OECD Reviews of Innovation Policy

SOUTH AFRICA

OECD

OECD Reviews of Innovation Policy

South Africa

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 30 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation's statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

This work is published on the responsibility of the Secretary-General of the OECD. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the Organisation or of the governments of its member countries.

Corrigenda to OECD publications may be found on line at: *www.oecd.org/publishing/corrigenda*.

Foreword

This review of South Africa’s Innovation Policy is part of a new series of OECD country reviews of innovation policy. It was requested by the South African authorities, represented by the Department of Science and Technology, and was carried out by the OECD Directorate for Science, Technology and Industry (DSTI) under the auspices of the Committee for Scientific and Technological Policy (CSTP).

This review draws on a background report prepared by the South Africa’s National Advisory Council on Innovation (NACI), and on the results of a series of interviews with major stakeholders in South Africa’s innovation system and a peer review meeting within the CSTP.* The review was drafted by Gernot Hutschenreiter (Country Reviews Unit, DSTI, OECD), Erik Arnold (consultant to the OECD, Director, Technopolis Group) and Martin Bell (consultant to the OECD, SPRU, United Kingdom), under the supervision of and with contributions from Jean Guinet (Head, Country Review Unit, DSTI, OECD).

This review owes a lot to South African government officials, in particular Dhesigen Naidoo, Bok Marais, David Walwyn, Simon Mpele and Robyn Glaser, who helped in providing background information, arranging the interviews in South Africa, and advising the OECD team throughout the review process.

* During this meeting the examiners from member countries were Ward Ziarko and Olivier De Cock (Belgium) and Carl Gjersem (Norway).

Table of contents

OVERALL ASSESSMENT AND RECOMMENDATIONS

Since establishing a democratic government, South Africa has made huge progress in recovering from the apartheid era, when the country was socially, economically, politically and largely geographically divided on a racial basis. The government has consistently pursued key priorities: build a single nation, accelerate economic growth, reduce unemployment, eliminate poverty, expand the sphere of the formal economy, and play a leading role in building a better Africa. Modern governance, co-ordinated and coherent policies, and taking government closer to the people are seen as instrumental to achieving these goals.

Post-apartheid South Africa has succeeded in swiftly opening its economy to international trade and capital flows and in stabilising the economy while achieving reasonably good growth performance, mainly driven by productivity gains. However, important socioeconomic problems persist: unemployment, poverty and the exclusion of a large fraction of the population from the formal economy.

The country is now in the midst of two specifically economic transitions: it is responding to globalisation, and it is shifting the structure of its economy away from dependence on primary resource production and associated commodity-based industries. This report assesses South Africa's innovation system both as actor in and contributor to this process and as a key structural determinant of the country's capacity to create employment while retaining dynamic productivity-driven growth.

Achievements and challenges

Achievements

An assessment of South Africa's innovation system must adopt an evolutionary perspective, taking into account both that its transformation has been furthered by revolutionary changes in the political and social context and that it remains constrained by the legacy of the past.

The radical political changes of the 1990s did not lead to collapse of the former innovation system, since many of its basic building blocks have remained but have been restructured, re-scaled and re-oriented, while new elements have been added. The key story has been the reshaping of a relatively strong innovation system serving one set of social, economic and political goals towards another strong system serving a very different set of goals.

In this regard, South Africa's most striking achievement has simply been to surmount the difficulties created by the extremely poor framework conditions of the early 1990s as they concerned the innovation system. The last decade has been negotiated so as to combine considerable transformation of many parts of the innovation system with what can now be seen (despite short-term dips in most indicators) as broadly sustained levels of performance, and several indicators have begun to reach new levels in the last few years.

Gross domestic product (GDP) per head is now about USD 11 400 (2004 in purchasing power parity – PPP), on a par with many newly industrialising countries, although the average conceals huge social inequalities in income. Companies spend about 1.8% of their sales revenue on innovation activities, moderate by OECD standards but still significant, especially given the importance of resource-based industry in South Africa's economy. Its importance is in part also reflected in the fact that the major national revealed comparative advantage in trade is in medium-low technology goods. Formal research and development (R&D) is 0.87% of GDP, and the government's target is to raise this to 1% by 2012, quite an ambitious goal, given the industrial structure.

South Africa has a nucleus of technologically strong, innovation-performing business enterprises, and this base appears to be broadening. R&D expenditure by business enterprises has been rising in recent years and constitutes a larger fraction of total R&D than in most other economies with similar levels of per capita GDP or similar R&D/GDP ratios.[1] Moreover, corporate R&D seems locally connected to an unusual degree: for instance, business funding accounts for a larger share of university R&D than in many other countries.

1. The business sector funds 45% of formal R&D and performs 58%. These proportions demonstrate that South Africa has an important platform of industrial R&D competence upon which to build, although one can argue that the share of business is high because of constraints (especially people and money) that limit the state's ability to invest in human capital for innovation and research, both via the knowledge infrastructure and in more direct partnership with industry.

Summary table: South Africa's strengths, weaknesses, opportunities and threats (SWOT)

Strengths	Opportunities
• Resource-based industries and related knowledge-intensive business services (KIBS) • Knowledge infrastructure, albeit small in relation to the size of the overall population • High proportion of business enterprise expenditure on R&D (BERD) in gross expenditure on R&D (GERD) • Tradition of linkage between major industries and the knowledge infrastructure • International industrial and academic networks • Political awareness of the importance of science, technology and innovation for sustainable growth • Open, participative governance with mechanisms in place for cross-departmental co-ordination	• Raise economic performance by building on existing innovation system strengths in industry – including large firms – and the knowledge infrastructure • Investment boom provides window of opportunity for technology development, acquisition and learning and increasing absorptive capacities • Attract foreign direct investment (FDI) to establish durable South African capacities • Exploit latent talents of the majority • Build on industry-research sector interactions as "focusing devices" for developing the knowledge infrastructure • Revise mental models of how the innovation system operates to put producers in the centre • Further modernise the state's role in the innovation system via "agencification" and the creation of a national policy arena
Weaknesses	**Threats**
• Poor quality schooling for many citizens • Human resource shortages at all levels in mathematics, science and technology • Lack of design, engineering, entrepreneurial and management actors (DEEM) and R&D capacity leading to an "engineering gap" • Ageing, white, male dominance of industrial and academic R&D. • Mental models of how the innovation system operates overly focused on the role of the state • Governance of the state components of the innovation system insufficiently holistic • Strategy implementation capacity in the state's part of the innovation system • Use of "level playing field" idea in funding higher education impedes the development of new institutions • Large "second economy" with insufficient entrepreneurial and technological skills • Inconsistencies between immigration policies and the human resource needs of the innovation system	• HIV/AIDS • Social unrest, if the pace of development falters • Demographic pressures on education, research and innovation systems caused by a large increase in the cohort of people born in the 1990s

Another valuable national asset is a too small but good collection of established universities and a research institute (science council) system with core areas of considerable strength and experience. Centres of academic research excellence, mainly located in a nucleus of long-established universities, achieve high quality in several areas of research, as reflected in the presence of South African publications among the top 1% of internationally cited publications in several fields and in some cases in the higher quartiles of that group.

Important segments of the services sector, which has been the main engine of growth in the most recent period, have achieved a strong record of success in innovation, especially in areas of information technology (IT) applications, and several are emerging as particularly strong R&D performers.

Since 1994 South Africa has made good progress in improving the governance of the innovation system. The organisational structure of public governance has been transformed by the creation of a government department with responsibility for science and technology (now the Department of Science and Technology), and it appears to be well integrated in cross-departmental interaction at the ministerial and senior civil servant levels.

A number of new mechanisms for public funding of R&D have been created. Among these, the Technology and Human Resources for Industry Programme (THRIP) has been very effective in integrating the development of research-capable human resources with industry-university co-operation in R&D. The programme has been internationally recognised as particularly successful as compared with similar schemes in other countries.

Recent years have seen a phase of inventive evolution of organisational arrangements for undertaking and directly supporting innovation. Some of these are concerned with "technology-push" R&D activities, particularly in such fields as biotechnology and advanced manufacturing technology. It is also important that emerging demand-driven pressures from industry appear to be pulling the organisational structure towards new forms of arrangements for providing technical services and non-R&D forms of support for small and medium-sized enterprises (SMEs) in relatively traditional industries.

South Africa has developed a strong capability to provide strategic intelligence and analysis to support policy. The Human Sciences Research Council (HSRC) has played a leading role, particularly, but not only, by creating the Centre for Science, Technology and Innovation Indicators (CeSTII) to undertake basic R&D and innovation surveys and to build analytical work on the results. There are also research groups in this field in several universities. The resulting rich base of competence is drawn on by policy-making and advisory bodies like the Department of Science and Technology (DST), the Department of Trade and Industry (DTI), the

National Advisory Council on Innovation (NACI) and the Council on Higher Education (CHE).

Challenges

Unemployment and poverty remain stubbornly high and affect the lives of up to about 40% of the population, depending on the definition used. The persistence and scale of the "second economy", despite a decade of economic stability and reasonable growth, have come more sharply into political focus in the last few years. It is important to continue and accelerate efforts to develop the formal economy so as to include the large numbers of people currently excluded but also to engage more directly in improving the livelihood of those who remain in the second economy.

There are strong claims that the national innovation system is making an inadequate contribution to poverty reduction and the erosion of the second economy. While that may possibly be the case for public-sector R&D, an alternative view is that there is no clear understanding of what the contribution of the overall innovation system actually is, and hence no basis for assessing whether or not it is adequate. In the absence of such strategic understanding, expansion of financial support for the innovation system may be threatened as political forces push poverty reduction aims higher on the policy agenda.

The legacy of excluding the majority of the population from educational opportunities for such a long period persists in the form of very limited human resource availability at all but the most basic levels of education and training. At the same time, alongside its human and social costs, the high incidence of HIV/AIDS erodes the country's efforts to build a stronger and demographically restructured human resource base. While the constrained availability of skilled human resources adversely affects all aspects of the production of goods and services throughout the economy, there are looming crises in two human resource areas that are particularly important for innovation performance:

- A very large gap appears to be opening up between the supply of design, engineering and related managerial and technical capabilities and the demand for such resources being generated by the increased rate of investment across the economy.[2] This "engineering gap" threatens not

2. The economy is entering a phase of rapidly accelerating investment. Gross fixed capital formation has already risen from a low level of around 15% of GDP to about 20%, and the government aims for 25%. This acceleration cuts across most industrial sectors, with a heavy emphasis on infrastructure. It is government policy that the consequent growth in income and access to services will be more evenly shared than in the past.

only *i)* to constrain the full achievement of this surge of investment-driven innovation, but also *ii)* to undermine the efficiency with which new and existing facilities are operated, *iii)* to limit the extent to which improved infrastructural services are actually delivered, especially to more remote areas and more deprived communities, and *iv)* to frustrate the exploitation of major opportunities to expand engineering-intensive services exports.

- The expansion of innovative activity throughout the economy, as reflected partly in rising overall R&D and especially business enterprise R&D, will only be possible if it is balanced by considerable expansion of university research, mainly to provide the necessary research-capable human resources at all levels of qualification. However, the ageing of research performers in universities, combined with the limited ability of the human resource pipeline to deliver sufficient replacement cohorts, suggests that, far from being expandable, the current levels of university R&D may not even be sustainable.
- Changes in the international knowledge economy risk exacerbating these human resource constraints. A growing number of advanced economies face rising shortages of high-level scientific and technological competencies, and they are implementing immigration measures and other schemes to attract skills from the global talent pool, including South Africa. At the same time, international capital flows are increasingly attracted to knowledge-rich locations, and these are multiplying their advantages by attracting globally sourced research or development activities both in connection with foreign direct investment (FDI) and via independent contracts. A major challenge for South Africa is to avoid the dangers implied by these international trends and to exploit the opportunities they offer.

Partly as a result of human resource constraints, but also owing to other deficiencies of the innovation system, the economy's technological structure does not appear to be moving away from its concentration in capital-intensive, resource-based activities fast enough, either in a labour-absorbing direction or towards more knowledge-intensive, productivity-raising and higher-income-generating forms of production, except in some parts of the services sector. The capability to generate innovation in the production of goods and services is very limited across large areas of the economy, not only in small and micro-enterprises but also in many medium-sized and larger ones; and not only in the private sector but also in public-sector services, where innovation capabilities have actually fallen in many areas.

Shortcomings of current policy responses

The possibility for innovation policy to cope with these challenges currently appears to be limited by several shortcomings involving policy perspectives, processes and organisation:

- *Perspectives.* During the last decade the concept of the "national innovation system" has gained influence within the South Africa science, technology and innovation (STI) policy community. However, the practical details have been often mapped out in ways that are somewhat narrow, with too much focus on the role of public R&D-performing institutions. This may have obscured important issues: *i)* the central role of business enterprises in generating and implementing innovation; *ii)* the importance of enterprises, and not only education and training organisations, in creating scientific and technological human resources for innovation; *iii)* the key role played by innovation-generating activities other than R&D, especially in the services sector; and *iv)* the importance of articulated demand for innovation and new knowledge in driving the innovation process. The current forms of interaction between policy analysis and policy making contribute to the problem. A large proportion of research on and analysis of the innovation system is specifically commissioned by policy-making and advisory bodies which have developed a good holistic view of the R&D system but not yet of the whole innovation sphere.
- *Processes – priorities, selection and achieving critical scale.* There are indications that decisions are commonly made in ways that result in stretching resources too thin over too many activities. This seems to be the case at various levels of the innovation system: *i)* across activities in individual fields of science, technology and innovation; *ii)* across activities in individual organisations; *iii)* across portfolios of major national projects and centres; and *iv)* across major initiatives to facilitate the emergence of sectoral innovation systems. This may be inhibiting the extent to which individual activities reach the scale and critical mass needed to achieve their intended aims.
- *Processes – the connection between strategies and their implementation.* There appears to be too little connection between the articulation of important technological and innovation priorities and their subsequent implementation. This arises in two ways. On the one hand, major initiatives that have been identified as priorities in the national strategy have not been effectively implemented, such as the technology missions in the National Strategy for Research and Development concerned with *i)* technology and knowledge related to resource-based industries and *ii)* technology and innovation for poverty reduction. On the other hand,

large programmes have been implemented that were not identified as priorities in recent broad-ranging strategy reviews, such as the launch of major R&D and engineering activities for the Pebble Bed Modular Reactor programme.

- *Organisational structure: vertical specialisation and differentiation.* The vertical structure of roles and organisations responsible for governance of the innovation system incorporates less specialisation and differentiation than what is now common practice among OECD countries, in particular between responsibilities for supporting research and for supporting innovation (combined in the National Research Foundation), and between those for R&D funding and R&D performing (combined within several of the science councils). There is also insufficient specialisation and differentiation among the organisations that perform R&D and other innovation-supporting activities, and policy approaches tend to reinforce this. In particular, there appear to be expectations that all universities will/should engage in SME support activities for which only some (at best) will have the necessary specialised competencies. There also appears to be a tendency for several different kinds of organisation and programme to cluster around general R&D-based, technology-push roles, with unclear differentiation between those that specialise in providing a wide range of technological and other support to business enterprises and those that focus on developing and applying particular areas of technology.

- *Organisational structure: horizontal integration and co-ordination.* The horizontal dimensions of the governance structure incorporate less integration than is now common practice in many OECD countries as they seek to develop more holistic forms of innovation policy, which call for much greater cross-cutting coherence than in the past. This is apparent at several levels:

  - Although there is strong “informal” interaction among various bodies responsible for public funding of R&D and other innovation-support activities, there is the question of whether the roles and responsibilities of these different bodies should be further clarified and perhaps integrated in a more user-friendly organisational arrangement, an issue that has been highlighted in several reports, including the proposal to establish a foundation for technological innovation in the National Strategy for Research and Development.

  - Although there is also strong co-operative interaction among government departments with an important policy role as regards the innovation system, some important interfaces seem to require greater integration, for example, between the Departments of Science and

Technology and of Education with respect to research in the higher education sector, between the Departments of Science and Technology and of Trade and Industry with respect to a range of innovation-support measures, and between these two departments and the Department of Labour with respect to the development of higher-level innovation capability via training and related activities in business enterprises.

- There is no strong cross-departmental body at Cabinet level responsible for holistic oversight of the departmental strands of innovation system policy. Such a body could *i)* monitor the cross-system effects of planned departmental initiatives that pose non-marginal demands on available human resources; *ii)* foster cross-departmental integration in areas such as the interfaces noted above; and *iii)* support changes in the departmental location of those interfaces when appropriate.
- Although the National Advisory Council on Innovation appears to have good working relations with a range of departments, it reports only to the Department of Science and Technology, whose director general acts as its chief executive officer. This clearly has several advantages, but it must also constrain the Council's ability to address cross-departmental issues.

- *Organisational structure: linking national to provincial and local levels.* There appears to be fairly weak integration between national policy and organisations and innovation-related policy and support measures at the provincial and local levels.

