- The implementation of a research chair scheme, to fund an additional 55 research chairs a year across the higher education sector (subsequently implemented).
- Extending the Centres of Excellence scheme to include centres of excellence in industrial R&D, with industrial involvement.
- A mathematics and science teachers' training programme to combat the acute shortage of such teachers in schools.

Given the great importance of foreign research funding in South Africa, NRF is an important broker of information about opportunities to the research community. It is the contact point for the European Framework Programme and is therefore well placed to benefit from the greater opening up of Framework funding to third countries planned for the 7th Framework Programme in 2007.

In 2004/05, NRF received a total of 4 422 applications, of which it funded 52%, a very high proportion by international standards. Research councils in Europe tend to fund somewhere between 5-10 and 30% of proposals, with a growing number towards the bottom of this range. Success rates naturally vary across different NRF activities. Thus the Centres of Excellence competition was highly competitive, with only 6 of 70 applications being funded.

The RISA division of NRF operates two important schemes that involve industry: the Technology and Human Resources for Industry Programme and the Innovation Fund. THRIP has been operating in various forms since 1991, and was universally praised. Its aims are to:[23]

- Help increase the quantity and quality of people with the appropriate skills for developing and managing technology for industry.
- Promote increased interaction and mobility among researchers and technology managers in industry, higher education and research institutes, with the aim of developing skills for the commercial exploitation of science and technology.
- Stimulate industry and government to increase their investment in research, technology development, diffusion and the promotion of innovation.

THRIP’s budget of ZAR 131 million in 2004/05 was provided by the Department of Trade and Industry. The programme subsidises company investments in joint projects with the research sector at the rate of ZAR 2 per ZAR 1 invested by the firm. Companies able to benefit from such an arrangement needed to be fairly large and to have significant absorptive capacity. THRIP allowed them to break through some human resource bottlenecks and helped to direct academic attention to problems of industrial interest. It was therefore a useful instrument for aligning both research agendas and human resource development in the higher education sector with the needs of large-scale South African industry.

23. National Research Foundation, Annual Report, 2004/05.

The evaluation of the programme (Van den Heever *et al.*, 2001) noted its success in linking industrial needs with the research system and promoting the development of the desired human resources. The evaluators said they encountered broadly four types of project:

- Those aimed at capacity building within higher education institutions over the medium-term. These are typically supported by large firms, although SMEs may also be involved. Funding has often continued over an extended period of time and, although individual projects can be identified, the size and continuity of funding means they are more akin to a programme of research than discrete projects. The distinctive factor in these projects is that sponsors appear to be taking a strategic view of the need to develop capabilities within HEIs and are expecting the impact to be felt outside and beyond the specific projects they support.
- Projects for which the key company interest is specific technological outputs, with human resources at most a secondary consideration. This is often the case with SME participants.
- Projects in which industry sponsors have a real interest in the specific technological outputs, but human resource development, via student involvement in projects, is also a key consideration. As would be expected, this is often the case with large firms, but some SMEs also act in this way.
- Projects in which the industrial partner's interest is in technologies for the future rather than more immediate application, and the HEI is able to bring knowledge and capabilities that the company does not have in house.

The evaluation also noted that THRIP projects were highly concentrated among and within the most established universities and that formerly black universities were struggling to enter the programme. It recommended extending the programme to tackle in addition some of the empowerment and equity issues involved.

The THRIP strategy for 2004/07 and the subsequent year-by-year implementation of the programme, however, have attempted to refocus the programme on shorter-term outputs and the SME sector. This report will argue that, while it is vital to increase the technological capabilities of small firms, as well as the capacity to carry out firm-relevant research of high quality in more of the higher education system, these goals can be better achieved by dedicated instruments. Failure to recognise and support the role of large companies in developing both the knowledge infrastructure and the innovation system more widely will further disadvantage South Africa as a location in which these large-scale generators of wealth and jobs may consider undertaking R&D and other innovation activities. Unless replaced by an alternative scheme (possibly a competence centres scheme, see below) this reorientation of THRIP will break an important link between industrial need and the development of the knowledge infrastructure and undermine one of the more important successes of South Africa's innovation system approach to date.

The Innovation Fund was set up in 2001 and is run by the NRF on behalf of the DST; it had a budget of ZAR 210 million in 2004/05. It invests in technology development projects emerging from the knowledge infrastructure through its Technology Advancement Programme (TAP), which invests in projects in the range of ZAR 1-5 million and its Missions in Technology (MiTech) programme which handles larger investments of ZAR 5-15 million. MiTech requires a commercial partner that will share the financial risks. Alignment between the areas of investment and national technology strategies raises the chances of obtaining finance. The Innovation Fund also makes top-down investments in projects on the instructions of the DST.

Applications are split rather evenly between the private and public sectors, but the private sector has to date received 33% of the investment volume, the science councils collectively 39% and universities 28%. The CSIR has so far received about 20% of the Fund's total investments. During its lifetime, the Fund has added additional support functions:

- A commercialisation office, which provides commercialisation support services to inventors in the state R&D system.
- A seed fund, intended to take up the results of TAP and MiTech projects and help fund their commercialisation. Typically, the fund invests ZAR 5 million in return for a 20% equity stake in the company.
- The Intellectual Property Management Office, whose functions include investing in patents on behalf of the knowledge infrastructure, developing patent attorney capabilities and managing IP.
- Operating the National Innovation Competition, open to all students under 35 years of age.

The Innovation Fund has a partly independent Board of Trustees but is chaired by a senior DST official. It claims a number of early successes in commercialising technologies originating in the knowledge infrastructure.

The South African Agency for Science and Technology Advancement (SAASTA) is a small agency within the NRF which has taken on the science communications tasks envisaged in the National Strategy for R&D. It is at an early stage of development, operating a science and technology museum and workshops, but aims to build integrated awareness activities with other national facilities and to attract additional funding from outside DST.

2.3.4. Other agencies of the Department of Science and Technology

The DST sets policy and for implementation it instructs a range of agents to act on its behalf. For example, it recently set up an Indigenous Knowledge Trust to safeguard and exploit indigenous knowledge systems. There is a long list of R&D performance units engaged in various ways in implementing policy, and these are more or less embedded in universities or PRIs. They include the Laser Centre, the Meraka Institute (for information and communication technology – ICT), the Biotechnology Regional Innovation Centres, the South African AIDS Vaccine Initiative, the South African Bioinformatics Initiative, the Automotive Industry Development Centre, the Innovation Hub, the South African Centre for Epidemiological Modelling and Analysis, the South African Malaria Initiative, and the S&T centres of Armscor. It is estimated that the total budget of these units was approximately ZAR 500 million (USD 192 million in PPP) in the 2004/05 financial year.

The Tshumisano Trust was set up with support from the German Aid Agency GTZ to provide technical and financial support to technology stations, which are based at universities of technology/technikons and had a budget of ZAR 33 million in 2004/05. The technology stations offer technology solutions, services and training to SMEs. The aims of the Tshumisano programme are not only to assist companies but also to help develop the research and technology skills of faculty and students in the new universities.

Technology stations that fall under the control of the Trust are:

- Tshwane University of Technology: electronics and electrical engineering, complemented by information technology.
- Central University of Technology, Free State: metals value adding and product development.
- Tshwane University of Technology: chemistry and chemical engineering.
- Mangosuthu Technikon: chemistry and chemical engineering.
- Vaal University of Technology: materials and processing technologies.
- Nelson Mandela Metropolitan University: automotive components.
- Cape Peninsula University of Technology: clothing and textile.
- University of Johannesburg: metal casting technology.