Recommendations

The following broad guidelines and specific recommendations do not constitute a comprehensive agenda for action. They are highly selective: in part they reflect the limited scope of the OECD review, in part they are shaped by the review team's impressions concerning issues that have received insufficient attention, and in part, they are influenced by the team's views about experience in other countries which might be particularly illuminating. In several areas, the full report offers more detailed suggestions.

Strategic goals and guiding principles for government action

As in any other country, the overriding objective of South Africa's innovation policy should be to encourage creative responses by the public and private sectors to many social aspirations: increased wealth through job-creating and sustainable economic growth; improved health, security and environment; enriched cultural life, etc. This report focuses on the economic aspects of a broad and deep innovation agenda. From this narrower perspective, the major task of the South African government is to stimulate, channel and empower the forms of creativity and entrepreneurship which can contribute directly to:

- Structural change, away from heavy dependence on the growth of resource-based industries and towards more knowledge-intensive production, including through the diversification of these industries into specialised supplier industries and services.[3]
- Closing the gap between the first and second economy in order to: *i)* secure sustained political commitment to science, technology and innovation by ensuring that STI provides tangible benefits to the majority; *ii)* on the supply side, enlarge the pool of human resources that can be engaged in innovative activities; and *iii)* on the demand side, increase domestic demand for innovations.
- Reinforce the knowledge infrastructure capacity to contribute to economic structural changes and human resource development.

In accomplishing these tasks, the government should subject its policy to some key guiding principles:

- *A rigorous but comprehensive rationale*. The idea that market failure leads to under-investment in research has been the principal rationale for state funding of R&D since the early 1960s. The experience of OECD countries suggests that the presence of bottlenecks or other failures that impede innovation processes can also constitute crucial obstacles to growth and development. These failures[4] justify state intervention not only to fund research, but more widely to ensure that the innovation system performs as a whole.

3. The past growth trajectory had considerable limitations. It was very capital-intensive, generating relatively slow rates of income growth and limited employment growth. On the downswing of commodity cycles it contributed to falling terms of trade, and on the upswings its exchange rate effects disadvantaged exports from other sectors.

4. *Capability failures* (these amount to inadequacies in potential innovators' ability to act in their own best interests; *institutional failures* (*e.g.* failure to (re)configure institutions so that they work effectively within the innovation system); *network failures* (these relate to problems in the interactions among actors in the innovation system); *framework failures* (effective innovation depends partly upon regulatory frameworks, health and safety rules, etc., as well as other background conditions, such as the sophistication of consumer demand, culture and social values.

- *A broad approach to innovation.* Reinforcement of the "R&D core" of the innovation system should be pursued as part of an overall strategy to enhance innovation capabilities throughout the economy, including in non R&D-based activities in the manufacturing and services sectors, drawing on all forms of creativity, including indigenous knowledge.

- *Efficiency and equity.* Reconciling efficiency and equity is rightly regarded as a fundamental priority in every sphere of South Africa policy. Achieving a balance in innovation policy is very demanding but vitally important. For example, the need to promote excellence in university research through selective funding that rewards current achievements should be reconciled with the need to build research capabilities in historically disadvantaged universities.

- *Timeliness.* The time dimension is central and a sense of urgency should inspire reforms or new initiatives in the field of innovation policy. So far, policy has been based on reconciliation and on efforts to exploit the positive aspects of the legacy as a platform on which to raise the performance of the whole innovation system and the economy. But key parts of the legacy – not least the generation that is able to lead the R&D system – are ageing and will need to be replaced at a much faster rate than is now possible. Politically, it is not clear for how much longer the poor will tolerate a policy that aims to improve their well-being only through incremental growth.

- *Openness.* Innovation policy should be receptive to the needs expressed by all stakeholders, including beyond the STI community. Building a vision shared by all private and public actors of what should be collectively achieved is a prerequisite for the successful formulation and implementation of a government policy that attains the right balance between top-down and bottom-up initiatives. Participation in the national innovation system by foreign individuals, firms and other knowledge organisations, as well as access to foreign markets for research outputs generated in South Africa will be critical to success.

- *Quality/relevance/critical mass.* Reconciling these three objectives entails concentration of limited resources in areas in which South Africa's capabilities can match opportunities in national and global innovation networks, active involvement of research end users in defining research priorities, and rigorous selection of research projects and teams eligible for public support.

- *Good governance*. For both vertical steering and horizontal co-ordination, efficient governance organisational arrangements and practices should: *i)* resolve the tension between a participatory approach to policy formulation, which may lead to some dilution of priorities, and the search for efficiency in the allocation of public support, which entails concentration of resources in priority areas to reflect comparative advantage and achieve critical mass; and *ii)* ensure effective policy implementation.

Suggestions concerning some areas for action

Widen the system perspectives that help to shape innovation policy

- Bring business enterprises (*i.e.* all kinds of producers of goods and services) more into the centre of the innovation system, as generators and implementers of innovation and as creators of human resources for innovation. In this regard the envisaged R&D tax incentive could send a powerful signal to SMEs as well as to R&D-intensive multinational companies, and induce additional privately financed R&D, provided its design takes due account of the rich body of international experience in this field.

- Give greater recognition in practical terms to the important innovation-generating role of activities other than R&D, as well as the importance of non-R&D capabilities (*e.g.* those concerned with engineering, design and related management and technical functions) as innovation generators in their own right and as resources within enterprises that give rise to more formally organised R&D.

- Give much greater emphasis to the international openness of the national innovation system, taking note of: *i)* the multiple, two-way, international flows of knowledge and human resources in which the national system is deeply embedded; ii) the ways in which these influence and are influenced by the domestic system and its policy components; and *iii)* possible changes in the long-term trends of these flows.

- Devote concrete attention to the practicalities of articulating the demand for knowledge and innovation in the system and not only to measures that encourage their supply.

- NACI, for instance, might extend the scope of its evidence-generating studies in directions that embrace these neglected dimensions of the national system. NACI and the DST should also ensure an adequate diversity of funding channels to support studies of the national innovation system, including "open" channels in addition to their specific commissions and contracts.

Re-examine the major national innovation priorities and missions

Review the apparently loose connection between the articulation of major technology and innovation priorities and their implementation, and consider whether it is now time to reconsider the priorities set nearly five years ago in the National Strategy for Research and Development. In doing so, consider in more detail:

- The value of defining such priorities and missions primarily in terms of sectors in which innovation will be implemented (rather than in terms of selected technologies that might contribute to innovation).
- The value of developing a strategic assessment of how the innovation system affects the second economy.
- Ways in which such sector-centred priorities might contribute to the changes in the structure of the economy that are widely considered important: increased job creation and more knowledge-intensive, high-growth and high-income production of goods and services.
- The kinds of governance structure for the innovation system that might help to ensure the most comprehensive identification and assessment of such priorities and the most appropriate balance between flexibility and stability in subsequent implementation (see also below).

Improve the governance structure of the innovation system

This may require the following changes:

- Establishing a body at Cabinet level to provide a holistic overview of strategies, policies and budgets for the development of the system and to ensure a balance between departmental initiatives that make competing claims on the system's resources, especially its human resources. (The relevance to South Africa of the different forms of such arrangement in several OECD countries might usefully be assessed.)
- Widening the cross-cutting scope of NACI by moving its link to government from a single ministry to such a cabinet-level body, taking note of the particular features of such arrangements in other countries which have contributed to the difference between effective advisory bodies and inconsequential talking shops.
- Strengthening the mechanisms for integration across, or changing the current organisational location of, key interdepartmental interfaces concerned with funding research in the higher education sector, providing innovation-related and other support for enterprises, and fostering high-level human resource development by enterprises.

- Increasing the degree of specialisation and differentiation between functions within the vertical structure of governance.

The full report provides information about, and some discussion of, other countries' experience in these areas.

Strengthen the human resource base for science, technology and innovation

Formal education and training: from school to university

Considerable efforts are being made to strengthen and expand the entire chain of education and training from primary school to PhD, and more specifically the development of knowledge and skills in mathematics, technology and science. The review team can only endorse the recognised urgency and magnitude of this challenge and suggest that it may be appropriate to review at the highest government level the appropriateness of the current balance between public investment in physical and human capital. At a more detailed level:

- Take steps to offset the high opportunity costs faced by students, especially black students, who complete postgraduate and post-doctoral research training.
- Identify and address the other factors that affect completion rates at postgraduate level, and consider such measures as a PhD "completion bonus" to help reduce completion times and drop-out rates.
- Reform the current cost-based university fee system which discourages students from taking expensive subjects like engineering.

Human resource development by business enterprises

- Continue to strengthen enterprise-level training supported by the levy grant and the Sector Education and Training Authorities (SETA) system, with its emphasis on basic, artisanal and technical skills. Also take steps to stimulate investments by business enterprises, especially medium-sized and larger firms, to develop their higher-level human resources for innovation. In particular:
  - Generate greater understanding of the scale and importance of this enterprise-based complement to the basic education and training provided by the higher education system, addressing not simply R&D capabilities but also the much broader base of design, engineering and associated management and higher technical

capabilities that underpin the R&D process and link it to the implementation of innovation.

– Identify the role of this investment by enterprises in the innovation system: its role in creating knowledge capital within the investing enterprises but also its role in creating externalities and spillovers that disperse this knowledge capital more widely in the economy, frequently to smaller firms and new start-ups.

– Identify feasible funding mechanisms to encourage such investment and more explicitly to maximise its spillover potential, for example through a supplementary form of levy-grant scheme focused specifically on larger firms and higher-level skills, and/or cost-sharing schemes that enhance the scale of, and broaden access to, corporate training and career development schemes.

– Consider the role that might be played by investment financing bodies such as the Industrial Development Corporation in facilitating their clients' greater investment in these forms of knowledge capital alongside their investment in physical assets.

The international dimension of human resource development

The development of international channels and mechanisms as a means of strengthening the human resource base of the domestic innovation system should be more explicitly included in the policy agenda. Specifically the government should:

- Seek to modify current immigration policy, going beyond steps that merely reduce difficulties for incoming highly skilled people, and instead develop a more proactive "green card" type of scheme that is at least as attractive to international scientific, technological and other talent as similar schemes in other countries. Its goal should be to meet South Africa's needs and place South Africa on a level playing field in the global competition for talents.

- Take steps to exploit inward foreign investment more effectively as a vehicle for human resource development, recognising that: *i)* this is essentially an issue about complementarities of measures in the host economy and measures of multinational corporations (MNCs); *ii)* it is not just an issue that arises at the time of the initial investment, but evolves as firms progressively deepen their local human capital resources; and *iii)* it is an area in which integration between national policy and provincial/local action has been especially important in other countries.

- Consider steps to stimulate greater investment in the higher-level human capital components of major industrial and infrastructure investment projects that draw heavily on imported technology, taking note of the potentially important role of investment financing bodies like the Industrial Development Corporation.

Improve funding of university research

The problems of sustaining and expanding the scale of university R&D are well recognised, and measures have been taken to address them. Several mechanisms serve to focus substantial components of university research in areas of social and economic priority. These should be continued and where possible enhanced. Beyond that, further attention should be given to two aspects of the funding mechanism for university research:

- The formula underpinning the Department of Education funding stream should be reassessed with a view to providing stronger incentives for, and greater selectivity in resource allocation to, work of high quality.
- The mechanisms of combined funding in all streams should be reviewed to assess whether they give adequately strong, selective and enduring support for the long process of building new nodes of research excellence, especially in the historically disadvantaged universities. While the principle of a nearly level playing field should continue to be the basis for allocating the bulk of funding to the most competitive players, forms of ring-fenced funding are needed to encourage newcomers to enter the competition for funds.

Develop greater differentiation in public R&D and innovation support organisations, especially to the benefit of SMEs

International experience indicates that the characteristics of these organisations differ and evolve in response to differences and changes in the characteristic of firms and technologies in their industrial environments. The government should consider whether the time has come to develop greater specialisation and differentiation in the functions of public organisations undertaking R&D and innovation support activities.

Such differentiation is needed to correct the weakness of South Africa’s innovation system with respect to SMEs. In particular, in pursuing its planned initiative to develop an SME-centred scheme to complement THRIP, the government should take account of:

- The wide range of SMEs and their very different needs.
- The recent emergence in some industries of enterprise-driven demand for modes of support that are less R&D-centred than some currently on offer and more able to provide a range support services.
- The particular sets of competencies required to provide efficient polytechnic modes of support to SMEs in many more traditional industries.
- International experience suggesting that universities have only rarely been effective suppliers of SME support services, and that decentralisation to provincial, local and cluster levels is particularly important.

A major gap in current innovation policy is indeed the lack of comprehensive support to innovation in SMEs. While there have recently been widespread initiatives under the Accelerated and Shared Growth Initiative for South Africa (ASGISA) and the Joint Initiative on Priority Skills Acquisition (JIPSA) to address skills development in this area, South African innovation policy appears to do surprisingly little in the area of operational technical support for SMEs.[5] In OECD countries, the SME support function is undertaken by organisations with specialist resources and skills relevant to this function. Recent initiatives, such as the proposal to establish a National Casting Technology Centre under the Metals Sector Development Strategy within the DTI's Customised Sector Programmes appear to mark a potentially important move in this direction. Further initiatives might include:

- A front-line advisory or brokerage service that helps companies diagnose needs and connects them to specialists able to help. (Examples include the UK Business Links, the TE-Keskus regional offices of TEKES, the Industry Ministry and the Ministry of Labour in the Finnish regions, Innovation Norway's regional offices.)
- Tailored SME services that tackle non-technical aspects of business start-up and management. (In South Africa, the DTI provides some of these services). An especially useful example is Norway's FRAM

5. The Tsumishano programme, which is based on a European practice of locating such centres at polytechnics, is a useful step in the right direction but it is tiny in comparison to the needs of the SME sector and it is already hamstrung by the lack of people with skills and experience in both technology and business. The National Technology Transfer Centre (NTTC, which has been transferred from CSIR to DTI) is similarly under-dimensioned. Other technology-related policies for SMEs (Support Programme for Industrial Innovation [SPII] and the Godisa programme, which has now been incorporated into the DTI's Small Enterprise Development Agency [SEDA]) tend to focus on technology-based start-ups and therefore make little contribution to raising the general technological (and broader competence) level of SMEs.

programme, which takes small classes of entrepreneurs through a strategy development process that has a goal of a 10% improvement in profits.

- A range of more technology-oriented offers, such as vouchers to buy simple services from research institutes (*e.g.* testing or advice on choice of materials), technology audits, manufacturing advice services and so on.
- An infrastructure of institutes able to provide concrete help with product development. In many countries, there is a special scheme for SMEs, allowing them to access expertise at low cost. In most countries, the institutes' services are subsidised, which allows them to operate in areas considered by the private sector to be too risky.
- Loans and investments on more favourable terms, for example, with the state shouldering the risk by lending against less collateral than the private sector would require.
- Regional and cluster-based technology and innovation centres, sometimes associated with industrial parks, as in the new National Casting Technology Centre.

ÉVALUATION D'ENSEMBLE ET RECOMMANDATIONS

Depuis l'avènement de la démocratie, l'Afrique du Sud a accompli des progrès considérables qui l'ont vue se remettre progressivement du régime de l'apartheid, marqué par une division sociale, économique, politique et aussi largement géographique du pays selon des critères raciaux. Le gouvernement a maintenu le cap sur un certain nombre de priorités fondamentales : construire une nation unifiée, accélérer la croissance économique, réduire le chômage, éradiquer la pauvreté, étendre la sphère de l'économie formelle et jouer un rôle moteur dans le processus de construction d'une Afrique meilleure. L'adoption d'une gouvernance moderne, la mise en œuvre de politiques coordonnées et cohérentes et le rapprochement du gouvernement des citoyens sont considérés comme des instruments clés pour la réalisation de ces objectifs.

Depuis la fin de l'apartheid, l'Afrique du Sud a réussi à s'ouvrir rapidement aux échanges et aux flux de capitaux internationaux, à stabiliser son économie et à dégager une croissance relativement satisfaisante, tirée principalement par l'amélioration de la productivité. Le pays reste néanmoins confronté à d'importants problèmes socioéconomiques, en particulier le chômage, la pauvreté et l'exclusion d'une large fraction de la population de l'économie formelle.

L'Afrique du Sud traverse actuellement deux transitions plus spécifiquement économiques, l'adaptation à la mondialisation et la transformation de la structure de l'économie, lourdement tributaire, jusqu'à présent, de la production de ressources primaires et des secteurs associés. Ce rapport évalue le système d'innovation de l'Afrique du Sud en tant qu'élément constitutif et que stimulant de ces deux processus de transition interdépendants, mais aussi en tant que déterminant structurel clé de la capacité du pays à créer des emplois et à maintenir une croissance dynamique, tirée par la productivité.

Réalisations et défis

Réalisations

Il faut évaluer le système d'innovation de l'Afrique du Sud dans une perspective évolutive, en tenant compte du fait que sa transformation a été à la fois stimulée par les mutations révolutionnaires du contexte politique et social et freinée par l'héritage du passé.

Les changements politiques radicaux des années 90 n'ont pas marqué la fin de l'ancien système d'innovation. Bon nombre de ses composantes ont été maintenues en place, au prix, certes, de restructurations, de réorientations et de changements d'échelle, et complétées par des éléments nouveaux. Pour les autorités, il s'est agi, en somme, de transformer un système d'innovation relativement solide asservi à un ensemble donné d'objectifs sociaux, économiques et politiques en un système également solide mais axé sur la poursuite d'objectifs complètement différents.

À cet égard, le tour de force majeur de l'Afrique du Sud a résidé simplement dans la manière dont elle est parvenue à s'affranchir des conditions-cadres extrêmement médiocres qui régissaient le système d'innovation au début des années 90. La dernière décennie a été négociée de telle sorte que la transformation radicale de nombreuses composantes du système d'innovation a pu être conjuguée avec un niveau de performance qui, au vu des données récentes, s'est largement maintenu (malgré des creux de courte durée pour la plupart des indicateurs) ; et plusieurs indicateurs ont repris leur progression au cours des dernières années, dépassant leurs niveaux antérieurs.

Le PIB par habitant s'élève à quelque 11 400 USD (en PPA de 2004), soit un niveau proche de celui de nombreux nouveaux pays industrialisés, mais cette moyenne masque des inégalités de revenu énormes au sein de la société. Les entreprises consacrent environ 1.8 % de leur chiffre d'affaires aux activités d'innovation. Bien que modéré en comparaison de la moyenne de l'OCDE, ce pourcentage est significatif si l'on tient compte de l'importance des secteurs basés sur les ressources dans l'économie sud-africaine. Le poids de ces secteurs se reflète également en partie dans le fait que le principal avantage comparatif révélé de l'Afrique du Sud sur le plan des échanges se situe dans les biens de niveau technologique moyen ou faible. Le gouvernement s'est fixé pour objectif de porter la part de la R-D formelle dans le PIB à 1 % en 2012 (contre 0.87 % actuellement), ce qui est plutôt ambitieux eu égard à la structure industrielle de l'économie.

Tableau synthétique : analyse des forces, des faiblesses, des possibilités et des menaces de l'Afrique du Sud

Forces	Possibilités
• Les secteurs basés sur les ressources et les services aux entreprises à forte intensité de connaissances associés • Les infrastructures cognitives, même si elles sont restreintes en comparaison de la population totale • La proportion élevée des dépenses intérieures brutes de R-D du secteur des entreprises (DIRDE) dans les dépenses intérieure brutes de R-D (DIRD) • L'existence traditionnelle de liens entre les principaux secteurs d'activité et les infrastructures cognitives • La participation aux réseaux industriels et académiques internationaux • Des dirigeants politiques conscients de l'importance de la science, de la technologie et de l'innovation pour la croissance durable • Une gouvernance ouverte et participative, dotée de mécanismes de coordination intergouvernementale	• Améliorer les performances économiques en exploitant les atouts actuels du système d'innovation dans l'industrie – y compris les grandes entreprises – et les infrastructures cognitives • L'essor des investissements ouvre des possibilités de développement, d'acquisition et d'apprentissage technologiques et, par ce biais, de renforcement des capacités d'absorption • Attirer les investissements directs étrangers (IDE) pour établir des capacités durables en Afrique du Sud • Exploiter les talents latents de la majorité • Se servir des interactions entre la recherche et l'industrie comme d'un dispositif de mise au point afin de développer les infrastructures cognitives • Revoir les modèles mentaux du fonctionnement du système d'innovation en plaçant les producteurs au centre • Poursuivre la modernisation du rôle de l'État dans le système d'innovation à travers « l'agencification » et la création d'un forum de politique national

Faiblesses	Menaces
• Un enseignement de qualité médiocre pour de nombreux citoyens • Un manque de ressources humaines dans tous les domaines, y compris les mathématiques, la science et la technologie • Le manque d'acteurs et de capacités de R-D dans les domaines de la conception, de l'ingénierie, de l'entrepreneuriat et de la gestion, avec à la clé un « déficit technique » • Un personnel de R-D industrielle et universitaire vieillissant et dominé par les hommes blancs • La focalisation excessive des modèles mentaux du fonctionnement du système d'innovation sur le rôle de l'État • Le manque d'approche globale dans la gouvernance des composantes publiques du système d'innovation • Problème de capacités d'application des stratégies dans les composantes publiques du système d'innovation • L'approche égalitariste du financement de l'enseignement supérieur empêche l'émergence de nouvelles institutions • Une économie seconde importante, qui manque de compétences entrepreneuriales et technologiques • Une politique de l'immigration inadaptée aux besoins de ressources humaines du système d'innovation	• Le VIH/SIDA • Un risque de troubles sociaux si le rythme de développement ralentit • Les pressions démographiques exercées sur les systèmes éducatif, de recherche et d'innovation par la forte augmentation des naissances dans les années 90

Le pays dispose d'un noyau d'entreprises commerciales innovantes et technologiquement solides qui est en train de s'étoffer. Les dépenses de R-D des entreprises commerciales ont augmenté ces dernières années et représentent une fraction plus élevée de la R-D totale que dans la plupart des pays affichant un PIB par habitant ou un ratio R-D/PIB similaire[6]. En outre, fait inhabituel, la R-D des entreprises semble très liée aux infrastructures locales – par exemple, les financements des entreprises représentent une plus large part de la R-D universitaire que dans de nombreux autres pays.

Autre atout précieux, l'Afrique du Sud dispose d'un parc solide (quoique sous-dimensionné) d'universités établies et d'un système d'instituts de recherche (science councils) qui peut se prévaloir de compétences et d'une expérience considérables dans plusieurs domaines clés. Les centres d'excellence en recherche universitaire, situés pour la plupart dans quelques universités établies de longue date, effectuent des recherches de grande qualité dans plusieurs domaines. On trouve ainsi des publications sud-africaines relevant de différentes disciplines dans le centile supérieur des publications les plus citées dans le monde, et même parfois dans les premiers quartiles du centile supérieur.

Des segments importants du secteur des services, principal moteur de la croissance au cours des dernières années, ont obtenu des résultats remarquables sur le plan de l'innovation, en particulier dans le domaine des applications informatiques, et plusieurs d'entre eux commencent à s'imposer comme des acteurs de poids dans la R-D.

Depuis 1994, l'Afrique du Sud a accompli des progrès notables dans l'amélioration de la gouvernance de son système d'innovation. La structure organisationnelle de la gouvernance publique a été transformée avec la création d'un ministère en charge de la science et de la technologie (aujourd'hui le Department of Science and Technology, DST), et cette structure s'insère parfaitement dans le réseau d'interactions intergouvernementales tant au niveau ministériel qu'à celui de la haute fonction publique.

Plusieurs nouveaux mécanismes de financement public de la R-D ont été introduits. Parmi eux, le Programme Technologie et ressources humaines pour l'industrie (Technology and Human Resources for Industry Programme, THRIP) est parvenu, avec une grande efficacité, à intégrer le développement

6. Le secteur des entreprises finance 45 % et réalise 58 % de la R-D formelle. Ces chiffres montrent que l'Afrique du Sud dispose d'un réservoir de compétences en R-D industrielle important qu'elle peut mettre à profit. Cela étant, le poids élevé des entreprises pourrait s'expliquer par les contraintes (notamment en termes de ressources humaines et financières) qui limitent la capacité de l'État à investir dans le capital humain axé sur l'innovation et la recherche, que ce soit par le biais des infrastructures cognitives ou au moyen de partenariats directs avec l'industrie.

de ressources humaines aptes à la recherche avec la coopération entre l'industrie et l'université en matière de R-D. À l'échelle internationale, ce programme est perçu comme étant particulièrement efficace en comparaison d'initiatives similaires menées dans d'autres pays.

Les dernières années ont été placées sous le signe d'une évolution créative des modalités d'organisation des activités d'innovation et de soutien direct à l'innovation. Certaines de ces modalités concernent les activités de R-D poussées par la technologie, notamment celles qui relèvent de domaines technologiques particuliers tels que la biotechnologie et les technologies de fabrication avancées. Mais, fait tout aussi important, les pressions émergentes exercées par la demande provenant de l'industrie, ont pour effet de tirer la structure organisationnelle vers de nouveaux types de dispositif axés sur la fourniture de services techniques et de formes de soutien non liées à la R-D en faveur des petites et moyennes entreprises (PME) des secteurs relativement traditionnels.

Peu à peu, l'Afrique du Sud s'est dotée de solides capacités de collecte de renseignements stratégiques et d'analyse à l'appui des politiques. Le Conseil de la recherche en sciences humaines (Human Sciences Research Council, HSRC) a joué un rôle majeur à cet égard, notamment (mais pas uniquement) à travers la création du Centre des indicateurs scientifiques, technologiques et d'innovation (Centre for Science, Technology and Innovation Indicators), qui a pour mission de mener des enquêtes sur la R-D fondamentale et l'innovation et d'analyser les résultats. Il existe également des centres de recherche qui s'occupent de ces questions dans plusieurs universités. Ces organismes offrent un abondant réservoir de compétences qui peuvent être mises à profit par les instances décisionnaires et consultatives telles que le ministère de la Science et de la Technologie, le ministère du Commerce et de l'Industrie (Department of Trade and Industry, DTI), le Conseil consultatif national sur l'innovation (National Advisory Council on Innovation, NACI) et le Conseil de l'enseignement supérieur (Council on Higher Education, CHE).

Défis

Le chômage et la pauvreté restent désespérément élevés et touchent, selon les définitions, jusqu'à 40 % environ de la population. La persistance et l'ampleur de l'économie seconde, qui a résisté à une décennie de stabilité économique et de croissance raisonnable, occupent une place grandissante dans les débats politiques depuis quelques années. Il est important de poursuivre et d'accélérer les efforts de développement de l'économie formelle, afin de pouvoir y insérer la large fraction de la population qui en est actuellement exclue, mais aussi de contribuer plus directement à améliorer les moyens de subsistance des personnes qui restent tributaires de l'économie seconde.

On entend affirmer avec vigueur que le système national d'innovation n'apporte pas une contribution suffisante à la réduction de la pauvreté et au recul de l'économie seconde. Si ce point de vue se défend en ce qui concerne la composante du système d'innovation ayant trait à la R-D du secteur public, une autre opinion est que l'on ne connaît pas précisément la contribution du système d'innovation dans son ensemble et qu'il est impossible, dans ces conditions, de déterminer si elle est adéquate ou non. En l'absence d'une compréhension stratégique de cette question, l'expansion du soutien financier au système d'innovation pourrait être menacée car les forces politiques concourent à donner aux objectifs de réduction de la pauvreté un rang de priorité de plus en plus élevé dans l'action publique.

L'Afrique du Sud ne s'est pas entièrement remise de la longue période durant laquelle la majorité de la population a été privée de la possibilité de s'instruire. En effet, la disponibilité des ressources humaines ayant une formation qui dépasse le niveau élémentaire est extrêmement limitée. Parallèlement, en marge de ses coûts humains et sociaux, l'incidence élevée du VIH/SIDA sape les efforts déployés par le pays pour se doter d'un capital humain plus solide et démographiquement restructuré. Le manque de main-d'œuvre qualifiée a des répercussions négatives sur l'ensemble du système de production de biens et de services, mais une crise guette en particulier deux catégories de ressources humaines qui sont très importantes pour l'innovation.

- Un écart très important est en train de se former entre l'offre de capacités en conception, en ingénierie et dans les domaines techniques et de gestion associés et la demande pour ces ressources, stimulée par la hausse des investissements dans l'économie.[7] Ce déficit technique risque non seulement *i)* d'empêcher le plein aboutissement de cet élan d'innovation tiré par l'investissement, mais aussi *ii)* d'amoindrir l'efficience des installations nouvelles et existantes, *iii)* de limiter la mise en œuvre effective des services infrastructurels améliorés – en particulier dans les zones les plus reculées et les communautés les plus pauvres, et *iv)* de freiner la concrétisation des possibilités importantes de développement des exportations de services à forte intensité technique.

7. L'économie entre dans une phase d'accélération rapide de l'investissement. La formation brute de capital fixe est déjà passée d'un niveau modeste d'environ 15 % du PIB à environ 20 %, et le gouvernement vise la barre des 25 %. Cette accélération est visible dans la plupart des secteurs industriels, mais particulièrement dans les infrastructures. Le gouvernement escompte que la croissance des revenus et de l'accès aux services qui résultera de cette accélération sera répartie plus uniformément que par le passé.

- L'expansion des activités d'innovation dans l'économie, qui se traduit notamment par une hausse de la R-D globale et plus spécialement de la R-D des entreprises, ne sera possible que si elle s'accompagne d'une expansion considérable de la recherche universitaire, essentiellement pour garantir la disponibilité de personnel apte à la recherche à tous les niveaux de diplôme. Cependant, le vieillissement des chercheurs universitaires, conjugué à la difficulté de former des cohortes suffisantes pour les remplacer, donne à penser que loin de pouvoir être augmenté, le niveau actuel de la R-D universitaire ne sera peut-être même pas maintenu.

Les changements à l'œuvre dans l'économie internationale de la connaissance rendent encore plus aigu le problème de la disponibilité des ressources humaines. De plus en plus d'économies avancées sont confrontées à des pénuries de compétences scientifiques et technologiques et mettent en place des mesures en faveur de l'immigration et d'autres initiatives pour attirer les talents du monde entier, y compris d'Afrique du Sud. Parallèlement, les pays riches en connaissances constituent une destination de plus en plus attrayante pour les flux de capitaux internationaux. En outre, ces pays augmentent leurs avantages en attirant des activités de recherche ou de développement externalisées à l'étranger – que ce soit à travers les IDE ou par le biais de contrats indépendants. L'un des défis majeurs, pour l'Afrique du Sud, consistera à éviter les dangers inhérents à ces tendances internationales et à exploiter les possibilités qu'elles offrent.

En partie à cause de la limitation des ressources humaines, mais aussi en raison d'autres déficiences du système d'innovation, la structure technologique de l'économie, lourdement dominée par les activités à forte intensité capitalistique basées sur les ressources, tarde à opérer sa mutation au profit d'autres secteurs – activités à forte capacité d'absorption de la main-d'œuvre ou formes de production présentant une intensité de connaissances, un potentiel de gains de productivité et des capacités de recettes plus élevés – à l'exception de certains segments du secteur des services. Le réservoir de capacités d'innovation sous-jacentes pour la production de biens et de services est très limité dans de larges pans de l'économie – aussi bien dans les petites et les micro-entreprises que dans les entreprises moyennes et plus grandes ; et aussi bien dans le secteur privé que dans le secteur des services publics, qui a vu ses capacités d'innovation décliner dans de nombreux domaines.

Défauts de la réponse actuelle des pouvoirs publics

L'aptitude de la politique de l'innovation à relever ces défis est actuellement limitée par un certain nombre d'imperfections au niveau des perspectives, des processus et de l'organisation.

- *Perspectives.* Au cours de la dernière décennie, le concept de « système national d'innovation » a reçu une attention croissante de la part des responsables de la politique scientifique, technologique et d'innovation en Afrique du Sud. Cependant, les détails pratiques de ce concept ont souvent été formulés de façon quelque peu étroite, les institutions publiques de R-D se voyant accorder un rôle trop important. Il est possible, de ce fait, que plusieurs questions importantes aient été sous-estimées, en particulier : *i)* le rôle central des entreprises commerciales dans la production et la mise en œuvre des innovations ; *ii)* l'importance des entreprises – et non pas uniquement des organismes d'enseignement et de formation – dans la création de capital humain scientifique et technologique apte à l'innovation ; *iii)* le rôle clé des activités génératrices d'innovations autres que la R-D, en particulier dans le secteur des services ; et *iv)* l'importance, pour le processus d'innovation, de l'existence d'une demande d'innovations et de connaissances nouvelles structurée. Les formes d'interaction actuelles entre l'analyse et l'élaboration des politiques ont leur part de responsabilité dans ce problème. Une large part des travaux de recherche et d'analyse sur le système d'innovation est effectuée spécifiquement à la demande d'organes décisionnaires et consultatifs qui ont développé une vision globale adéquate du système de R-D, mais pas encore du système d'innovation dans son ensemble.

- *Processus – sélection des priorités et obtention d'une masse critique.* D'après les indications disponibles, les décisions sont prises de manière telle qu'elles conduisent souvent à un émiettement excessif des ressources entre un trop grand nombre d'activités. Ce problème semble se manifester à plusieurs niveaux du système d'innovation : *i)* entre les activités menées dans des domaines individuels de la science, de la technologie et de l'innovation ; *ii)* entre les activités menées au sein d'organismes individuels ; *iii)* entre des grands groupes de projets et de centres nationaux ; et *iv)* entre des initiatives majeures visant à faciliter l'émergence de systèmes d'innovation sectoriels. Il est possible que cela empêche les activités individuelles d'atteindre l'échelle et la masse critique qui leur sont nécessaires pour accomplir leurs objectifs.