- Durban Institute of Technology: reinforced and moulded plastics.
- Cape Peninsula University of Technology: agri-food processing technologies.

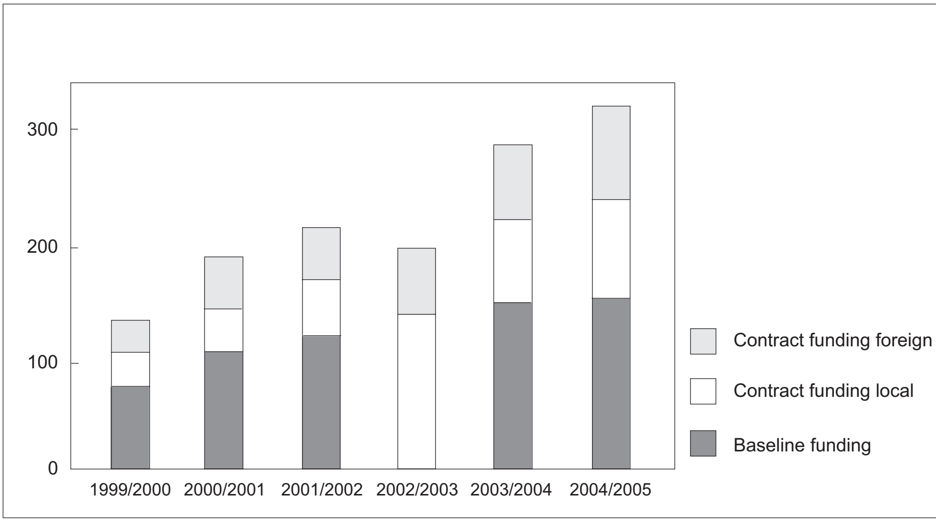
A total of 455 SMEs benefited from the work of the stations in 2004/05, of which 206 received training (DST, Annual Report, 2004/05). Each technology station has a small management element to identify and support companies and to make the necessary links to the university. The direct services to SMEs are provided by technical experts including professors, lecturers, postgraduates and external consultants, thus enriching the R&D of the host institution as well as solving the technology-based problems of SMEs. To identify SMEs' specific needs in terms of product and process improvement, the Trust increased its stations from three in 2001 to ten in 2004 to accommodate the wide range of needs in various economic sectors.

By establishing stations regionally, at historically black institutions, the Trust aimed to make technology support more accessible than it would be with the more established institutions of the higher education sector. The evaluation of the 2002 R&D strategy indicated that the Tshumisano centres were suffering from the use of a German technology transfer model in young South African institutions and argued that this was limiting their effectiveness (Maharaj *et al.*, 2003). The review team felt that the main problem was instead an acute shortage of people with the breadth of business and technology skills needed to offer useful and credible advice to the companies involved.

3.3.4.1. The Medical Research Council

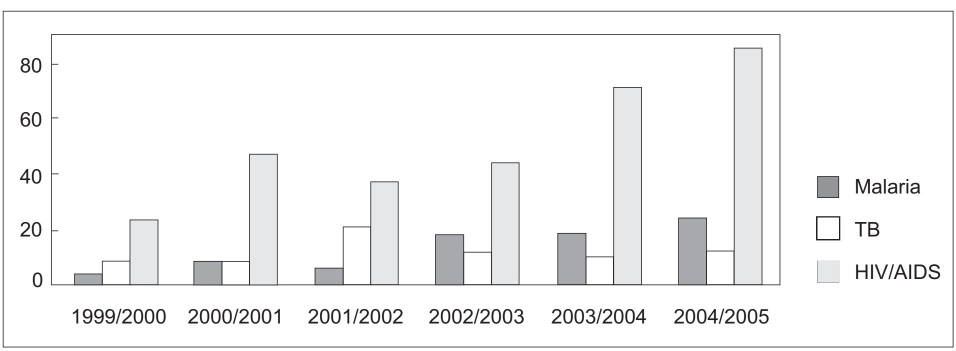
The Medical Research Council (MRC) was established in 1969 as a research facility of the Department of Health. It currently has a staff of 830, revenues of ZAR 335 million (2005) and produces about 600 peer-reviewed journal articles a year and two to five patents. It is the only one of the research councils to act as an R&D funding agency. In 2005, 74% of the MRC's revenues were spent extramurally, compared with 80% for the US National Institutes of Health, 40% for the UK Medical Research Council and 83% for the Indian Council on Medical Research (MRC, 2006). The Nordic countries' medical research funders spend 100% of their budget externally. About a fifth of the MRC's income is from abroad (Figure 2.14) and is heavily associated with the Council's focus on AIDS research (Figure 2.15).

Figure 2.14. MRC funding (ZAR millions)



Source: MRC, SETI Review 2006, MRC (2006).

Figure 2.15. Primary disease foci of MRC funding (ZAR millions)



Source: MRC, SETI Review 2006, MRC (2006).

MRC has 47 research units organised into six categories:

- Environment and Development.
- Health Systems and Policy.
- Non-communicable Diseases.

- Infection and Immunity.
- Molecules to Disease.
- Women and Child Health.

However, these categories have no leaders, are more descriptive than organisational and are not reflected in the planning process. MRC aims to increase the clarity of its role as a promoter and strategic planner for research, as a professional support organisation and as translator of research into practice through improved information and stakeholder links. In effect, this means completing the transition from research performer to research funding agency.

2.3.5. Concluding remarks on overall policy framework and developments

Since 1994, and the abandonment of the peculiar needs of apartheid and the end of the country's isolation, South Africa's innovation and research policies have been significantly modernised and have entered the international mainstream. The government has developed a more holistic view of science and technology by centralising responsibility in the DST. National needs and strategy have been openly debated both in government and through a foresight process. Priority has been explicitly given to innovation, rather than expansion of traditional, researcher-directed university research, though major projects in fundamental research continue to be important.

In practice, however, some planned institutional changes have not taken place. An innovation agency has not been set up; instead, the role of NRF has been expanded to encompass innovation. Innovation programmes aimed at poverty reduction and the exploitation of South Africa's strong position in mature industries have not been launched.

Currently, most countries that review the structure of their innovation and research governance systems are gravitating towards a Finnish model, with a central forum or arena to debate policy. The priority given to innovation is often reflected in the involvement of the prime minister. South Africa belongs to the group of countries that has created such forums to some extent but not taken the step of creating a single national body which acts as the ultimate arbiter and co-ordinator of policy. NACI has the potential to play this role, but is limited by its ties to DST. It lacks the wider overview needed (for example, of policies pursued by DTI and of various sectoral ministries) to debate and help set national priorities and to co-ordinate the national effort.

So far, progress in separating customers and contractors in public R&D has mainly taken place within the spheres of the DST and the DTI. Further agencification in other parts of government would expose science councils to more competition and would allow cross-sectoral approaches to innovation and research issues, such as health and environment. One option would be to expand the role of the NRF and build a single research and innovation agency that would implement policies for multiple ministries and thereby have the potential to provide the necessary *de facto* horizontal co-ordination.