- *Processus – lien entre les stratégies et leur mise en œuvre.* On note un lien trop lâche entre la formulation des priorités technologiques et d'innovation importantes et leur mise en œuvre ultérieure. Ce problème se manifeste de deux manières. D'une part, certaines initiatives majeures ayant été identifiées comme des priorités dans la stratégie nationale n'ont pas réellement été mises en œuvre – c'est le cas, par exemple, des missions technologiques prévues par la stratégie nationale de R-D, qui portaient sur les technologies et les connaissances utiles pour les secteurs basés sur les ressources et sur les technologies et l'innovation au service de la réduction de la pauvreté. D'autre part, certains grands programmes ont accédé au stade de la mise en œuvre sans avoir été identifiés comme des priorités stratégiques dans les examens stratégiques généraux menés peu avant – c'est le cas, par exemple, du lancement d'activités de R-D et d'ingénierie de grande ampleur pour le programme de Réacteur modulaire à lit de boulets (Pebble Bed Modular Reactor).

- *Structure organisationnelle – spécialisation verticale et différenciation.* L'organisation verticale des fonctions et des entités en charge de la gouvernance du système d'innovation est moins spécialisée et différenciée qu'elle ne l'est aujourd'hui dans la plupart des pays de l'OCDE. C'est frappant, en particulier, pour les fonctions de soutien à la recherche et de soutien à l'innovation (qui sont regroupées au sein de la Fondation nationale de la recherche – National Research Foundation), et pour les fonctions de financement de la R-D et d'exécution de la R-D (regroupées au sein de plusieurs conseils scientifiques). On note également un manque de spécialisation et de différenciation parmi les organisations qui effectuent des travaux de R-D et d'autres activités de soutien à l'innovation, et l'approche poursuivie par les politiques publiques renforce cette tendance. En particulier, les pouvoirs publics attendent des universités qu'elles se consacrent toutes à des activités de soutien aux PME, alors que quelques-unes (au mieux) seulement ont les compétences spécialisées requises pour le faire. Par ailleurs, certains types d'organisme et de programme ont tendance à articuler leurs activités autour de missions relativement générales basées sur la R-D et poussées par la technologie, sans qu'une distinction nette soit établie entre ceux qui fournissent un large éventail de services technologiques et autres formes de soutien aux entreprises commerciales et ceux qui se concentrent sur l'élaboration et l'application de technologies particulières.

- *Structure organisationnelle – intégration horizontale et coordination.* Les dimensions horizontales de la structure de gouvernance présentent un degré d'intégration moindre que celui observé aujourd'hui dans de nombreux pays de l'OCDE, ceux-ci s'efforçant d'élaborer des approches plus globales en matière de politique d'innovation, qui nécessitent une cohérence transversale beaucoup plus importante que par le passé. Ce manque d'intégration est perceptible à plusieurs niveaux.

- Bien que d'importantes interactions informelles s'opèrent entre les différents organismes en charge du financement public de la R-D et des autres activités de soutien à l'innovation, on est en droit de se demander si leurs rôles et leurs responsabilités respectifs ne devraient pas être clarifiés davantage et, le cas échéant, être intégrés au sein d'une structure organisationnelle plus pratique – un point qui a déjà été soulevé dans plusieurs rapports, y compris dans la proposition visant à établir une Fondation pour l'innovation technologique dans le cadre de la Stratégie nationale de R-D.

- Bien qu'il existe également de solides liens de coopération entre les différents ministères qui jouent un rôle majeur au regard du système d'innovation, il serait nécessaire de renforcer le degré d'intégration au niveau de plusieurs interfaces importantes, par exemple, entre le ministère de la Science et de la Technologie et celui de l'Éducation pour les questions touchant à la recherche dans l'enseignement supérieur, entre le ministère de la Science et de la Technologie et celui du Commerce et de l'Industrie pour un ensemble de mesures de soutien à l'innovation, et entre ces deux ministères et le ministère du Travail pour les efforts de développement des capacités d'innovation menés à travers la formation et les activités associées dans les entreprises commerciales.

- Il n'existe pas, au niveau du gouvernement, de structure transversale solide qui chapeaute et supervise les différentes composantes ministérielles de la politique d'innovation. Une telle structure serait utile, notamment pour *i)* évaluer les effets, sur l'ensemble du système, des initiatives ministérielles envisagées qui nécessitent un volume de ressources humaines non négligeable, *ii)* encourager l'intégration interministérielle dans des domaines tels que ceux situés aux interfaces susmentionnées, et *iii)* encourager, lorsque c'est nécessaire, le déplacement de ces interfaces à d'autres niveaux de la structure ministérielle.

- Bien que le Conseil consultatif national sur l'innovation entretienne de bonnes relations de travail avec plusieurs ministères, il ne rend de comptes qu'à un seul d'entre eux, le ministère de la Science et de la Technologie, et le Directeur général de ce ministère lui sert de Président directeur général. Cette situation a des avantages manifestes, mais elle limite la possibilité pour le Conseil de traiter des dossiers de nature transversale.

- *Structure organisationnelle – liens entre l'échelon central et les échelons provinciaux et locaux.* Le degré d'intégration entre les politiques et organisations de portée nationale et les politiques et mesures de soutien liées à l'innovation menées aux échelons provincial et local est relativement faible.

Recommandations

Les principes directeurs généraux et les recommandations spécifiques qui suivent ne forment en aucun cas un programme d'action exhaustif. Il s'agit de suggestions extrêmement sélectives, qui reflètent en partie le cadre restreint de l'examen de l'OCDE et qui traduisent les impressions et points de vue de l'équipe quant aux domaines qui n'ont pas reçu suffisamment d'attention et ceux dans lesquels l'expérience des autres pays pourrait se révéler particulièrement instructive. Le texte qui suit ce résumé contient des recommandations plus détaillées sur certains thèmes.

Objectifs stratégiques et principes directeurs pour l'action gouvernementale

En Afrique du Sud comme dans tout autre pays, l'objectif prioritaire de la politique de l'innovation doit être d'encourager les secteurs public et privé à apporter des réponses créatives à de nombreuses aspirations sociales : augmentation des richesses grâce à une croissance économique soutenue génératrice d'emplois, amélioration de l'état sanitaire, de la sécurité et de l'environnement, enrichissement de la vie culturelle, etc. Ce rapport se concentre sur les aspects économiques de ce vaste domaine qui est la politique de l'innovation. Selon cette perspective délibérément restreinte, la mission principale du gouvernement sud-africain devra consister à stimuler, canaliser et renforcer les formes de créativité et d'entrepreneuriat qui peuvent contribuer directement à :

- Modifier la structure de l'économie, lourdement tributaire de la croissance des secteurs basés sur les ressources, au profit d'activités de production à plus forte intensité de connaissances, y compris en encourageant la diversification des secteurs de ressources en industries et services d'amont spécialisés[8].

8. La trajectoire de croissance passée de l'Afrique du Sud présentait de sérieuses limites : elle reposait sur une intensité capitalistique élevée et générait des taux de croissance des revenus relativement faibles et une croissance de l'emploi limitée. Lors des phases descendantes des cycles des produits de base, elle contribuait à la dégradation des termes de l'échange, et pendant les phases ascendantes, ses effets sur le taux de change pénalisaient les exportations des autres secteurs.

- Combler le fossé entre l'économie première et l'économie seconde afin *i)* de garantir un engagement politique durable en faveur de la science, de la technologie et de l'innovation (STI) en faisant en sorte que la STI produise des avantages tangibles pour la majorité ; *ii)* d'élargir, du côté de l'offre, le réservoir de ressources humaines aptes à exercer des activités d'innovation ; et *iii)* du côté de la demande, d'accroître la demande intérieure d'innovations.

- Donner aux infrastructures cognitives davantage de moyens pour contribuer à ces changements économiques structurels et au développement des ressources humaines.

Pour mener à bien à ces différentes tâches, le gouvernement devrait se conformer à un certain nombre de principes clés :

- *Une justification rigoureuse, mais néanmoins complète de l'intervention de l'État*. Depuis le début des années 60, le principal argument utilisé pour justifier le financement public de la R-D est l'idée selon laquelle les défaillances du marché conduisent à un manque d'investissements dans la recherche. Au vu de l'expérience des pays de l'OCDE, l'existence de goulets d'étranglement et d'autres déficiences entravant les processus d'innovation peut aussi être un frein majeur à la croissance et au développement. Ces déficiences[9] justifient que l'État intervienne non seulement à travers le financement de la recherche, mais aussi, de manière plus générale, en veillant au bon fonctionnement du système d'innovation dans son ensemble.

- *Une approche large vis-à-vis de l'innovation.* Le renforcement de la R-D, « cœur » du système d'innovation, doit s'inscrire dans le cadre d'une stratégie globale d'amélioration des capacités d'innovation dans l'ensemble de l'économie, y compris dans les activités non liées à la R-D des secteurs manufacturiers et de services, et cette stratégie doit prendre en compte toutes les formes de créativité, y compris les connaissances locales.

9. *Défaillances des capacités* (c'est-à-dire, défaillances qui restreignent la capacité des innovateurs potentiels à agir dans leur meilleur intérêt) ; *défaillances institutionnelles* (par exemple, incapacité à [re]configurer les institutions de manière à ce qu'elles fonctionnent efficacement au sein du système d'innovation) ; *défaillances des réseaux* (problèmes d'interactions entre les acteurs du système d'innovation) ; *défaillances du cadre* (l'efficacité de l'innovation dépend en partie des cadres réglementaires, des règles sanitaires et de sécurité, etc., ainsi que d'autres conditions-cadres telles que le degré de sophistication de la demande des consommateurs, la culture et les valeurs sociales.

- *Efficience et équité.* La conciliation de l'efficience et de l'équité est considérée, à juste titre, comme un impératif majeur pour tous les secteurs de la politique publique sud-africaine. Il est particulièrement important d'atteindre cet équilibre dans la politique de l'innovation, même si cela demande beaucoup d'efforts. Par exemple, la nécessité de promouvoir l'excellence de la recherche universitaire en récompensant les meilleures performances par un financement sélectif doit être conciliée avec la nécessité de renforcer les capacités de recherche des universités traditionnellement désavantagées.

- *Rapidité.* La dimension temporelle est essentielle, et le sentiment d'urgence devrait servir d'aiguillon à la mise en œuvre de réformes ou de nouvelles initiatives en matière de politique de l'innovation. Jusqu'à présent, la politique publique a été marquée par une volonté de réconciliation et s'est efforcée d'exploiter les aspects positifs de l'héritage du passé et de s'en servir comme base pour améliorer les performances de l'ensemble du système d'innovation et de l'économie. Cependant, des composantes essentielles de cet héritage – en particulier la génération d'individus aptes à exercer des fonctions de commandement dans le système de R-D – commencent à vieillir et a besoin d'être remplacée à un rythme beaucoup plus rapide que ce n'est le cas actuellement. Politiquement, il n'est pas sûr que les nombreux pauvres du pays toléreront encore longtemps une politique qui table uniquement sur la croissance incrémentale pour améliorer leur bien-être.

- *Ouverture.* La politique de l'innovation doit être attentive aux besoins exprimés par l'ensemble des parties prenantes, et pas uniquement la communauté STI ; pour réussir à formuler et mettre en œuvre une politique gouvernementale qui établisse le juste équilibre entre approches descendantes et ascendantes, il est essentiel de développer une vision commune de ce qui doit être accompli collectivement parmi les acteurs publics et privés. La participation de personnes, d'entreprises et d'organisations fondées sur le savoir étrangères au système national d'innovation et l'accès aux marchés étrangers pour les résultats des recherches effectuées en Afrique du Sud seront des facteurs de réussite clés.

- *Qualité/pertinence/masse critique.* La réalisation de ces trois objectifs passe par plusieurs conditions : une concentration minimum des ressources limitées du pays dans les domaines où ses capacités s'accordent avec les possibilités offertes par les réseaux d'innovation nationaux et mondiaux ; la participation active des utilisateurs finals de la recherche dans la définition des priorités de recherche ; et la sélection rigoureuse des projets et des équipes de recherche admissibles à un soutien public.

- *Bonne gouvernance*. Dans le domaine du pilotage vertical comme de la coordination horizontale, il y a lieu de mettre en place des pratiques et des modes d'organisation de la gouvernance efficients, qui s'attachent à : *i)* résoudre l'antagonisme entre l'approche participative de la formulation des politiques, qui peut entraîner une certaine dilution des priorités, et la recherche de l'efficience dans l'affectation du soutien public, qui nécessite de concentrer les ressources dans les domaines prioritaires de manière à refléter les avantages comparatifs et à pouvoir atteindre une masse critique ; et à *ii)* garantir la mise en œuvre efficace des politiques.

Suggestions pour certains domaines d'action précis

Élargir les dimensions du système qui facilitent la définition de la politique de l'innovation

- Faire jouer aux entreprises commerciales (à savoir, l'ensemble des producteurs de tous types de biens et services) un rôle beaucoup plus central dans la sphère de l'innovation – à la fois en tant que producteurs et exécutants d'activités d'innovation et formateurs de ressources humaines pour l'innovation. À cet égard, l'incitation fiscale à la R-D envisagée enverrait un signal puissant capable de se propager à tous les échelons du système, y compris les PME et les entreprises multinationales à forte intensité de R-D, et exercerait un effet catalyseur sur les efforts de R-D financés par le secteur privé, si tant est que cette incitation soit conçue à la lumière de la riche expérience internationale accumulée dans ce domaine.

- Accorder davantage d'attention, en termes pratiques, au rôle majeur que peuvent jouer les activités autres que la R-D dans la production d'innovations, ainsi qu'à l'importance des capacités ne relevant pas de la R-D (par exemple, les capacités d'ingénierie et de conception et les fonctions techniques et de gestion associées) qui peuvent elles-mêmes être sources d'innovations et qui peuvent donner naissance à une R-D plus structurée dans les entreprises.

- Prendre bien davantage en compte l'ouverture internationale généralisée du système national d'innovation, et en particulier : *i)* les flux internationaux, multiples et bidirectionnels de connaissances et de ressources humaines dans lesquels le système national est très étroitement intégré : *ii)* les relations d'influence réciproque entre ces flux et le système national et les politiques qui le composent ; et *iii)* les changements possibles de ces flux à long terme.

- Accorder une attention concrète aux aspects pratiques de la structuration de la demande de connaissances et d'innovations au sein du système et non pas seulement aux mesures permettant d'accroître leur offre.
- Le NACI, par exemple, pourrait étendre le champ de ses études consacrées à la production de données probantes afin d'y englober ces dimensions négligées du système national. Le NACI et le DST devraient également faire en sorte que les sources de financement des études et analyses sur le système national d'innovation soient suffisamment diversifiées – et notamment qu'il existe des mécanismes de financement « ouverts » en complément de leurs propres mandats et contrats spécifiques.

Réexaminer les grandes priorités et missions nationales en matière d'innovation

Revoir les liens, manifestement assez lâches, entre la formulation et la mise en œuvre des principales priorités technologiques et d'innovation, et déterminer si le moment n'est pas venu de réexaminer la liste des priorités, qui ont été arrêtées dans le cadre de la Stratégie nationale de recherche et de développement il y a maintenant presque cinq ans. Dans ce contexte, il y aurait lieu d'examiner plus en détail :

- L'intérêt de définir ces priorités et ces missions essentiellement sur la base des secteurs dans lesquels les innovations seront mises en œuvre (et non pas des technologies qui peuvent contribuer à l'innovation).
- L'intérêt de déterminer, au moyen d'une évaluation stratégique, l'influence du système d'innovation sur l'économie seconde.
- La contribution potentielle de ces priorités sectorielles aux changements structurels qui, de l'avis général, sont nécessaires à l'économie – à savoir, les changements en faveur d'activités créant davantage d'emplois et les changements favorisant la production de biens et de services à plus forte intensité de connaissances et à potentiel de croissance et de revenus élevé.
- Les types de mécanisme de gouvernance dont le système d'innovation aurait besoin pour garantir l'identification et l'évaluation les plus complètes possibles de ces priorités et le meilleur équilibre possible entre souplesse et stabilité lors des phases ultérieures de mise en œuvre (voir également ci-dessous).

Améliorer la structure de gouvernance du système d'innovation

Cela pourrait nécessiter les changements suivants :

- Établir un organe gouvernemental qui serait chargé de superviser les stratégies, les politiques et les budgets liés au développement du système et l'équilibre entre les initiatives ministérielles exerçant des pressions concurrentes sur les ressources réelles du système, en particulier ses ressources humaines. (Il pourrait être utile, à cet égard, d'évaluer l'intérêt pour l'Afrique du Sud des mécanismes de ce type qui existent déjà dans plusieurs pays de l'OCDE)
- Élargir la dimension transversale du NACI, en faisant en sorte qu'il soit relié au gouvernement non plus par l'intermédiaire d'un ministère unique mais au travers de ce nouvel organe gouvernemental, en prenant note des caractéristiques spécifiques des dispositifs de ce type mis en place dans d'autres pays, qui ont contribué à en faire des organismes consultatifs efficaces et non pas de simples coquilles vides.
- Renforcer les mécanismes d'intégration ou modifier l'emplacement, des principales interfaces intergouvernementales chargées, par exemple, de financer la recherche dans l'enseignement supérieur, d'apporter différentes formes de soutien aux entreprises, notamment en matière d'innovation, et d'encourager le développement de capital humain de haut niveau dans les entreprises.
- Accroître le degré de spécialisation et de différenciation des fonctions au sein de la structure verticale de gouvernance.

Le rapport détaillé qui suit décrit et, dans une certaine mesure, commente les expériences des autres pays qui ont été confrontés à des problèmes similaires.

Renforcer le réservoir de ressources humaines pour la science, la technologie et l'innovation

Enseignement et formation formels – de l'école à l'université

Des efforts considérables ont déjà été engagés pour renforcer et développer l'ensemble de la chaîne de l'enseignement et de la formation, depuis l'école primaire jusqu'au doctorat, et pour consolider en particulier le développement des connaissances et des compétences en mathématiques, en technologie et en sciences. L'équipe qui a effectué cet examen ne peut que souligner l'urgence et l'ampleur, aujourd'hui admises, de ce défi et suggère que les plus hautes autorités de l'État s'interrogent pour savoir si la répartition des investissements publics croissants entre capital physique et capital humain est appropriée. À un niveau plus détaillé :

- Prendre des mesures pour atténuer les coûts d'opportunité élevés auxquels sont confrontés les étudiants, en particulier les étudiants noirs, qui accèdent aux études universitaires supérieures et à la recherche post-doctorale.
- Identifier et corriger les autres facteurs qui affectent les taux de réussite dans l'enseignement universitaire supérieur, et envisager des mesures telles qu'une prime d'achèvement de doctorat pour réduire les délais d'achèvement des études et les taux d'abandon.
- Réformer le régime de droits universitaires basé sur les coûts, qui dissuade les étudiants de s'engager dans des filières onéreuses telles que l'ingénierie.

Développement des ressources humaines dans les entreprises commerciales

- Poursuivre le renforcement de la formation au niveau des entreprises, financée par le régime de subventions par prélèvement (*levy grant*) et le système des Autorités d'éducation et de formation sectorielles (Sectoral Education and Training Authorities – SETA), qui mettent l'accent sur les compétences artisanales, techniques et de base. Par ailleurs, prendre des mesures pour inciter les entreprises commerciales (en particulier les entreprises moyennes et grandes) à investir dans le développement de leurs ressources humaines de haut niveau dans une perspective d'innovation. En particulier :
    - Étoffer les connaissances sur l'étendue et l'importance des formations assurées au niveau des entreprises, en tant que compléments de l'enseignement et de la formation de base délivrés par le système d'enseignement supérieur, en s'intéressant non seulement aux capacités axées sur la R-D mais aussi au champ beaucoup plus large des capacités de conception et d'ingénierie et des compétences techniques supérieures et de gestion associées qui sous-tend le processus de R-D et le relie à la mise en œuvre des innovations.
    - Identifier le rôle des investissements en formation des entreprises dans le système d'innovation – non seulement leur rôle interne en tant que générateurs de capital cognitif au sein des entreprises mais aussi le rôle des externalités et des effets de retombée, qui diffusent ce capital cognitif plus largement dans l'économie, atteignant fréquemment les petites et les nouvelles entreprises.

- Identifier des mécanismes de financement viables à la fois pour encourager ces investissements et pour maximiser explicitement leurs retombées potentielles – par exemple, un système de prélèvements complémentaire spécifiquement axé sur les grandes entreprises et les compétences de haut niveau, et/ou des dispositifs de partage des coûts qui permettrait d'étendre et de rendre plus accessibles les programmes de formation en entreprise et d'orientation professionnelle.

- Examiner, en particulier, par quels biais des organismes de financement de l'investissement tels que la Société de développement industriel (Industrial Development Corporation) pourraient encourager leurs clients à investir davantage dans ces formes de capital cognitif en marge de leurs investissements en actifs corporels.

La dimension internationale du développement des ressources humaines

La politique publique devrait s'intéresser plus explicitement au développement des mécanismes et vecteurs internationaux qui sont à même de renforcer le réservoir de ressources humaines du système national d'innovation. Plus spécifiquement, le gouvernement devrait :

- Modifier la politique d'immigration actuelle – en ne se contentant pas de réduire les obstacles à l'entrée de personnes hautement qualifiées, mais en adoptant un système plus volontariste du type carte verte qui soit au moins aussi attrayant pour les personnels scientifiques et technologiques et autres talents du monde entier que ne le sont les dispositifs similaires en place dans les autres pays (ce système devra comporter des éléments adaptés aux besoins spécifiques de l'Afrique du Sud et placer celle-ci sur un pied d'égalité avec les autres pays dans la chasse mondiale aux talents).

- Prendre des mesures pour pouvoir exploiter les investissements de l'étranger de façon plus efficace en tant que vecteurs de développement des ressources humaines, en ayant conscience *i)* que les complémentarités entre les mesures prises par le pays d'accueil et celles prises par les multinationales sont essentielles ; *ii)* que cette question ne concerne pas uniquement la phase d'investissement initiale mais qu'elle reste de mise, sous des formes différentes, à mesure que les entreprises approfondissent leurs ressources locales en capital humain ; et *iii)* qu'il s'agit d'un domaine dans lequel l'intégration des politiques nationales et des actions locales ou provinciales s'est révélée particulièrement importante dans d'autres pays.

- Envisager des mesures en faveur d'une hausse des investissements en capital humain de haut niveau effectués dans le cadre des projets d'investissements industriels et infrastructurels de grande dimension qui font largement appel aux technologies importées, en notant, encore une fois, le rôle potentiel majeur d'organismes de financement de l'investissement tels que la Société de développement industriel.

Améliorer le financement de la recherche universitaire

Les problèmes liés au maintien et à l'expansion de la R-D universitaire sont connus et admis, et diverses mesures ont été prises pour corriger la situation. Par ailleurs, plusieurs mécanismes ont été mis en place pour cibler les composantes importantes de la recherche universitaire sur les domaines socioéconomiques prioritaires. Ces efforts doivent être poursuivis et, si possible, renforcés. D'autre part, deux aspects du financement de la recherche universitaire méritent une attention accrue.

- Le ministère de l'Éducation devrait revoir les modalités d'affectation de ses financements, de manière à fournir des incitations plus fortes aux travaux de grande qualité et à renforcer la sélectivité de l'affectation des ressources en faveur de ces travaux.

- Il y a lieu de réévaluer les mécanismes de financement combinés de l'ensemble des filières pour vérifier s'ils fournissent un soutien suffisamment solide, sélectif et durable à l'effort de longue haleine que constitue le développement de nouvelles unités d'excellence en matière de recherche, en particulier dans les universités traditionnellement désavantagées. Si le principe d'égalité presque parfaite des chances doit continuer de servir de base pour l'affectation de la majorité des financements en faveur des acteurs les plus concurrentiels, des formes de financement réservé sont nécessaires pour favoriser l'émergence de nouveaux compétiteurs.

Renforcer la différenciation des organismes publics de soutien à la R-D et à l'innovation, en particulier au bénéfice des PME

S'appuyant sur l'expérience internationale commune, de laquelle il ressort que les caractéristiques de ces organismes diffèrent et évoluent en fonction des différences et des changements des caractéristiques des entreprises et des technologies dans leur environnement industriel, le gouvernement devrait se demander si le moment n'est pas venu d'accroître la spécialisation et la différenciation des fonctions des organismes publics qui exercent des fonctions de soutien à la R-D et à l'innovation.

Cette différenciation est cruciale si les autorités veulent corriger une faiblesse importante du système d'innovation de l'Afrique du Sud. En particulier, lors de la mise en œuvre de son projet de création d'un programme axé sur les PME venant compléter le THRIP, le gouvernement devra tenir compte des facteurs suivants :

- La grande diversité des PME et de leurs besoins.
- L'émergence récente, dans certains secteurs et sous l'impulsion des entreprises, d'une demande pour des formes de soutien qui soient moins centrées sur la R-D et qui assurent une gamme de services plus étendue que certains types de soutien actuellement proposés.
- Les gammes de compétences spécifiques qui sont nécessaires pour fournir aux PME un soutien multitechnique efficient dans de nombreux secteurs considérés comme plus traditionnels.
- L'expérience internationale, qui donne à penser que les universités sont rarement bien placées pour fournir des services efficaces de soutien aux PME, et que la décentralisation aux échelons provincial, local et des groupements d'entreprise est capitale.

L'une des lacunes majeures de la politique d'innovation actuelle réside dans l'absence de soutien exhaustif à l'innovation axé sur les PME. Bien que des efforts de grande ampleur aient été récemment mis en œuvre dans le cadre de l'Initiative pour une croissance accélérée et partagée en Afrique du Sud (Accelerated and Shared Growth Initiative for South Africa, ASGISA) et de l'Initiative conjointe pour l'acquisition des compétences prioritaires (Joint Initiative on Priority Skills Acquisition, JIPSA) pour développer les compétences dans ce domaine, la politique d'innovation de l'Afrique du Sud semble étonnamment inactive sur le plan du soutien technique opérationnel aux PME[10]. Dans les pays de l'OCDE, les fonctions de soutien aux PME incombent à des organismes qui disposent de ressources et de compétences

10. Le programme Tsumishano, qui s'inspire de la tradition européenne consistant à établir ces centres dans des écoles polytechniques, est un pas utile dans la bonne direction. Il est néanmoins insuffisant en comparaison des besoins des PME, et son fonctionnement est entravé par la pénurie de personnel disposant d'une expérience et de qualifications à la fois techniques et commerciales. Le Centre national de transfert de technologie (le National Technology Transfer Centre – NTTC, qui a été transféré au DTI) est lui aussi sous-dimensionné. Certaines autres mesures à caractère technologique axées sur les PME (telles que le Programme de soutien à l'innovation industrielle [Support Programme for Industrial Innovation – SPII] et le programme Godisa, qui a été intégré à l'agence pour le développement des petites entreprises [Small Enterprise Development Agency – SEDA] du DTI) se concentrent plutôt sur les nouvelles entreprises technologiques et, de ce fait, ne contribuent guère à améliorer le niveau technologique général (et les compétences plus larges) des PME.

spécialisées pour s'acquitter de cette mission. Des initiatives récentes telles que la proposition visant à établir, dans le cadre des Programmes sectoriels personnalisés du DTE, un Centre national des technologies de coulée (National Casting Technology Centre) qui s'inscrirait dans la Stratégie de développement du secteur de la métallurgie, marquent une étape potentiellement importante dans cette direction. D'autres initiatives seraient utiles :

- Un service de conseil ou de médiation de première ligne, qui aiderait les entreprises à diagnostiquer leurs besoins et les mettrait en relation avec les spécialistes capables de les aider. Plusieurs services de ce type existent dans d'autres pays : les Business Links au Royaume-Uni, les bureaux régionaux partagés TE-Keskus du TEKES et des représentations régionales du ministère de l'Industrie et du ministère du Travail en Finlande, et les bureaux régionaux d'Innovation Norway.

- Des services aux PME personnalisés abordant les aspects non techniques du démarrage et de la gestion des entreprises. (En Afrique du Sud, le DTI fournit certains de ces services). Parmi les exemples existants dignes d'intérêt, on peut citer le programme norvégien FRAM, qui permet à de petits groupes d'entrepreneurs de participer à un processus de développement stratégique dont l'objectif est d'améliorer les bénéfices de 10 %.

- Un ensemble de prestations plus axées sur les technologies, par exemple, un système de bons permettant d'acheter des services simples auprès des instituts de recherche (tests ou conseils sur l'achat des matériaux par exemple), des audits technologiques, des services de conseil en fabrication, etc.

- Un panel d'instituts pouvant offrir une aide concrète en matière de développement des produits. De nombreux pays ont mis en place un programme spécial à l'attention des PME, qui permet à ces dernières d'accéder à ce type d'expertise pour un prix modique. Dans la plupart des pays, les services assurés par ces instituts sont eux-mêmes subventionnés et peuvent donc viser des secteurs jugés trop risqués par le secteur privé.

- Des prêts et des investissements assortis de conditions plus ou moins favorables, pour lesquels, notamment, l'État assumerait une partie du risque en demandant, en contrepartie de ses prêts, une garantie moindre que celle qui serait exigée par le secteur privé.

- Des centres technologiques et d'innovation implantés au niveau des régions et des groupements d'entreprises et pouvant être associés, le cas échéant, à des parcs industriels, comme c'est le cas du nouveau Centre national des technologies de coulée en Afrique du Sud.

INTRODUCTION

The purpose of this OECD report is to review the current level of innovation capabilities in South Africa, and to help the government determine how such capabilities may be increased. The review was tasked with:

- Providing an independent and comparative assessment of the strengths and weaknesses of South Africa's innovation system.
- Formulating concrete recommendations for optimising South Africa's innovation policy and instruments, drawing on the experience of the OECD countries.

The review is based on a background document prepared by the South African National Advisory Council on Innovation (NACI), an advisory body to the Department for Science and Technology (DST), and on the results of a series of interviews with major stakeholders of South Africa's innovation system by the OECD review team.[11] Many people were very generous with their time and information in connection with both the background report and the visit (see Annex A). As a result, the review team was able to form a good picture of the parts of the innovation system that relate to government, the knowledge infrastructure and to a lesser extent of activities in large companies and relevant policies that lie outside the remit of the DST. Information made available about innovation activities that are not linked to formal research and development (R&D) and informal innovation in the "second economy" was patchier. These limitations, as well as those imposed by a necessarily short exposure to what is a very large and complex phenomenon – the evolving innovation system of a country undergoing a deep and lengthy socioeconomic transformation – need to be borne in mind in reading the report.

11. The team was composed of Jean Guinet (Head of Mission, Science and Technology Policy Division, DSTI, OECD), Gernot Hutschenreiter (Science and Technology Policy Division, DSTI, OECD), Erik Arnold (consultant to the OECD, Director of the Technopolis Group, United Kingdom), Martin Bell (consultant to the OECD, SPRU, United Kingdom), Ward Ziarko (Belgium Science Policy, Delegate to the CSTP and TIP Group) and Olivier de Cock (IWT, Flanders, Delegate of Belgium to the TIP Group).

The report takes an evolutionary view of South Africa's innovation system. The dynamics of the system is particularly important in South Africa and is different from that of most other countries. It involves not steady expansion and incremental evolution of structures and institutions but a radical transformation under a unique set of constraints and opportunities. In the 1990s, South Africa undertook radical changes in the political and economic framing conditions of its innovation system. In contrast to the experience of other countries that have undergone revolutionary political changes in the last two decades, this did not lead the system to collapse, since many of its basic building blocks remain in place (strong universities and research institutes and innovative business enterprises) although they have been subjected to strong pressures for accelerated changes to reflect the new economic and social conditions. Although these building blocks have been restructured, re-scaled and re-oriented and new elements have been added, the central story since the early 1990s has been the reshaping of a relatively strong innovation system that had served one set of social, economic and political goals into another strong system designed to serve a very different set of goals. This transformation has been both furthered and constrained by the legacy of the past: not only the inherited elements of the system, but also the wider context of social, economic, bureaucratic and political structures and relationships.

The way in which these interconnected transformations are taking place inevitably raises questions about the tension between *i)* continuity, to secure economic efficiency in the short run and gradually consolidate a broad and sustainable social consensus; and *ii)* change, to secure political acceptance in the short run and economic efficiency in the longer run (*e.g.* by removing key human resource bottlenecks). Managing such tension is a challenge in all countries, but it is magnified at South Africa's present historical juncture. OECD countries can thus derive useful lessons from South Africa's unprecedented endeavour. At the same time, South Africa can learn from OECD countries how to incorporate universal good policy practices to build a socially inclusive and economically efficient national innovation system.

This report seeks to contribute to both forms of international learning. It is structured in four chapters. Chapter 1 provides background information on South Africa's economic structures and performance and discusses growth-enhancing structural adjustment paths. Chapter 2 starts with aspects of the innovation system as it was at the end of the apartheid era. It then sets out in some detail what has been achieved, covering the overall performance of the system and the broad features of policy and institutions, as they now exist. It then discusses some of the challenges the innovation system currently faces: the persistence of pervasive poverty and high levels of unemployment; demographic changes; the planned surge in investment in the economy and the associated gap in a wide range of engineering skills; and the rapidly rising international openness of the innovation system.