The review team had a rather partial view of innovation activities related to the DTI and a still less complete one of what is being done by the provinces. DTI has a number of instruments that have been imported from Europe and have the potential for working well, provided important aspects of the South African context, such as the acute shortage of people with the experience needed to provide innovation support to smaller firms, are taken into account. However, the review team was unable to identify a clear rationale for the mix of instruments used or – no less important – justification of the absolute and relative amounts of money devoted to different parts of the instrument portfolio. Few OECD countries can provide such a rationale, but it is perhaps especially important to have one in the South African context of resource shortages.

As in many other countries, the Department of Education handles both schools and the higher education sector. It has introduced a new funding formula for universities which provides some (weak) incentives to encourage good research performance. At present, historically disadvantaged universities benefit from this research incentive whatever their research performance. It is not clear that this is sufficient to help them build serious research capacity, in part because funding that goes centrally to the universities is hard to prioritise.[24] More broadly, general incentives for quality in higher education research need to be complemented by centres of excellence and competence centres that reinforce critical mass and specialisation; otherwise the universities are likely to disperse the available research resources.

The Department of Education wisely provides a National Student Financial Aid Scheme that helps poorer students obtain a university education. Nonetheless, the burden of student debt appears to discourage

24. The Nordic countries (especially Sweden, via the Knowledge Foundation) have set up dedicated funding instruments in the new regional universities which are sheltered for a period from competition with the established institutions. These focus on setting up small research centres so that the new universities can establish their own research profiles, typically in concert with regional industry.

people from taking higher degrees, and it may be useful to consider forgiving some student debt upon graduation at a higher degree level. The use of cost-related university fees appears to be a further disincentive to study in high-cost areas like science and engineering. It could be useful to rebalance the fee system to reflect needs and demand, while still maintaining the same level of overall income to the universities.

In general, looking across the portfolio of instruments used in innovation and research policy, it is not always easy to understand relative priorities. For example, the fact that the technology-push Innovation Fund is almost twice the size of the demand-led THRIP, which supports the development of capabilities relevant to existing industry, is hard to explain. International practice tends to put substantial effort into ensuring that the needs of the existing economy are satisfied and to place smaller bets on invention outside existing industrial structures. The relative priorities allocated to highly visible fundamental research projects, the needs of the nuclear energy industry and innovation for poverty reduction might usefully be debated in the kind of co-ordination forum discussed above.

2.4. Research and innovation performers

2.4.1. R&D in business

South Africa's pattern of investment in R&D is more typical of developed than developing economies, in that 45% of all R&D is funded by business and 58% of R&D is performed in the business sector. As in many other countries, R&D performance is concentrated:

- 72% of business enterprise expenditure on R&D (BERD) is performed by large companies.
- 20% of BERD is carried out by multinationals.
- BERD is heavily concentrated in Gauteng Province (61%), the Western Cape (14%) and KwaZulu-Natal (9%).
- 18% of BERD is financed from abroad.

The state has played a significant role in the past as an incubator and developer of technology. BERD includes the substantial R&D efforts of state and privatised state corporations. Stripping out major state companies such as Denel, Eskom-PBMR and Transnet would reduce private-sector performance of R&D to about 40%. Removing the R&D work of the now-privatised Sasol would reduce it further, to somewhere in the range of 30-35% (Kahn, 2005).

Table 2.10 lists some key characteristics of BERD, based on the three R&D surveys done in South Africa to date. (It is likely that at least some of the rising proportion of BERD as a percentage of GDP is caused by the improving coverage of the R&D survey.)

Table 2.10. Main characteristics of BERD, 2001/05

	2004/05	2003/04	2001/02
BERD	ZAR 6 766 billion	ZAR 5 591 billion	ZAR 4 023 billion
BERD as a percentage of GDP	0.49%	0.45%	0.41%
Percentage of BERD financed by industry	69.0%	80.5%	81.4%
Percentage of BERD financed by government	7.1%	6.2%	8.9%
Percentage of BERD financed by other national sources	6.1%	3.8%	5.2%
Percentage of BERD financed from abroad	17.9%	9.6%	4.5%
Total business sector R&D personnel (FTE)	11 296.0	9 131.7	6 210.3
Total business sector researchers (FTE)	5 300.7	4 152.9	2 952.0

Source: R&D Survey, 2004/05.

Manufacturing industry performs almost 45% of BERD. As will be seen, a surprisingly high share of BERD (28%) is done in the services sector, the main performers being clinical medical services, the financial sector and engineering services of various kinds (related largely to resource-based industry and construction).

Over three-quarters of people acting as researchers in a full- or part-time capacity in industry are white. Taking R&D-performing personnel in business as a whole, two-thirds are white, so non-whites are better represented in the lower than in the higher R&D grades (Table 2.11). Women are under-represented in almost every category. Another striking feature is the low proportion of PhDs among industrial R&D workers.

Table 2.11. Business R&D personnel headcount by race, qualification and gender, 2004/05

		African		Coloured		Indian		White		Total		TOTAL	%
		M	F	M	F	M	F	M	F	M	F		
Researchers	Doctoral degree or equivalent	51	55	22	0	24	21	634	186	731	262	993	6.9%
	Masters, Hons, Bachelor or equivalent	386	224	76	21	274	114	2 779	883	3 515	1 242	4 757	33.2%
	Diplomas	64	89	12	17	32	51	460	101	568	258	825	5.8%
	TOTAL	501	367	110	38	330	186	3 872	1 170	4 814	1 761	6 575	45.9%
	Percentage	7.6%	5.6%	1.7%	0.6%	5.0%	2.8%	58.9%	17.8%	73.2%	26.8%		
Technicians	Doctoral degree or equivalent	0	0	0	0	0	0	12	0	12	0	12	0.1%
	Masters, Hons, Bachelor or equivalent	142	106	9	29	132	36	715	255	998	427	1 425	9.9%
	Diplomas	422	248	55	62	80	62	1 146	212	1 704	584	2 288	16.0%
	TOTAL	564	354	65	91	213	99	1 873	467	2 714	1 011	3 725	26.0%
	Percentage	15.1%	9.5%	1.7%	2.4%	5.7%	2.6%	50.3%	12.5%	72.9%	27.1%		
Other	Doctoral degree or equivalent	16	19	0	0	14	13	38	52	68	83	151	1.1%
	Masters, Hons, Bachelor or equivalent	26	178	2	24	2	13	211	122	241	337	578	4.0%
	Diplomas	84	185	10	20	10	31	178	148	283	385	668	4.7%
	Other qualifications (incl. non-formal)	1 418	420	82	81	84	33	259	263	1 843	798	2 641	18.4%
	TOTAL	1 544	802	94	126	110	91	686	585	2 435	1 603	4 038	28.2%
	Percentage	38.2%	19.8%	2.3%	3.1%	2.7%	2.2%	17.0%	14.5%	60.3%	39.7%		
	Grand total	2 609	1 523	269	255	653	375	6 432	2 222	9 963	4 375	14 338	
	Percentage	18.2%	10.6%	1.9%	1.8%	4.6%	2.6%	44.9%	15.5%	69.5%	30.5%		100.0%

Table 2.12. Headcount enrolments in public higher education, 2003

Institutions	Overall contact	Distance	Total	Black contact	Distance	Total	Subject SET	Business	Humanities
Historically black universities	89 432	11 497	100 929	98%	100%	98%	26%	15%	59%
Historically white universities	192 220	44 059	236 279	48%	88%	55%	31%	17%	52%
University of South Africa (UNISA)	514	150 019	150 533	60%	65%	65%	11%	39%	50%
Total universities	282 166	205 575	487 741	64%	72%	67%	24%	24%	52%
Historically black technikons	71 146	0	71 146	97%		97%	42%	39%	19%
Historically white technikons	95 532	12 499	108 031	78%	98%	80%	41%	32%	26%
Technikon South Africa	0	50 875	50 875		83%	83%	11%	84%	5%
Total technikons	166 678	63 374	230 052	86%	86%	86%	35%	46%	19%
Total	448 844	268 949	717 793	72%	75%	73%	28%	31%	41%
	63%	37%	100%						

Source: Department of Education, Education Statistics in South Africa at a Glance in 2003, Pretoria, 2005.