Chapters 3 and 4 examine in more detail some features of the innovation system that will be important as South Africa moves ahead. Their focus is selective and should not be seen as offering a comprehensive agenda for the future. Chapter 3 considers the role of business enterprises in the innovation system. It outlines the critical challenges with respect to the development of human resources for the innovation system as a whole, noting that many perspectives on these problems neglect the major role of enterprises, especially larger ones, as developers and not just employers of human resources. It highlights the major role of business enterprises in R&D and their even more dominant role in the pervasive forms of innovation that are driven by design and engineering and by continuous incremental upgrading of existing production.

Chapter 4 turns to other actors and aspects of the innovation system. In the light of international experience it assesses the balance and relationships between university and business enterprise R&D, as well as the overall role and portfolio of activities of public research institutes. Finally, the overall governance of the research and innovation system is reviewed, with consideration of both vertical steering and horizontal co-ordination.

Chapter 1

ECONOMIC PERFORMANCE AND STRUCTURAL ADJUSTMENT

1.1. Macroeconomic performance

South Africa is one of the largest countries as well as the largest economy on the African continent. The country's history, including its economic and social development, is exceptional in many respects. Since the watershed of 1994, marked by the end of apartheid and the beginning of democratisation, South Africa has undergone fundamental changes in political, economic and social terms. In the following years, South Africa's new government implemented far-reaching reforms, liberalising domestic markets and foreign trade and thus creating a more open, market-oriented economy.

As a consequence, the economy is better integrated in the world economy and progress has been made in many areas. Macroeconomic reforms and a prudent monetary and fiscal policy stance have had remarkable success in stabilising macroeconomic fundamentals. The country's monetary and fiscal stability is reflected in low inflation and sound public finances. Monetary policy has underpinned relatively low and stable inflation and relatively low short-term interest rates. A prudent fiscal stance has contained the public deficit at low levels. The stabilisation of the economy has helped the South African economy perform well in recent years.

Despite these achievements, great challenges remain: high levels of unemployment, inequality, poverty, crime and the prevalence of HIV/AIDS. The South African economy also remains characterised by a pronounced dualism, many parts of society remain outside the formal sector and a large proportion of the population has limited access to essential services. Managing the country's social and educational system presents enormous problems.

1.1.1. Economic performance: the first decade after apartheid

From 1870 to the immediate period post-World War II period, South Africa's economic development was well on its way. The economy had achieved impressive per capita growth, especially between 1929 and 1950. South Africa was clearly on a catching-up trajectory, closing the gap with more advanced countries. However, this period of high growth was followed by a "remarkable long-run deterioration in South Africa's performance" (Feinstein, 2005, p. 5) which lasted until the end of apartheid. Consequently, in a long-term perspective, South Africa was for some time part of the "convergence club" but eventually dropped out (Dowrick and DeLong, 2003).

Indeed, the decade preceding the democratic transition marked a low in South Africa's economic performance. Trade and financial sanctions as well as mounting political opposition within the country stifled the economy. From 1985 to 1994, gross domestic product (GDP) (at 2000 market prices) grew at an average annual rate of 1.1%, which represented a contraction by -1.1% a year on a per capita basis.

With the transition, many of the constraints holding back the economy and society were loosened and expectations of greater social well-being were high. Indeed, as many had expected, economic growth picked up in the decade following 1994, but some found the pace disappointing. From 1995 to 2004 real GDP growth reached 3.1% a year on average but only 1.2% in terms of GDP per capita.

Towards the end of 1998 the South African economy embarked on a long upswing. Between 1999 and 2005 GDP grew at an annual average of 3.9%, accelerating in 2004 and 2005 to 4.8 and 5.1%, respectively, for real per capita growth of 3.4 and 3.7%. Recent forecasts indicate growth in the range of 4.6% in 2006. Forecasts for 2007 and 2008 remain in the range of 4% (World Bank, 2007; International Monetary Fund, 2006). Recent growth performance has raised hopes that South Africa can meet the current growth targets of 4.5% a year until 2009 and 6% between 2010 and 2014 contained in the Accelerated and Shared Growth Initiative for South Africa (ASGISA), a new policy framework put forward in late 2005.

Table 1.1. Key economic indicators, 2000-05

	2000	2001	2002	2003	2004	2005
GDP (current PPP USD millions)	428 598	455 861	478 433	502 585	533 330	n.a.
GDP per capita, PPP (current international USD)	9 741	10 173	10 551	10 967	11 417	n.a.
GDP growth, constant 2000 prices (%)	4.2	2.7	3.7	3.1	4.8	5.1
Consumer price index (% annual change)	5.4	5.7	9.2	5.8	1.4	3.4
Prime interest rate (average)	14.5	11.5	15.7	15.0	11.0	10.5
Nominal ZAR/USD exchange rate (average)	6.94	8.61	10.54	7.56	6.45	6.36

Source: South African Reserve Bank; International Monetary Fund, *International Financial Statistics*; World Bank, *World Development Indicators*.

Gross fixed capital formation has also turned around. While the decade preceding 1994 was marked by disinvestment (at an annual average rate of -1.7%), South Africa achieved a respectable average annual rate of fixed capital formation of 4.6% in the first decade after apartheid. Growth rates approaching 10% were recorded in 2004 and 2005. Gross fixed capital formation as a percentage of GDP also increased from a low of 13.9% in 1994 to 17.1% in 2004. However, this is still quite low both by international standards and from the perspective of what would be required to sustain high growth of output and employment. (It is generally assumed that growth in the range of 6-7% a year is required to make a dent in unemployment.)

Since the early 1990s inflation has been held to single digits, and since 2000 the South African Reserve Bank has successfully contained inflation within its 3 to 6% target band (except for the spike in 2002, which was linked to a severe but short-lived currency depreciation in late 2001). Low inflation as well as a strong appreciation of the rand have allowed for a more relaxed monetary policy since 2002, with interest rates declining consistently.

Fiscal policy performance, as reflected in low budget deficits, has also been favourable (Table 1.2). Strong macroeconomic performance has improved private-sector business confidence and created room for increased public-sector fixed investment. Indeed, fixed investment as a share of GDP has picked up since 2000 and especially since 2003, with a contribution from both the private and the public sector. The government plans to spend nearly ZAR 400 billion (approximately 30% of South Africa's annual GDP) on public infrastructure projects over the next five years.

Table 1.2. Macroeconomic aggregates as a percentage of GDP

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

Source: South African Reserve Bank.

The macroeconomic situation presents two difficulties. The first is the low level of national savings (Table 1.2, last row) which represents a potential long-term constraint on economic growth. Consumption has been encouraged by developments in interest rates and the rand's strong appreciation since 2002. Together with rising investment requiring foreign capital goods, consumption has contributed to the strong rise in imports, which has been accompanied by a stagnation of exports since 2000, despite high commodity prices. As a result, the current account deficit has risen steadily and reached 6.4% of GDP in the first quarter of 2006, compared to a 2005 average of 4.2%. However, the capital account balance has moved into surplus as emerging markets have attracted a larger share of global portfolio investment. As a result, capital inflows have been more than sufficient to finance the growing current account deficit.

Table 1.3. Working age population, 2005

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

Source: Statistics South Africa (2005a).

One of the most critical features of South Africa's economic development is the persistence of a very high level of unemployment. The unemployment rate according to the narrow definition was 26.7% in 2005, not much different from that of 1994. According to the broad definition, which includes discouraged workers (*i.e.* those who have stopped looking for work), unemployment stood at 38.8% (Table 1.3). (There was in fact a substantial drop in the broad unemployment rate in 2005, despite a moderate rise in the narrow unemployment rate.) Over a five-year period, both unemployment rates have declined slowly, but need to drop at a substantially faster pace if South Africa is to meet its Millennium Development Goals. Box 1.1 provides an overview of the policy initiatives that have supported economic stabilisation and growth.

Box 1.1. Economic policy initiatives since 1994

In 1994 the new government adopted the Reconstruction and Development Programme (RDP) as its basic policy framework. The RDP identified economic policy strategies across a wide range of issues and sectors, including macroeconomic policy, but by late 1995, its limited growth and employment impact was generally found disappointing. The government came to the view that a macroeconomic stimulus was necessary, but while policy was being formulated, a foreign exchange crisis hit South Africa in February 1996. The new macroeconomic policy, announced in June 1996 as the Growth, Employment and Redistribution (GEAR) strategy, focused on stabilising the foreign exchange market and on growth. It aimed to raise both foreign direct investment (FDI) and domestic fixed investment by improving the credibility of macroeconomic policy through tighter fiscal and monetary policy. Further objectives included increasing exports with a stable real exchange rate and enhanced competitiveness owing to labour market reform, skills training and accelerated tariff reform. Although GEAR was successful in achieving many of its macroeconomic targets (such as containing the fiscal deficit), it did not succeed in reaching the explicit targets of 6% annual growth and 500 000 new jobs by 2001. Since 2001/02 there has been a shift from fiscal austerity to more growth-oriented policies. The new Accelerated and Shared Growth Initiative South Africa (ASGISA), put forward in late 2005, is intended to address these objectives. Government has set itself the goal of halving poverty and unemployment by 2014, with an average growth rate of 5% a year over ASGISA's ten-year horizon.

1.1.2. Sources of economic growth

Sustained accelerated growth is a major concern of current economic policy making in South Africa. In this context it is important to understand the patterns of growth, including its main sources. According to the increasing body of relevant evidence, there appears to be a consensus that the relative contribution of proximate sources of growth in the South African economy has transformed the growth process significantly. This view is supported by a number of empirical studies using the growth accounting approach. Growth accounting quantifies the proximate causes of economic growth, in particular the relative contribution of factors of production – capital and labour – and of total factor productivity (TFP), which measures changes in technology and efficiency in the use of factor inputs.

These studies (*e.g.* Fedderke, 2002, 2004; Arora and Bhundia, 2003; Du Plessis and Smit, 2006) find a sharp turnaround in the contribution of TFP to economic growth: Whereas TFP actually restrained growth in the decade up to the end of apartheid, it has become the single most important driver during the decade from 1995 to 2004 (Du Plessis and Smit, 2006, p. 15), outpacing the contributions of increased labour and capital inputs.

The underlying causes of this change require further investigation. Empirical evidence suggests that improved TFP performance may be due to policy and institutional changes, increased openness to international trade and investment – which has provided new channels for knowledge spillovers and improved access to technologically more sophisticated intermediate and capital goods – as well as increased private sector participation in economic activity (Arora, 2006). An earlier study (Arora and Bhundia, 2003) reported a robust long-run relationship – and a positive correlation – between TFP on the one hand and openness and private investment on the other.[12]

These results indicate substantial gains in efficiency in the South African economy. The dynamism of TFP growth, a feature lacking in other countries, should be maintained and fostered as a source of sustainable economic growth. The sectoral pattern of growth in the South African economy is dealt with below.

1.1.3. Millennium Development Goals and equity issues

A broader look at South Africa's recent economic and social developments shows that over the last decade the country has made rather slow progress in achieving the Millennium Development Goals (Table 1.4). Prevailing poverty rates indicate a large degree of inequality in the distribution of wealth and income. More than one-third of the population still lives on less than USD 2 a day, and the Human Development Index (combining indicators on income, education, health, etc.) declined significantly between 1996 and 2003.

It is estimated that over 5 million people (11.4% of South Africa's population) were HIV-positive in 2002 (Human Sciences Research Council, 2003). The HIV/AIDS pandemic has been a major factor in South Africa's regression with respect to life expectancy, infant mortality and education, and ultimately the rising levels of poverty. The drop in the primary school enrolment rate may also be linked to HIV/AIDS; the number of AIDS orphans in the country was estimated at 660 000 in 2001 (World Bank, 2003).

12. In contrast, no robust relationship could be established between R&D and TFP growth in this particular exercise.

Table 1.4. South Africa and the Millennium Development Goals

Early 1990s and post-2000; actual year in brackets

Item	Description	Early 1990s	Post-2000
a	Total population (millions)	36.2 (1991)	44.5 (2001)
b	Percent of population living on less than USD 1 a day	n.a.	10.7 (2003)
c	Percent of population living on less than USD 2 a day	n.a.	34.1 (2001)
d	Human Development Index	0.69 (1996)	0.65 (2004)
e	Life expectancy at birth (years)	62 (1990)	45 (2004)
f	Under five mortality rate (per 1 000 live births)	73 (1990)	85 (2004)
g	Maternal mortality rate (per 100 000 live births)	150 (1992 to 1998)	150 (2002)
h	Adult literacy rate (% of people 15 and over)	81.2 (1990)	85.0 (2004)
i	Net primary enrolment rate (% of age group)	88 (1991)	89 (2003)
j	Urbanisation (% of population)	53.7 (1996)	56.1 (2000)

Source: a, b, c, e, f, h, i: World Development Indicators; d. United Nations Human Development Programme; g, j: Gelb (2003).

Comparisons of income distribution before and after 1994 are difficult as a result of the lack of official data or estimates for the earlier period, and the unreliability of the early official estimates after 1994. Unofficial estimates during the 1980s, however, suggest that South Africa was among the two or three most unequal countries in the world, with a Gini coefficient of about 0.67 that was thought to have remained relatively constant between 1975 and 1991. The first official estimates of a Gini coefficient in 1995 placed it much lower than previous estimates at about 0.56, deteriorating to 0.59 in 2000. An unofficial but careful estimate using official data suggests a smaller decline between 1992 and 2000 from 0.57 to 0.58, levels close to the official figures (Hoogeveen and Özler, 2004).[13]

Notwithstanding the uncertainty over the extent of inequality, aggregate inequality (within the population as a whole) appears to have increased only slightly over the past 30 years, as income shares have shifted from both rich and poor groups towards the middle classes. There is also wide agreement that in contrast to the population as a whole, inequality within the four (apartheid-defined) race groups[14] has risen steadily since the mid-1970s.

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

14. Of South Africa's 2001 population of 44.5 million, 79% were African, 9.5% white, 9% coloured (mixed race) and 2.5% Asian.

Since 1994, a systematic process of black economic empowerment (BEE), focusing especially on affirmative action in the labour market and ownership transfers of equity in the capital market, has accelerated the upward mobility of the black middle classes, especially managers and professionals (as distinct from entrepreneurs).

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

Inequality and poverty also depend heavily on employment status. Wages account for 66% of inequality across all households, and remittances and state transfers for 28%. Only 22% of people living in poor households were employed (Bhorat *et al.*, 2001). In 2005, only 26.9% of the working age population were employed in the formal sector and 8.3% in the informal sector. A further 6% were in the agricultural sector and private households,[15] so that the official unemployment rate (counting only those willing and able to work, and who had actively looked for work in the previous four weeks) was 26.7%. The broad definition of unemployment includes discouraged individuals who want to work but have given up searching, and on this criterion, the unemployment rate was 38.8%. The broad definition is widely believed to be the more appropriate one in South Africa given the disjointed spatial settlement patterns and the structural mismatch in the demand for and supply of skills, owing to the legacy of apartheid. Even on the narrow definition, however, unemployment is extremely high. Encouragingly, there was robust employment growth in 2005, with 658 000 new jobs created, but the unemployment rate rose nonetheless, as the number of new labour force entrants grew even faster than jobs.

Race and gender are both significant determinants of employment status. Over 2001-05, 32.7% of women were unemployed compared to 24.4% of men. Since a greater proportion of discouraged workers are female, the gender differential is even larger under the broad definition (Statistics South Africa, 2005a). The average unemployment rate among Africans over the period was 33.8% compared to 21.9% among coloureds, 17% among Indian/Asians and only 5.5% among whites (Table 1.5).

15. Agricultural labourers and domestic workers are excluded from the formal and informal sector categories owing to difficulties in measuring and categorising these types of labour.

The educational profile of the working age population according to various employment categories is given in Table 1.6. The level of education is low: 21.8% of the formally employed had post-secondary schooling, compared to only 3.8% of those employed in the informal sector. Less than 10% of the 859 000 domestic workers in 2005 had matriculated and none had acquired post-secondary education. Individuals who had completed grades 8 to 11 made up the largest portion of the unemployed population (43.2%), while only 4.2% of the unemployed were individuals with post-secondary schooling.

Table 1.5. Unemployment rate

Percentage; narrow rate unless otherwise specified

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

Source: Statistics South Africa (2005a).

Table 1.6. Employment status by educational attainment, September 2005

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

Source: Statistics South Africa (2005a).

1.2. International trade and foreign direct investment

With the end of apartheid South Africa made great strides in opening up to international trade and capital flows. Shedding the constraints prevailing in the late phase of the apartheid regime was a precondition for progressing to a more open and market-oriented economy. As will be seen, this led to significant gains in efficiency and contributed to the South African economy's improved growth performance.

As it does for other countries, the recent acceleration of globalisation holds great opportunities, but it also raises the danger of falling behind in a rapidly changing global environment if opportunities are not seized. There are indeed indications that the integration of South Africa's economy into the world economy has not in fact kept pace.

International linkages through international trade and foreign direct investment are also of great importance for a country's innovation performance. International trade and FDI are channels of knowledge flows both in an immediate sense and more indirectly through the transfer of knowledge embodied in imported goods.

1.2.1. International trade

Under apartheid, specifically at the end of the 1980s, South Africa's trade was constrained by a very restrictive and highly complex trade regime characterised by high average tariffs and an extensive set of import controls complemented by a large export subsidisation scheme. Trade liberalisation started in the early 1990s. With the end of apartheid, trade sanctions were rapidly removed and the highly restrictive former trade regime was subject to far-reaching liberalisation (Hviding, 2006). South Africa swiftly (re-) opened to international trade as well as to capital flows.

Trade liberalisation was accomplished via multilateral and bilateral agreements. Integration within the southern African region, in particular the South African Development Community (SADC), deserves special mention (Goldstein, 2004). As a result of trade liberalisation, the combined ratio of exports and imports to GDP (excluding gold) rose from a low of 33% in 1992 to a high of more than 60% in 2002. However, in a long-term perspective, South Africa's export performance in terms of exports per capita is very poor by international standards. Exports per capita in constant USD have grown by just 0.64% a year from 1960 to 2004 (Hausmann and Klinger, 2006, p. 4). Other natural-resource-exporting countries such as Argentina, Australia, Canada or Malaysia performed much better over that period.

Trade restrictions during apartheid seriously impeded both exports and imports. The pattern of protection seems to have favoured a bias towards capital-intensive primary and manufactured commodities, since it was particularly unfavourable to the export of non-commodity manufactured goods (Edwards and Lawrence, 2006, p. 54).

In terms of structure, South Africa's exports continue to be dominated by mineral-based items. The main sectors with large *net* exports are mining (in particular gold, coal) and basic iron and steel. Industries such as automobiles, other machinery and equipment, other transport, food and leather products also generate large exports. However, these are counterbalanced by even larger imports (Hausmann and Klinger, 2006, p. 23).

Over time, South Africa's exports have become more diversified and less dependent on primary commodities. Diversification came rather late. In the early 1990s there was some re-orientation of South Africa's export basket, which created opportunities for further structural transformation (Hausmann and Klinger, 2006, p. 23): Between 1994 and 1996 South Africa developed a revealed comparative advantage in various iron and steel products, textile-related products, non-metallic mineral manufactures, specialised machinery, organic chemicals, articles of pulp and paper, vegetables and fruits, petroleum products, metalliferous ores and metal scrap, oils and light perfume materials, and leather materials.

The acceleration of globalisation poses new challenges, with industries such as textiles hard hit by fierce new international competition. It also offers opportunities, yet in spite of significant growth in the post-apartheid era, South Africa's export performance has been less dynamic than that of other countries, especially the newly emerging economies. Recently, South Africa seems to be held back by the structural composition of its exports (Edwards and Lawrence, 2006, p. 16). To seize opportunities more effectively may require further adjustment in South Africa's export basket.

1.2.2. Foreign direct investment

In the 1980s and up to 1993, FDI inflows were next to nil, not least because of the trade and financial sanctions imposed on South Africa in the mid-1980s. In the last phase of apartheid South Africa suffered a period of disinvestment as many foreign companies closed their operations in South Africa. The democratic transition restored South Africa's access to international financial markets. At the end of apartheid, expectations were high concerning FDI as a source of financing investment in South Africa.

In principle, FDI can serve multiple purposes in the economic development process. In South Africa's current situation, for example, FDI inflows may help to compensate for the nation's low savings rate and thus promote economic growth. In relation to the performance of the national innovation system, FDI plays a central importance. Inward FDI acts as a channel of knowledge flows towards South Africa and helps establish local networks around or involving foreign companies. Outward FDI by South African companies to knowledge centres and networks abroad can also play an important role.

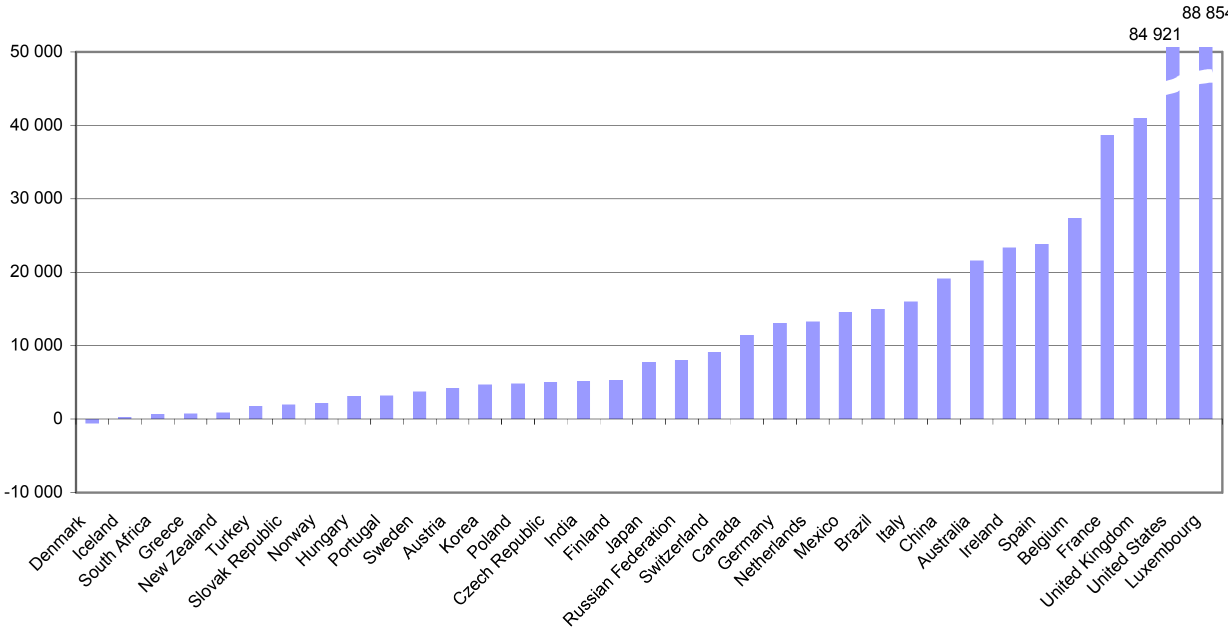
In 2003, South Africa's stock of outward FDI was 16.4% of GDP and the inward FDI stock was 27.4%. The corresponding OECD averages are 25.5% and 20.3%, respectively. Compared to other emerging economies South Africa attracts relatively little inward FDI (Figure 1.1). The share of portfolio investment in total capital flows to South Africa is high (Du Plessis and Smit, 2006, p. 22). Annual inward FDI was less than 1.5% of GDP a year on average compared to 2 to 5% for a group of comparable countries (Arvanitis, 2006). Spikes in 1997 and 2002 were related to the sale of government shares in Telkom and the takeover of De Beers by Anglo American (primarily listed in London).

While a great deal of FDI in South Africa comes from the United Kingdom (76% of the total stock in 2002), it is diversified in terms of sectors of destination (mainly finance and services, mining and manufacturing). Inward FDI primarily concerns cross-border mergers and acquisitions (*i.e.* existing assets); it rarely concerns greenfield investment.

The FDI projects of European, US and Japanese multinational carmakers offer an interesting example of deepening the industrialisation and broadening the competitive advantage of South Africa (Goldstein, 2004, pp. 81 ff.). They consist of assembly plants and component production. Exports have increased rapidly and the industry contributes significantly to overall manufacturing performance.

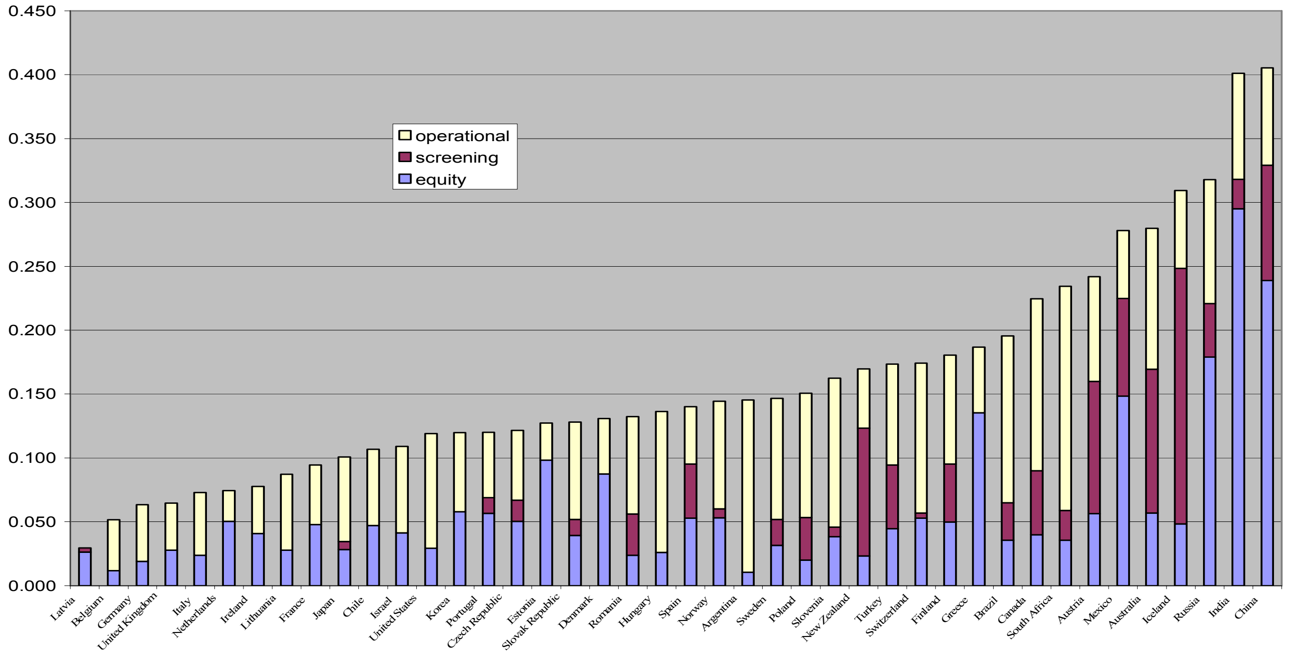
The high expectations regarding FDI at the end of apartheid have yet to be realised. Available data do not allow for a rigorous explanation. An assessment of the available evidence (Arvanitis, 2006, pp. 73 ff.) indicates that lagging economic growth, infrastructure development, trade openness, skills and tax rates may be significant factors. Business surveys identify the perceived incidence of crime as a major deterrent to investment.

Figure 1.1. Inflows of FDI, USD millions, average 2002-04



Source: OECD Factbook 2006.

Figure 1.2. Nine-sector FDI regulatory restrictiveness by type of restriction[1]



1. This aggregate Index covers the following sectors and sub-sectors: Business (legal, accounting, architectural, and engineering services), Telecommunications (fixed line telephony and mobile telephony), Construction, Distribution, Finance (insurance and banking), Tourism, Transport (air transport, maritime transport and road transport), Electricity and Manufacturing. *Source:* Koyama and Golub (2006).

An indicator-based international comparison covering nine sectors shows that South Africa has comparatively high levels of regulatory restrictiveness on FDI (Koyama and Golub, 2006). These restrictions are mainly located in the operational sphere rather than in screening and equity provisions (Figure 1.2). The electricity sector remains closed and restrictions are relatively tight in the telecommunications sector (and far above the OECD and selected emerging economy averages). Restrictions in the insurance and manufacturing sectors are lower but still slightly above averages for the OECD area and selected emerging economies. South Africa has below-average restrictions in the business services sector (legal, accounting, architecture and engineering services).

FDI is a major aspect – both as outcome and as driver – of the globalisation process. While FDI inflows are significant, South Africa still has a long way to go to approach the levels of leading emerging economies. Some of the factors hampering an increase in inward FDI – such as skill shortages and infrastructure-related shortcomings – are also among the factors limiting the development of the South African innovation system in general.

Table 1.7. Economic activity by sector, 2000-05

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

Source: South African Reserve Bank.

Table 1.8. Value added and fixed capital formation by sectors, 2000-05

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

Source: South African Reserve Bank.

1.3. Structural features of the economy

The very specific structural features of the South African economy are partly due to its resource endowments but are also shaped by past and present institutional factors. It has been observed that the pattern of South Africa's exports resembles that of a capital-abundant rather than of a labour-abundant country. It has been argued in this context that the institutions of apartheid distorted markets, biasing production towards capital-intensive activities (Arora and Ricci, 2006, p. 31).

This section prepares the ground for a further discussion of the role of structural adjustment in the future development of the South African economy. Science, technology and innovation policy can play a major role in facilitating and stimulating diversification.

1.3.1. Industry structure

Economic activity, measured in terms of value added and employment, is shifting from the production of goods to the provision of services. This trend has persisted for two to three decades. Tables 1.7 and 1.8 provide a breakdown of the contribution of the major economic sectors to aggregate output and fixed capital formation over the period 2000-05.

The agricultural sector's share of value added in GDP is very small and has been declining over the past decade, from 3.9% in 1995 to 2.8% in 2005.[16] South African agriculture is largely capital-intensive, but nonetheless accounts for a larger share (6.8%) of formal employment than its contribution to GDP would suggest, as well as 12.1% of informal employment (see Table 1.9). The period 2000-05 saw a decline in agricultural employment of almost 30%, most of it in formal agriculture.

The main focus of agricultural policy is less to increase output and food production (Van Rooyen, 2000) than to transform the sector for efficient production and generate farm incomes and employment. Given the many unemployed in rural areas, increasing labour absorption by the agricultural sector is an important challenge for the present government.

The main source of growth in the agricultural sector is exports. Increasing agricultural exports requires greater competitiveness, among others via factor productivity growth. Land reform and the removal of incentives for capital-intensive production and efforts to liberalise trade are important steps in this process. Nevertheless, improved labour and capital productivity in the agricultural sector poses significant challenges, as does improved access to export markets in developed countries via lower tariff and non-tariff barriers.

The industrial sector – mining, manufacturing and construction – contributed 28.4% on average to South Africa's GDP over the period 2000-05. The output shares of both mining and manufacturing have been falling, continuing a trend that started during the 1980s. The relatively small share of industry and the large share of services are atypical for a middle-income country and are the result of South Africa's historical development as a dual economy under apartheid. This phenomenon – which contrasts with the development pattern of other countries – has been interpreted as a sort of "premature de-industrialisation" (Rodrik, 2006).

16. For a recent review of agricultural policy in South Africa see OECD (2006a).

Table 1.9. Employment by sector, September 2001 and 2005

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

Source: Statistics South Africa (2005a).

Within manufacturing, labour-intensive sub-sectors such as food and beverages, textiles and clothing, and footwear grew slowly (at around 0.2% a year), and their share in manufacturing value added declined, while basic metals, wood products and chemicals (all capital-intensive) were the fastest-growing sub-sectors. The share of formal employment in both mining and manufacturing has fallen (see Table 1.9). The last column of the table shows that, in absolute terms, mining suffered enormous employment losses between 2000 and 2005, shedding over 25% of its labour force, while manufacturing jobs increased by 5.3% (a smaller increase than the overall growth of employment over the period). The construction industry, however, employed almost 50% more workers during this period and increased its share of both formal and informal employment.

The fastest growing sub-sectors across the economy were transport, storage and communications, and financial and business services. Services represent more than two-thirds of the growth in value-added and employment, and, as a result, its share rose during the period 2000-05, both in aggregate terms and in all sub-sectors except community, social and personal services (see Tables 1.7 to 1.9). This sub-sector is, together with financial and business services, the largest contributor to gross value added; employment is largest in community, social and personal services. The trade, catering and accommodation sub-sector is the second-largest employer, and the largest by far in the informal sector. Services employment grew by 76% over the period, although domestic workers (not included in the table) dropped by 7.6% from 930 000 in 2001 to 859 000 in 2005. Overall, services contribute 65% of gross fixed capital formation, with the financial and business services sub-sector alone contributing almost one-quarter of national fixed investment.

Labour productivity has grown rapidly since 2000, including – albeit less consistently – in the manufacturing sector. In addition, the capital-output ratio has fallen during this period, suggesting that capital productivity has also risen significantly.

Structural change in the South African economy is well under way. A salient feature is that, as in high-income countries, economic activity is shifting towards services, while manufacturing's share is declining. Thus, in relative terms, South Africa is undergoing a process of de-industrialisation.

1.3.2. Firm size

The size distribution of the total population of firms is important since firms' size is related to their capabilities, not least in the area of R&D and innovation, the role they play in the national innovation system and their specific requirements for facilitating their operations.