2.4.2. The higher education sector

While the number of higher education institutions has been reduced from 36 to 23, largely by merging technikons (technical colleges or polytechnics), the higher education sector as a whole has expanded dramatically since 1994, with the number of students rising from 473 000 in 1993 to 718 000[25] by 2003, for an 18% participation rate. The rate of faculty growth is slower. In the university sector, total faculty numbers grew from 20 500 in 2000 to 21 800 in 2003, an increase of 6%, as against an increase of 22% (18% in FTEs) in the size of the student body. The arithmetic result of these different growth rates was a rise from 21:1 to 23:1 in the student-faculty ratio over the four years.

The traditional (historically white) institutions now have about 37% of the student body with the balance split between comprehensive (42%) and technical (21%) universities. However, only 109 000 student graduated in 2003, so that graduations, as a proportion of the student body, were only 15% a year over the period 2000-03. This implies a high drop-out rate. Indeed, of the 2000 student cohort, 41% of university students and 58% of technikon students had dropped out by the end of 2002 (Department of Education, 2005). Drop-out rates appear to have been rising in line with the increasing proportion of students from disadvantaged backgrounds in the higher education system. There is thus a tension between the need to educate a higher proportion of people at university level, on the one hand, and the need to increase the number of faculty positions more rapidly than universities can pay for or find candidates to fill, on the other. Yet, the growing proportion of disadvantaged students means that it is necessary to reduce, rather than increase, the student-faculty ratio.

Table 2.12 shows the composition of the student body in South Africa's public higher education institutions. Included in the numbers shown for the university system are about 40 000 Master's students and a little over 8 000 working towards a PhD. A strikingly high proportion of all students (37%) are involved in distance learning. Some 53% of contact students and 56% of distance students are women. Women are significantly over-represented (70%) among distance learners at historically black universities (HBUs) and a little less so (66%) at historically white universities (HWUs). Women obtain over half the degrees awarded in all areas except science, engineering and technology. The table shows the legacy of apartheid in terms of study places in historically black *vs.* white institutions, but also that very significant progress that has been made in empowering the black community to attend the HWUs. There is very little white penetration of historically

25. 200 000 of these are at the distance learning University of South Africa.

black institutions. While financial support is available for students from poor families through the National Student Financial Aid Scheme, universities maintain a level playing field for admissions grades, in the sense that no allowance is made for the likely effects of inadequate schooling on the grades of leavers from many traditionally black public schools.

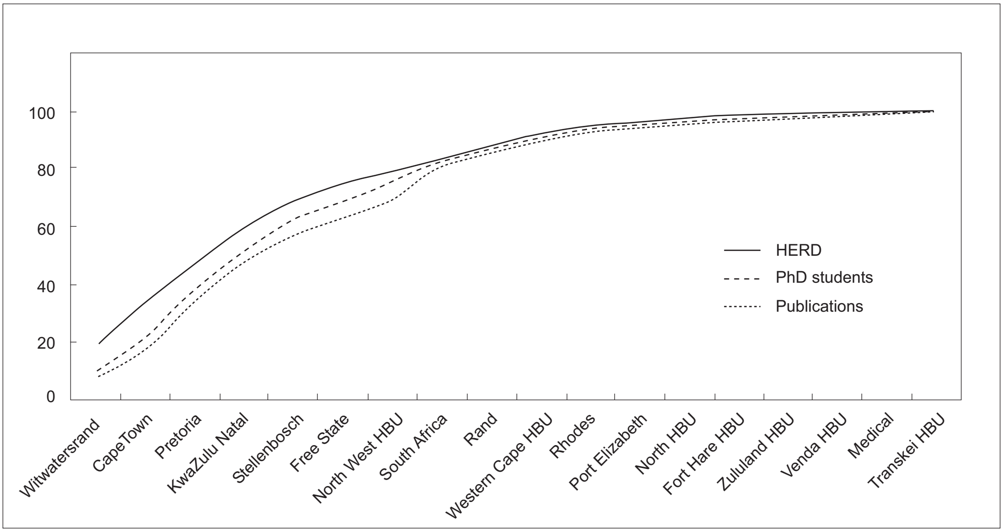
Table 2.13 shows the amount of R&D expenditure, number of publications and PhD students at South African universities. As in most systems, these values are concentrated in a small number of the most successful universities. Figure 2.16 plots the corresponding Pareto curves (cumulated percentage on the vertical scale). Historically black universities are tagged HBU. The figure shows, among other things, that 75% of higher education expenditure on R&D (HERD) is spent in six universities. The highest-spending HBU is the University of the North West, in seventh place.

Table 2.13. R&D expenditures, publications and PhD students at South African universities, 2003

University	**HERD** (ZAR millions)	Publications	PhD students
University of the Witwatersrand	330	557	620
University of Cape Town	312	564	783
University of Pretoria	254	954	1 529
University of KwaZulu-Natal	238	704	960
University of Stellenbosch	205	624	757
University of the Free State	86	334	529
North West University	84	267	558
University of South Africa	83	435	859
Rand Afrikaans University	82	277	578
University of the Western Cape	63	106	245
Rhodes University	60	165	193
University of Port Elizabeth	38	123	183
University of the North	19	63	75
University of Fort Hare	12	79	23
University of Zululand	11	61	128
University of Venda for Science and Technology	11	24	27
Medical University of South Africa	8	50	64
University of Transkei	6	14	1
Totals	1 900	5 401	8 112

Source: Michael Kahn.

Figure 2.16. Pareto curves of university HERD, publications and PhD students, 2003



Expansion and the need to upgrade teaching institutions on a very large scale imply increasing the hitherto small number of research-trained people on the faculty of the newer institutions. As in other countries that are expanding the size and capability of the higher education system, this has not only increased student numbers and created a need for in-service PhD training for existing faculty but also provoked a debate about whether radically increased participation rates can or should be achieved entirely in research universities. These issues are arising in the OECD area as overall higher education participation rates rise to about 50%, rather than the 20% currently in the National Plan for South Africa.

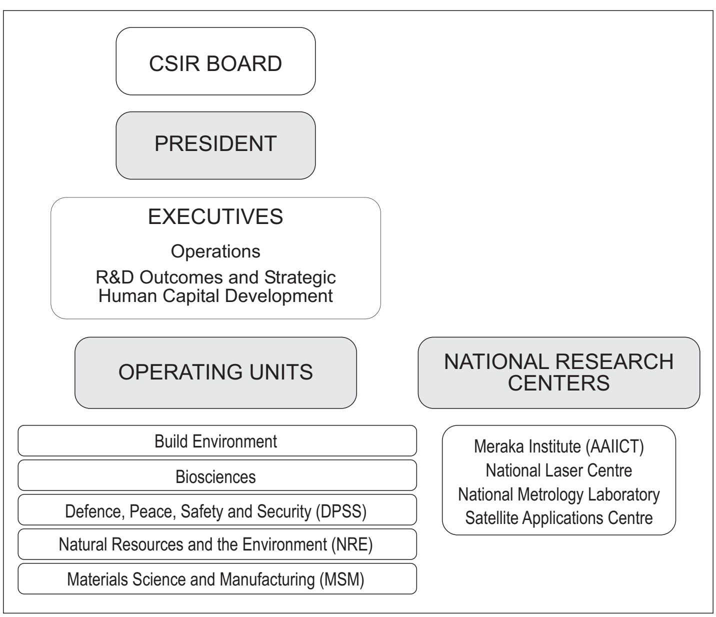
2.4.3. The public research institutes

There are currently 12 major PRIs, the largest and oldest of which is the Council for Scientific and Industrial Research, which was established in 1945. In principle the PRIs are funded by a mixture of parliamentary grant and contract income. From 2006, they are required to establish performance contracts with their parent departments and to maintain associated performance indicators.

Table 2.14. Income of major PRIs in South Africa, 2004/05

Organisation	Line department	Grants (000s)	Contracts (000s)	Grant %
Council for Scientific and Industrial Research	DTI (later on DST)	401	589	41%
South African Bureau of Standards	DTI	99	335	23%
Mintek	Minerals & Energy	89	167	35%
Council for Geoscience	Minerals & Energy	78	43	64%
Agricultural Research Council	Agriculture	321	238	57%
Medical Research Council	Health	156	179	46%
Human Sciences Research Council	DST	71	117	38%
Africa Research Institute of South Africa	DST	16	5	78%
South Africa Weather Service	DEET	97	54	64%
South Africa Energy Research Institute	DST			
South Africa Biodiversity Institute	DST	83	98	46%
Marine & Coastal Management Division	DEET			
Totals		1 411	1 825	44%

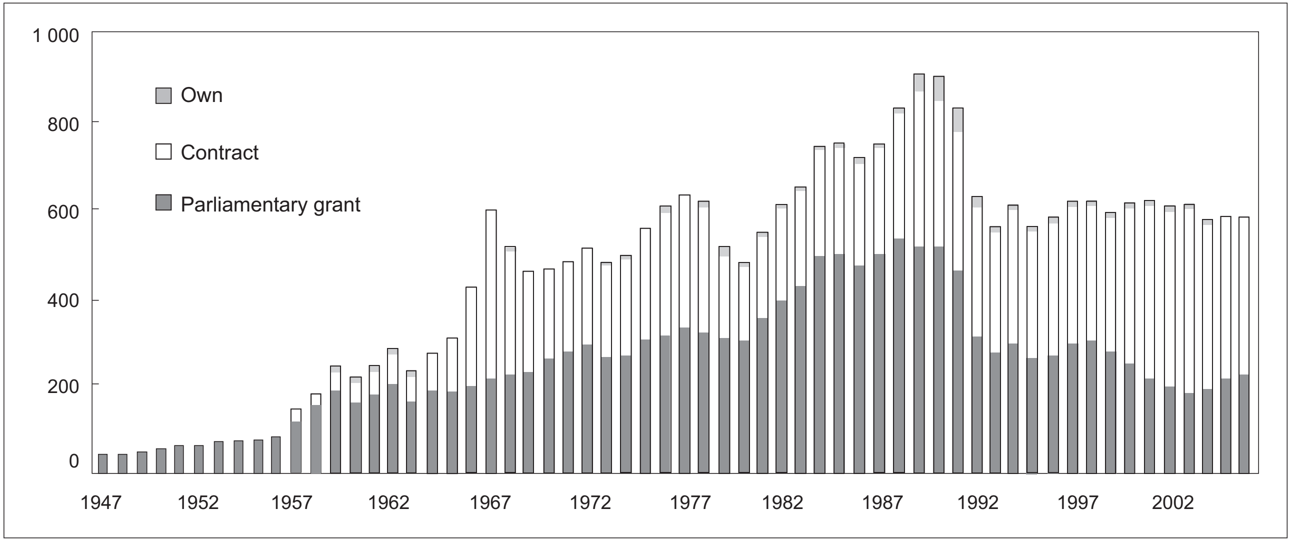
Figure 2.17. CSIR's internal structure, 2006



Source: CSIR.

Figure 2.18. CSIR sources of income

ZAR millions



Source: D. Walwyn and R.J. Scholes (2006), 'The Impact of a Mixed Income Model on the South African CSIR: A Recipe for Success or Disaster?'', *South African Journal of Science*, No. 102.

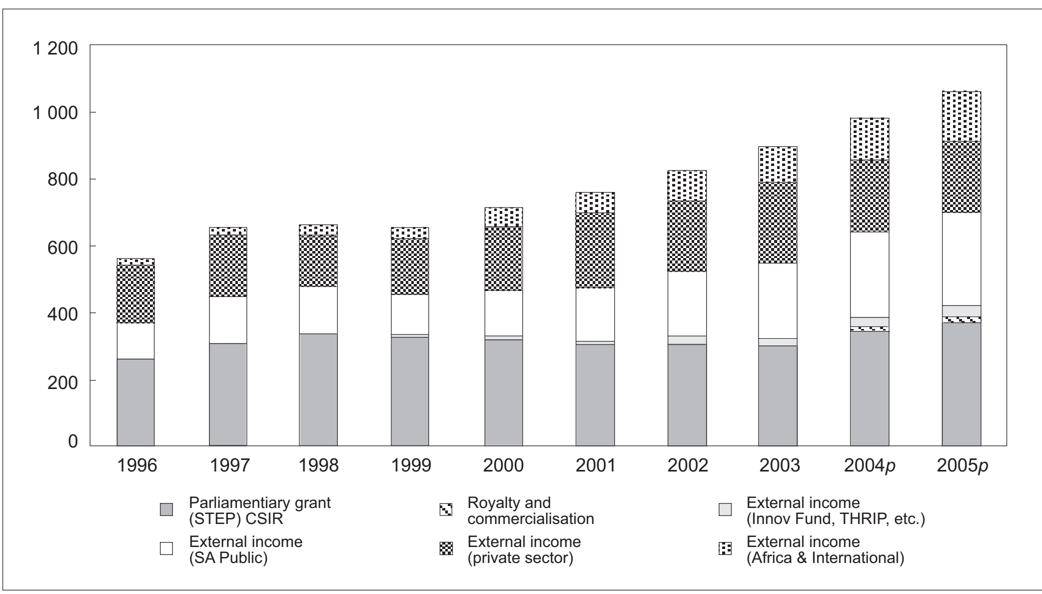
2.4.4. The Council for Scientific and Industrial Research

The CSIR was set up in 1945 and is by far the largest of the PRIs, with 2005 revenues slightly in excess of ZAR 1 billion. It functions as the major national industrially oriented research institute and is directly comparable to institutions such as VTT (Finland), SINTEF (Norway) and TNO (Netherlands). Like these, CSIR has rationalised its internal structure in recent years and is now structured as shown in Figure 2.17. Like TNO, CSIR functions as a defence evaluation and research institute, in addition to its industrial mission.

The historical pattern of financing of CSIR is also familiar from other countries, with the funding entirely provided by the state in the early years but with a growing expectation that contract income should be an important part of the total. CSIR was at its largest during the isolation years of the apartheid regime. It peaked at about 5 000 employees in 1984 and stood at 2 179 in 2006. As Figure 2.18 indicates, however, income peaked in 1990 at the end of the frantic burst of activity during which the apartheid government tried to maintain autarchic technological capabilities. Figure 2.19 indicates the various sources of income in the more recent part of the period.

Figure 2.19. CSIR's sources of income

ZAR millions



Source: Background report.

CSIR management devoted considerable attention to generating contract income in the period following the end of apartheid, and the work of the CSIR became increasingly short-term and service-oriented during the 1990s. Since 2000, the private sector and the universities have increasingly offered such services, and CSIR has been trying to refocus on a more research-related mission. In 2005, CSIR aimed to split its efforts as follows, and reported that it came within two percentage points of achieving each of these targets.

- 20%: strategic basic and applied research.
- 40%: experimental development.
- 30%: engineering.
- 10%: services and consulting.

This places CSIR slightly downstream of its European counterparts (listed above), which typically claim about 30% in each of the areas of strategic, basic and applied research. CSIR's manpower is less qualified than that of its European counterparts, however, with some 8% of the staff holding PhDs as compared with the 20-35% found elsewhere. In effect, CSIR mirrors what some European equivalents would have been like at a slightly earlier stage of industrial development.

Publication productivity is low: about 0.1 publications per researcher-year. This compares with CSIR's own target of one publication per researcher per year and is well below international norms. Like other established research-performing organisations in South Africa, CSIR's senior levels are dominated by ageing white males. The Annual Report indicates that this is only changing slowly, principally owing to the difficulty of finding suitably qualified recruits.

The 2003 panel-based evaluation of CSIR (Mashelkar *et al.*, 2003) strongly endorsed its work, its role in the innovation system and its alignment with national priorities. However, it also expressed concern that the science base of CSIR was weakening, owing to over-emphasis on generating external income. It pointed to a need for departments to specify more closely what they expected of CSIR in return for their contributions to its core parliamentary grant. The panel argued that a shortage of people able to define and run projects was one, if not the, critical blockage to CSIR development and recommended measures both to increase the quality and the quantity of research-capable manpower at CSIR, including much improved human resources and career management. It found a need for a more interdisciplinary approach in order to tackle real external problems as well as greater interaction with HEIs in order to sustain CSIR's science and technology capabilities.

Walwyn and Scholes (2006) have more recently provided evidence that failure to manage the core grant has allowed CSIR to use it for organisational slack and to cross-subsidise contract projects. Walwyn has put measures in place at CSIR to achieve tighter management of core-funded activities.

2.4.5. The Human Sciences Research Council

The HSRC was established in 1968. Its current mission is to undertake, stimulate and promote policy-relevant applied social science that contributes to the development of South Africa and the region. It is therefore South Africa's primary policy "think tank". It is organised by six research programmes:

- Education, science and skills development.
- Child, youth, family and social development.
- Democracy and governance.
- Social aspects of HIV/AIDS and health.
- Society, culture and identity.
- Urban, rural and economic development.

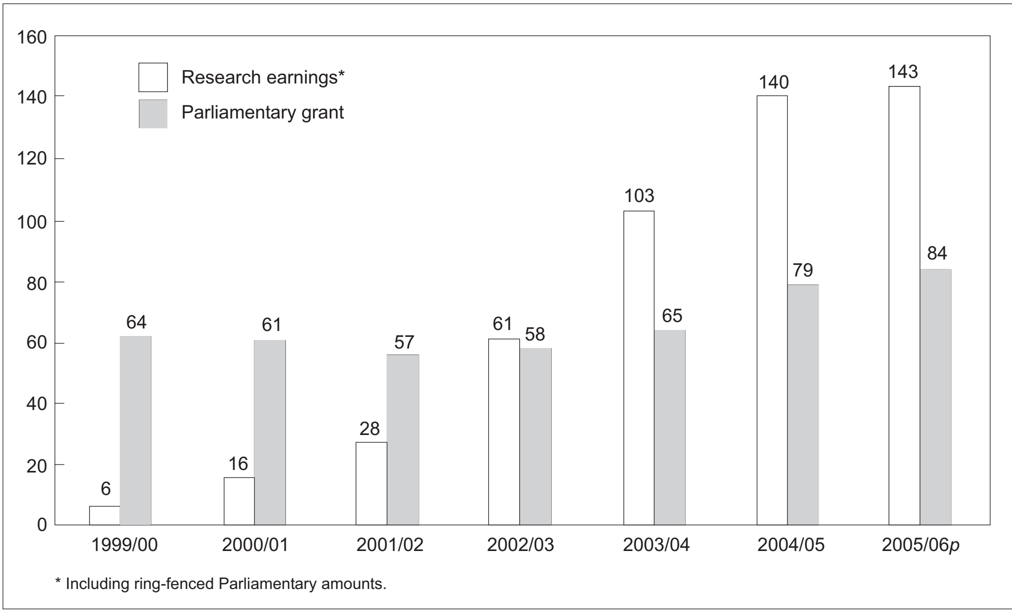
Matrixed across these are "cross-cutting units" for: Capacity Development; Gender and Development; Social Aspects of HIV/AIDS Research Alliance research network; Knowledge Systems; and Policy Analysis.

In 2005, the HSRC had total revenues of ZAR 237 million, of which ZAR 79 million (33%) were provided through its parliamentary grant (Figure 2.20). About ZAR 10 million is ring-fenced for the provision of R&D surveys and policy studies to the DST; the Council thus serves as an important source of strategic intelligence to the DST and the R&D policy system more broadly.

As in the natural sciences and engineering, this research council experiences great difficulty in recruiting experienced social scientists; hence, a substantial internal effort is devoted to human resource development. HSRC is also taking numbers of interns, who are to work in various branches of government once their grasp of social and policy science has been strengthened.

Figure 2.20. HSRC income

ZAR millions



Source: HSRC, Annual Report, 2004/05.

2.4.6. Concluding remarks on research and innovation performers

In the South African innovation system, R&D performance is concentrated in large companies and in state organisations. Business R&D is focused on the resource-intensive industries and the related (upstream, service and downstream) activities that have grown out of them, as well as on information technology. The number of researchers or people with PhDs in industry is low by OECD standards and one strand of future policy would usefully be to increase this proportion.

Research in the higher education sector is similarly concentrated, with five universities doing the lion's share and producing in many cases globally excellent research. It would be very risky to reduce the national commitment to these institutions, which form key knowledge nodes within South Africa and vital links to world research. In parallel, however, there is a need for funding that more explicitly develops capabilities in institutions that are behind the leaders.

The review team developed only a partial view of the PRIs. CSIR is on the way to becoming a research institute in the northern European manner, such as VTT in Finland. Provided it has a more consistent direction, is explicitly managed through performance contracts and is encouraged to build a balanced portfolio of capability development, research co-operation and technology transfer on the northern European model, there is every reason to expect it to be a major contributor to development in South Africa.

The HSRC plays a special role in the innovation system as a source of strategic intelligence, a point at which social science makes a major contribution to steering the innovation system. This is a very important activity and its results would be a crucial support for a national policy forum on innovation.

2.5. Towards a second transition: main policy challenges

Moving forward from the current situation, the South African innovation system faces a number of important challenges. These include: contributing to the reduction of persistent poverty and the unemployment concentrated in the second economy; responding to a range of demographic pressures; accelerating industrial and infrastructural investment in the face of a rising shortage of engineering skills; and engaging effectively with the changing demands of the global technological environment.

As sketched out above, the South African innovation system has made a remarkable transition from its weakness at the start of the 1990s. Essentially, however, most of that transition has been about consolidation, re-structuring and realignment, in effect, the construction of a new, viable platform from which to move forward to meet the challenges and opportunities of the next decade. These will involve a further, demanding transition. Numerous pressures will require unprecedented rates of quantitative expansion in many parts of the system, together with quite new roles for the system. The four challenges mentioned above seem particularly important.

2.5.1. Poverty, unemployment and the second economy

About half the country's population is part of the second economy, including the unemployed (widely defined) and those who are semi-employed in the informal sector and in subsistence agriculture. A considerable number of people have been able to move out of the second economy over the last decade, and aspects of the lives of some of those who remain have been improved as a result of increased social transfer payments, increased access to water and electricity, and via participation in schemes to increase employment opportunities. However, although growth in the economy appears to have generated a significant number of jobs over the last decade, the number of people seeking employment has increased faster. Consequently, the rate of unemployment, heavily concentrated among the black population, has increased rather than decreased.

There is now widespread recognition that simply relying on the first economy to absorb the second by various "trickle-down" processes will not work over a time scale that is acceptable in either human or political terms. Consequently, for instance, in the Accelerated and Shared Growth Initiative (ASGISA), the government restated and reinforced its intention of "Eliminating the Second Economy". It seems likely that the innovation system is inherently able to make only a somewhat limited contribution to achieving that aim, with other spheres of action being more important. However, overall strategies for the development of the innovation system have not yet systematically examined the full range of ways in which science, technology and innovation might throw their combined weight behind the elimination of the second economy.

2.5.2. Demographic pressures

Several types of demographic pressure seem to have increasingly important implications for almost all aspects of society. Here the focus is on a small number of these and on their implications for only one part of the innovation system – higher education and its critically important foundation in earlier stages of education.

One type of pressure stems from aims to achieve higher overall rates of participation in higher education. Meeting this challenge has already been an uphill struggle. Although there has been a large increase in the total number of students enrolled in universities over the last ten years, the overall university participation rate was only 15% in 2001, a fall from 17% in 1993. The Department of Education now aims to reverse that trend and boost the rate to 20% by 2012, a step towards the higher levels that are hoped for beyond then.

A second type of pressure is associated with changing the demographic composition of participation in higher education, in particular, through increased participation by the black population. Again, achieving this has been a struggle over the past decade. A very large part of the total absolute increase in student numbers has come from the black population but, given the overall scale of this previously excluded group, the university participation rate for black students has increased only marginally from 9 to 11% and some of this increase appears to be accounted for by increased numbers of foreign students.

The third type of demographic pressure on the higher education system stems from increasing absolute numbers in the younger cohorts of the population. For instance, the size of the 10-14 year age cohort in 2001 (*i.e.* the cohort currently entering higher education) was about 800 000 larger than the 20-24 year age cohort (*i.e.* the cohort that has just gone through the higher education stage). Adding this absolute increase to the expectations and plans for higher participation rates creates enormous pressures for expansion. For example, if one applies to these numbers the aim of an overall 20% participation rate by 2012, the size of the higher education system will have to increase by about one-third.

Finally, cutting across these pressures, there are the negative demographic effects of HIV/AIDS. While the rate of increase in HIV infection may be tailing off, the follow-on incidence of AIDS-related disease and death is accelerating. Although the demographic consequences and their implications for higher education remain uncertain, at least one of these is likely to make it even harder to achieve the kind of expansion that is sought. The capacity of the education system to cope even with existing numbers will be increasingly undermined by rising rates of illness and death among schoolteachers and university staff.

This combination of pressures, combined with the ageing profile of academic staff in universities, creates a need for something much more radical than incremental expansion of the higher education sector and its crucial foundations in the school system.

2.5.3. Surging industrial and infrastructural investment and the engineering gap

After a sharp fall in the early 1990s, the level of gross fixed capital formation bumped along for a decade at a historically low level of around 15% of GDP. However, it is now accelerating sharply and the government envisages a return to the levels of around 25% or more that were achieved in the early 1980s. This shift is already under way, with large increases in investment already being implemented or taken through advanced stages of design and planning. The result is that gross fixed capital formation is already rising to about 20% of GDP. These investments are being undertaken in the private and public sectors, and they span a host of production and infrastructure projects: power generation and distribution, road and rail transport, ports and related facilities, provincial infrastructure projects, and new mining developments, together with industrial projects across a wide range of sectors.

This investment will carry with it a tide of new technology, and will inject into the economy a flow of innovation that has no precedent in the last 20 years and probably much longer. This surge of investment-driven innovation could have a major positive impact on productivity growth, competitiveness, employment and welfare in the second economy. At the same time, it is likely to create a set of conditions that will attract follow-on private investment by both small firms and large.

There is, however, a looming snag, one which was identified as a binding constraint in the announcement of the ASGISA. This is the sharply increasing shortage of the skills needed to implement these projects and to operate and maintain them once completed. The shortages range from experienced engineers and project managers to the whole range of skilled artisans without which the projects can be neither built nor operated – broadly a spectrum of engineering capabilities.

2.5.4. Globalisation and the increasing openness of the innovation system

The need to increase the international openness of national innovation systems is well recognised by OECD countries. It is likely to become a matter of much greater significance for South Africa over the next decade.

One aspect involves the major shifts that are occurring via the global mobility of skilled people. Increasing numbers of advanced countries, facing growing shortages of the skills they need to sustain their economic development, are implementing stronger measures to attract skills from the global talent pool. Emerging economies like Singapore have developed even more active strategies to exploit that global pool, and they seem likely to be joined by some of the large economies like India and China, where key skill shortages are emerging. In the meantime, OECD countries increasingly operate "green card" schemes for key knowledge workers or policies that in practice give the immigration authorities flexibility in permitting entry not only for researchers but also broader categories of people likely to engage in aspects of the research or innovation process. For example, Germany has a scheme covering both R&D and IT workers.

South Africa does not yet appear to have developed a strategy in this respect. An excellent NACI study has addressed aspects of this international mobility issue (Kahn *et al.*, 2004). However, it focused primarily on the mobility of people employed in R&D, omitting issues of global shortages of engineers and the implications for the design and engineering component of the national innovation system.

A second aspect of the international openness of the innovation system concerns the much greater role that is likely to be played over the next decade by foreign direct investment, especially inward FDI. The issue does not seem to have been high on the policy agenda. It was barely mentioned in the 1996 White Paper on Science and Technology, the 2002 National Research and Development Strategy, or the 2006 NACI study of the South African National System of Innovation.

A third issue is the international openness of R&D activity. Selected aspects of this issue have attracted considerable comment in South Africa, in particular the relocation of existing R&D activities out of the country in the early to mid-1990s, the closing or downscaling of local R&D activities following inward FDI, and the location of new R&D activities overseas by South African companies in more recent years. Such events are sometimes seen as elements of a one-way process in which South Africa loses R&D activities and gains only ready-made technologies from foreign sources. This asymmetry in South Africa's relationship with the global R&D system is sometimes seen as a persisting or even accelerating trend.[26] However, this perspective does not fully recognise several important features of international R&D activity in recent years.

- While economic liberalisation in emerging economies has commonly been followed by closure, reduction and relocation of R&D activities, it is also becoming clear that this may be followed by the initiation and expansion of such activities in sectors of the economy that benefit from the new economic conditions (*e.g.* in the automobile industry in Brazil).
- The initiation of R&D activities overseas by local companies (*e.g.* Sasol's research centre at St. Andrew's University in Scotland) may not constitute a loss to the local innovation system. On the contrary, it may reflect a pattern of behaviour common among highly innovative large firms, in which they exploit knowledge-rich locations around the globe in order to augment their corporate knowledge assets and their locally centred innovative activities.
- As the organisational disintegration of innovative activities increases in advanced economies and multinational corporations (the rising "open innovation" model), South Africa may become increasingly embedded in international flows of funding for R&D and international re-locations of R&D activities that increasingly run two ways. Indeed, the fact that

26. For example, a report by NACI noted that, as part of an apparent "failure in the transformation of the business sector", there is "an increasing tendency for big business to divert their R&D activities outside South Africa, and reluctance by outside companies to invest in R&D activities in South Africa" (NACI, 2002, p. ii).

foreign funding accounted for 18% of locally executed business enterprise R&D suggests that this may already be occurring.

One way or another, South Africa's R&D activities will be increasingly enmeshed in a set of global, knowledge-centred interactions along with two other issues noted above – the international flows of highly skilled human resources and the international flows of FDI. Whether South Africa benefits or loses from these interactions is not predetermined. It will depend heavily on how the challenge is identified and then how it is addressed.

Annex A

Acknowledgements

This OECD review draws on the Background Report prepared under the aegis of the National Advisory Council on Innovation (NACI) by David Walwyn, Hermi Boraine, Steven Gelb, Hendrik Marais, Simon Mpele, Charles Mokonoto, Kate Morris, and Adi Paterson. It also owes a lot to many people who helped by providing information, advice and insight during the OECD review team's visit to South Africa in August/September 2006 or later on by responding to e-mail enquiries. The OECD team acknowledges the assistance of the people named below, with apologies to those inadvertently omitted. It is also immensely grateful to Simon Mpele (NACI) and Robyn Glaser (DST) for their efficient and friendly assistance in arranging the meetings and supporting the OECD review team throughout the visit.

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Acronyms and Abbreviations

AIDC	Automotive Industry Development Centre
AIDS	Acquired Immune Deficiency Syndrome
AMTS	Advanced Manufacturing Technology Strategy
Armscor	Armaments Corporation of South Africa
ASGISA	Accelerated and Shared Growth Initiative for South Africa
ASSAf	Academy of Science of South Africa
BEE	Black economic empowerment
BERD	Business Enterprise Expenditure on Research and Development
BPO	Business process outsourcing
BRIC	Biotechnology Regional Innovation Centre
CeSTII	Centre for Science and Technology and Innovation Indicators
CHE	Council on Higher Education
CIDAUT	Research and Development Centre in Transport and Energy, Spain
CIS	Community Innovation Survey
CRI	Crown Research Institute, New Zealand
CSIR	Council for Scientific and Industrial Research, South Africa
CSP	Customised Sector Programme (a DTI initiative)
DACST	Department of Arts, Culture, Science and Technology (now the DST)
DEAT	Department of Environmental Affairs and Tourism
DEEM	Design, engineering, entrepreneurial and management
DEET	Department of Environmental Affairs and Tourism
DESA	Development Bank of Southern Africa
DoE	Department of Education
DST	Department of Science and Technology
DTI	Department of Trade and Industry
Eskom	Electricity Supply Commission
EU	European Union

FDI	Foreign direct investment
FEST	Foundation for Education, Science and Technology
FFG	Austrian Research Promotion Agency
FRAM	Norwegian entrepreneurship training programme
FTE	Full-time equivalent
GDP	Gross domestic product
GEM	Global Enterprise Monitor
GEAR	Growth, Employment and Redistribution
GERD	Gross domestic expenditure on research and development
GTS	Advanced Technology Group, Denmark. A network of research institutes.
HBT	Historically black technikon
HBU	Historically black university
HEI	Higher education institution
HERD	Higher Education Expenditure on Research and Development
HIV	Human immunodeficiency virus
HSRC	Human Science Research Council
HWT	Historically white technikon
HWU	Historically white university
ICT	Information and communications technology
IDC	Industrial Development Corporation
IKS	Indigenous knowledge system
IMEC	Interuniversity Microelectronics Centre, Leuven, Belgium
IMS	Integrated Manufacturing Strategy
IP	Intellectual property
ISI	Institute for Scientific Information, Philadelphia
IT	Information technology
IWT	Institute for the Promotion of Innovation by Science and Technology in Flanders, Belgium
JIPSA	Joint Initiative on Priority Skills Acquisition
KIBS	Knowledge-intensive business services

MEC	Minerals-energy complex
Mintek	Council for Mineral Technologies
MiTech	Missions in Technology
MPE	Multotec Process Equipment
MNC	Multinational Corporation
MRC	Medical Research Council
MSDS	Metals Sector Development Strategy
NACI	National Advisory Council on Innovation
NCTC	National Casting Technology Centre
NECSA	Nuclear Energy Council of South Africa
NFTCC	National Fibre, Textile and Clothing Centre
NRF	National Research Foundation
NSTF	National Science and Technology Foundation
NTCCD	National Technology Transfer Center
PBMR	Pebble Bed Modular Reactor
PPP	Purchasing power parity
PRI	Public research institute
R&D	Research and development
RANNIS	The Icelandic Centre for Research
RCN	Research Council of Norway
RDP	Reconstruction and Development Programme
RISA	Research and Innovation Support and Advancement division of NRF
S&T	Science and technology
SAASTA	South African Agency for Science and Technology
SAAVI	South Africa AIDS Vaccine Initiative
SADC	South Africa Development Community
SEDA	Small Enterprise Development Agency
SETA	Sector Education and Training Authorities

SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology
SME	Small, medium and micro enterprise
SP	SP Technical Research Institute of Sweden (formerly the State Testing Authority)
SPII	Support Programme for Industrial Innovation
STI	Science, technology and innovation
STU	The Swedish National Board for Technological development
TAP	Technology Advancement Programme
TEKES	Finnish Funding Agency foe Technology and Innovation
TFP	Total factor productivity
THRIP	Technology and Human Resources for Industry Programme
TNO	Netherlands Organisation for Applied Scientific Research
UNISA	University of South Africa
VAT	Value-added tax
VINNOVA	Swedish Governmental Agency for Innovation Systems
VTT	VTT Technical Research Centre of Finland

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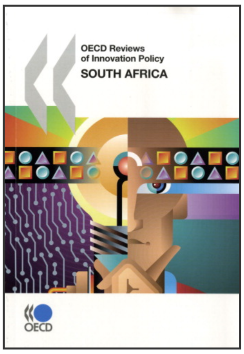

From:

OECD Reviews of Innovation Policy: South Africa 2007

Access the complete publication at:

https://doi.org/10.1787/9789264038240-en

Please cite this chapter as:

OECD (2008), "An Innovation System in Transition: Main Features and Current Policy Challenges", in *OECD Reviews of Innovation Policy: South Africa 2007*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264038240-6-en