While turnover is a common indicator of firm size it probably under-estimates the proportion of micro and small enterprises. For example, small enterprises that do not comply with tax filing requirements may be recorded as economically inactive even though they are still trading. Moreover, sole proprietorships and partnerships (typically smaller entities) are not formally incorporated in South Africa (Department of Trade and Industry, 2003). In 2003, 49% of all registered entities were micro-enterprises, 39% were very small, 8% small, 2% medium and only 1% were large.

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

Table 1.10. Percentage contribution to GDP by firm size, 2002

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

Source: Department of Trade and Industry (2003).

Table 1.11. Percentage contribution to employment by firm size, 2002

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

Source: Department of Trade and Industry (2003).

Small, medium and micro enterprises (SMEs) accounted for 36.1% of GDP in 2002 (Table 1.10) and provided the largest contribution to GDP in agricultural, forestry and fishing, in construction, in transport, storage and communication (56.4%, 50% and 48.1%, respectively). Their smallest contribution to sector-specific shares of GDP was in the mining and quarrying sector, where SMEs contributed only 6.3%.

Micro, very small and small enterprises account for approximately 72% of total employment and 77% of employment (2002) in the trade, catering and accommodation sector (Table 1.11). Of all micro industrial sector entities, micro construction enterprises contribute the most to employment, with 36% of total sector employment provided by micro enterprises. With the exception of the utilities sector, large enterprises contribute less than 5% to total employment.

The survey of employers and self-employed conducted by Statistics South Africa in March 2001 provides some useful information about informal sector businesses, taken to be businesses not registered for value-added tax (VAT). An estimated three-quarters of non-VAT-registered business owners in non-urban areas were in trade, catering and accommodation, compared with just under two-thirds in urban areas. Fewer than 3% of non-VAT-registered business owners in non-urban areas were in finance and business services, as against 10.5% of urban owners of informal firms. In other words, activities related to distributing ready-made products and services to consumers were significantly more prominent in small and micro businesses in non-urban than in urban areas.

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

1.3.3. Framework conditions for innovation

The existence of favourable framework conditions is a major factor in enabling and facilitating innovation throughout the economy. Innovation policy is not likely to compensate for seriously flawed framework conditions. At the same time, specific policy measures are often required to address specific market or systemic failures that hamper research and development (R&D) and innovation.

The macroeconomic framework, the general business environment, the intensity of competition, product and labour market regulations, and the degree and quality of entrepreneurship – which is shaped by institutional and cultural factors – are all of key importance for a country's innovative performance.

1.3.3.1. Macroeconomic framework and business environment

As mentioned, post-apartheid South Africa's prudent policy stance has made possible the establishment of a sound macroeconomic framework and a stabilised economy. This is a major success. Stabilisation has reduced uncertainty and made it possible to firmly integrate South Africa into the world economy. Moreover, it has made the country better equipped to respond to shifts in demand and to exogenous shocks in general.

Trade liberalisation has helped South Africa to make strides towards creating well-functioning product markets and an improved business environment, and, as various economic indicators and analyses demonstrate, business has seized the opportunities provided. Business confidence is also high, reflecting the largely favourable business environment and efficient financial markets. At the same time surveys indicate remaining problems (AfDB-OECD, 2006, p. 469). A high level of crime, for example, is perceived as a weight on economic activity.

A major bottleneck in the operation of business enterprises is deficiencies in the infrastructure. This concerns, in particular, the transport infrastructure (AfDB-OECD, 2006), but also to some extent the energy supply and telecommunications. Insufficient infrastructure also seems to be a major obstacle for attracting inward FDI. For example, economic growth has induced high demand for energy and has put increasing strain on South Africa's power grid, as evidenced by a series of blackouts. In 2004, the power utility Eskom was given a green light to invest in new power stations, transmission and distribution.

The shortage of skilled personnel is a major bottleneck for the development of South Africa's economy and innovation capability. Beyond their immediate effects, skill shortages also raise the cost of labour relative to capital (Arora and Ricci, 2006, p. 31) and thus reinforce South Africa's specialisation in capital-intensive goods. The issue of skill shortages will be dealt with in some detail in Chapter 3.

1.3.3.2. Competition, product and labour market regulation

Overall, exposure to competition has increased with the opening of the South African economy. Nevertheless, there is a lack of competition in some parts of the economy. In particular, the lack of competition in industries that produce intermediate goods, such as iron and steel, paper and chemicals, as well as in the telecommunications and energy sectors requires attention since it may be detrimental to innovation and adversely affect downstream producers.

In the telecommunications sector, steps have been taken to increase competition in both fixed-line and mobile telephone services (AfDB-OECD, 2006, p. 469). The telecommunications operator Telkom still appears to exert rather tight control over Internet access. Overall, the issue of competition should be seen in the context of the restructuring of state-owned enterprises in the sectors concerned.

Earlier empirical work (summarised in Fedderke, 2005) spanning the 1970s, 1980s and 1990s has found evidence of considerable pricing power in South African industry. This suggests that inefficiencies may have contributed to the South African economy's poor investment performance. Aghion *et al*. (2006), for example, find that mark-ups remain higher in South African industries than in corresponding industries worldwide. In addition the study finds that a reduction in mark-ups – *i.e.* increased competition – would have a very large positive impact on growth and employment.

Product-market regulation is very important for economic performance and business dynamics (Brandt, 2004). Some features of the country's regulatory system may impede firm entry. Product market competition is an important driver of productivity growth, either directly or indirectly through a positive impact on innovation, at least up to a certain intensity of competition (Aghion *et al*., 2002).

Labour market regulations are another dimension of the regulatory environment that can have a strong impact on the performance of the labour market. The main labour legislation is the Labour Relations Act and the Basic Conditions and Employment Act. Some authors argue that distortions in the labour market have dampened South Africa's growth performance. A number of authors also argue that labour market regulations cause rigidities in the labour market which contribute to the high rate of unemployment. Issues relating to labour market regulations regularly appear in the statements of business organisations and surveys among their members.

It has to be recognised, however, that the legacy of apartheid, which deprived the majority of the population of their rights, has created the need to balance the return of these rights to the formerly dispossessed with considerations of economic efficiency (Arora and Ricci, 2006, p. 26). In practice, this can be very difficult.

Other factors can also affect the performance of labour markets: skill shortages, inequality in the access of black Africans to education as well as workforce immobility may result in sub-optimal functioning of labour markets. It is worth noting that the Cabinet has taken a number of decisions regarding the regulatory environment for small businesses.

1.3.3.3. Entrepreneurship

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

The GEM (2005) also reveals that entrepreneurship correlates with age (individuals aged between 24 and 44 are most likely to be entrepreneurs), and race (Indian and white individuals are more likely) and education, but not with gender. However, men are 2.3 times more likely than women to employ people, while entrepreneurs with tertiary education have 2.5 times the potential to create employment than those with only secondary education, and 11 times more than those without secondary education. It was also found that very few new or established firms have a high level of customer orientation, are differentiated from competitors or are technology-orientated.

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

Empirical evidence (Kingdon and Night, 2004) indicates that compared to other African, Asian and Latin American countries the size of the informal sector is very small in view of the level of unemployment.

1.4. Promoting growth-enhancing structural change in the South African economy

The evidence presented so far shows that while economic performance has improved considerably, it has fallen short of expectations. Whether this performance is considered sufficient obviously depends on the benchmark applied. Recent expectations may be shaped not just by South Africa's performance in certain periods of its economic history, but also by the recent dynamism of a number of catching-up and newly emerging economies in other parts of the world. The evaluation of economic performance poses a number of methodological (as well as practical) problems. In an attempt to assess South Africa's post-apartheid economic performance, Du Plessis and Smit (2006, p. 28) conclude that it "was notably better than the preceding period and not clearly worse than could have been expected with the initial conditions of 1994".

Achievements of the post-apartheid era include:

- South Africa has become integrated in the world economy by opening up to international trade and capital flows.
- The stabilisation of the economy has been impressive.

- Growth of GDP has picked up in the post-apartheid era and has accelerated in recent years.
- GDP growth has been driven mainly by growth in total factor productivity.

At the same time expectations concerning South Africa's economic and social development have not been fully met and weaknesses in economic performance remain and need to be addressed, in particular:

- Unemployment remains at very high levels.
- The creation of jobs for the low-skilled in insufficient, particularly in the formal sector.
- Economic performance has not kept pace with that of other emerging economies.
- South Africa has not yet sufficiently benefited from globalisation. FDI remains very limited. Exports have grown but may be constrained by the structure of exports.

Not enough jobs have been created, in particular for the low-skilled. South Africa's growth and employment outlook depends on investment that absorbs rather than displaces labour (Arora and Ricci, 2006, p. 32). Rodrik (2006) sees the reason for persistently high unemployment and – by some measures – low growth in the decline of the non-mineral tradable sector (premature de-industrialisation), in particular the relative weakness of export-oriented manufacturing. In contrast, countries that are to some extent comparable – Rodrik uses Malaysia as an example – have succeeded in absorbing an increasing proportion of their workforce in manufacturing.

A significant policy challenge in the current phase of South Africa's economic development is to increase incentives for employment while promoting technological change and maintaining the efficiency gains and the dynamism due to strong total factor productivity growth. To tackle this two-pronged challenge is likely to require a "dual strategy". Structural change will play an important role.

There is widespread agreement that government policy should play a significant role in facilitating and stimulating change in the industrial structure of the South African economy. There is also broad consensus that one dimension of this change should involve moving away from heavy dependence on the growth of resource-based industries.

The past pattern of growth had considerable limitations. It was very dependent on capital-intensive activities, generated relatively low rates of income growth and very limited growth in employment. On the downswing of commodity cycles it contributed to falling terms of trade, and on the upswings the exchange rate effects disadvantaged exports from other (non-commodity) sectors. Also these industries were widely considered as based on old or mature technology and as part of the "sunset" segment of the economy – part of the past rather than the future.

There are, however, two different views of the direction in which the structure of the economy should be moving. One approach starts from concerns about the persistence of very high levels of unemployment and stresses the need to shift towards much more labour-intensive but less skill-intensive industries in both the manufacturing and services sectors. The other stresses long-term growth in income and emphasises the importance of shifting towards types of production that are commonly described as more technology-intensive or knowledge-based.

The first of these approaches has been increasingly emphasised in recent years, as the growth of manufacturing over the last decade has failed to result in increased employment. Indeed, although manufacturing output doubled between 1994 and 2001 and has continued to grow rapidly since, employment in manufacturing fell between 1995 and 2004. More broadly, the economy has followed a jobless growth path, with the number of jobs expanding only in the informal sector (Altman, 2003). Some authors conclude that there may be two limitations to achieving substantial increases in employment. First, there may be limited scope for labour-intensive export growth of the East and South-east Asian variety (Altman and Mayer, 2003). Second, general growth in demand is unlikely to trickle down more or less automatically to forge concrete links with employment-intensive supply capacities.

There are different views of the extent to which the South African economy is shifting towards an increasingly knowledge-intensive structure:

- One perspective notes that the evolution of manufacturing activities over the last decade does not appear to have led to a shift away from a resource-based economy. On the contrary, much of the growth in manufacturing has been heavily concentrated in those "old" industries (*e.g.* coke and refineries, basic chemicals, basic iron and steel, and basic non-ferrous metals) and the only significant manufacturing newcomer with above average growth has been the automobile industry (Roberts, forthcoming). Some might add that growth in "new" industries such as electronics and information technology (IT) has been limited.

- A second, more positive perspective notes that, behind the labels of broad industry categories, the technology intensity and skill intensity of production is increasing (Edwards, 2003). Also, manufacturing exports have increased rapidly, doubling as a proportion of manufacturing output between 1994 and 2001, while services exports, often with a high knowledge intensity, have also increased. Exports in medium- and high-technology categories have grown particularly fast, and the composition of manufactured exports has shifted towards non-commodity manufactures (Altman and Mayer, 2003; Edwards and Lawrence, 2006). However, these indicators of shifts towards a more "knowledge-intensive" economy involve relatively non-dramatic, underlying trends of cumulative, incremental change – not highly visible leaps into "new" and "modern" sectors. It is the limited extent of the latter that seems to attract most attention in the science, technology and innovation policy community.

Consequently, alongside the absence of any substantial shift towards rapidly growing employment-intensive production, the apparent absence of a significant shift from the "old economy" towards the "new" has made it more urgent to find new ways to help speed structural change. Not surprisingly, at least parts of the science, technology and innovation policy community give most attention to the role of the innovation system in contributing to the second kind of shift, from old to new, and within that, the focus of attention centres largely on the role of R&D. In some cases this leads to multiple emphases in certain policy mechanisms such as expecting publicly supported R&D activities to contribute significantly to both high-technology production and increased employment.

Alternatively, there are attempts to distinguish more clearly between policy directions centred on employment creation and those directed towards creating more knowledge-intensive forms of production. Altman and Mayer (2003) envisage a dual strategy:

- One component involves much more direct interventions to link demand to employment creation, especially in the production of non-traded goods and services in sectors like construction, social services and food.

- The other concentrates on reinforcing existing trends towards more knowledge-intensive production. In particular, emphasis is placed on achieving this by evolving more technology-intensive types of production around the economy's existing innovative strengths in the broadly defined resource-based industries. This would involve efforts to induce investment to move further "downstream" in those industries, a policy approach that is already being actively pursued. It would also involve stimulating lateral diversification into specialised supplier industries.

An alternative approach concerning the first pillar of a dual strategy – stimulating employment creation, especially for the relatively unskilled – centres on encouraging exports of non-mineral tradables (Rodrik, 2006). It is not the task of this report to settle, or even go deeper into, this issue. Instead, it focuses on the second pillar, while recognising that a dual strategy may be necessary.

The second pillar of this dual strategy – encouraging the evolution of new kinds of production out of existing areas of economic and innovative strength, rather than trying to leapfrog into new high-technology industries in which South Africa currently has limited strengths – has been explored in a series of studies by the HSRC.[17] There are several reasons why such a perspective merits much greater attention than it seems to have received:

- First, it highlights the limitations of discussing structural change in the economy simply in terms of the labels and presumptions attached to individual industries in the SIC classification system.[18] The key issue concerns the activities actually being undertaken in and around such industries. For example, various kinds of electronics industry may be classified as "high-technology" industries in OECD countries but involve only low-technology assembly activities in other contexts. Similarly, "low-technology" resource-based industries may be the driving nucleus surrounded by a dense cluster of sophisticated service activities and knowledge-intensive production of equipment, software, instruments and materials for both domestic and export markets.

---

17. *E.g.* Altman *et al*. (2003); Walker and Jourdan (2003); Steyn *et al*. (2004); Lorentzen (2006a); and Altman (2007).

18. Views about attempting to leapfrog into supposedly new technology industries are even more misplaced when they focus on industries that are not actually new at all. For example, the review team encountered frequent comments about the importance of South Africa establishing a greater presence in electronics and IT. But this was a major component of policy discussion in many countries in the 1970s and 1980s (part of the trio electronics, new materials and biotechnology) when the technology was highly dynamic and fluid and opportunities to enter the industry were relatively open. Two or three decades later, much of the technology has become standardised, though still fast-moving, economies of scale are enormous, established producers dominate the industry's technology and low-wage producers in China dominate manufacturing and survive on wafer-thin margins. If South Africa plans to follow the experience of Japan, Korea and Chinese Taipei in facilitating entry into global industries with prospective high growth rates and high rates of innovation, there is little point in following where others have been in the past. Instead it might target areas where others are going in the future and where it has a base of strength on which to build.

- Second, the development of knowledge-intensive production out of and around existing bases of economic and innovative strength would not simply focus on areas of manufacturing linked closely with the resource-based economy. As noted earlier, such strengths also exist in parts of the services sector, in particular in financial, business and medical services.
- Third, while the diversification of production in the ways suggested may sometimes be assisted by conventional R&D, it is likely that strong engineering, design and project management capabilities will also be a major requirement. For example, much diversification into new kinds of production is likely to be based on existing bodies of knowledge that have to be engineered to meet the specifications of products, processes and organisational procedures needed for local production. Similarly, procuring goods and services from new local suppliers is not just a commercial transaction. It frequently has a strong technological dimension: forging such supply links will often involve reverse engineering of what is needed, together with the technological upgrading of potential supply capability. The scope of public funding mechanisms to support such forms of innovation would need to be much wider than those that concentrate primarily on conventional R&D projects in which global technological novelty is a core requirement.
- Fourth, while public and collaborative organisations may often contribute in important ways to these kinds of innovation, whether they are R&D-based or engineering-centred, it is likely that the greatest impact will be achieved by the internal research, development, engineering and design capabilities of firms themselves. This places a premium on intensive accumulation (*i.e.* learning) of the necessary skills and knowledge by firms and within firms.

A major policy challenge is to increase employment, including for the relatively low-skilled, while retaining the dynamism of total factor productivity growth. Science, technology and innovation policy can play an important part in a dual strategy to achieve these objectives.

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

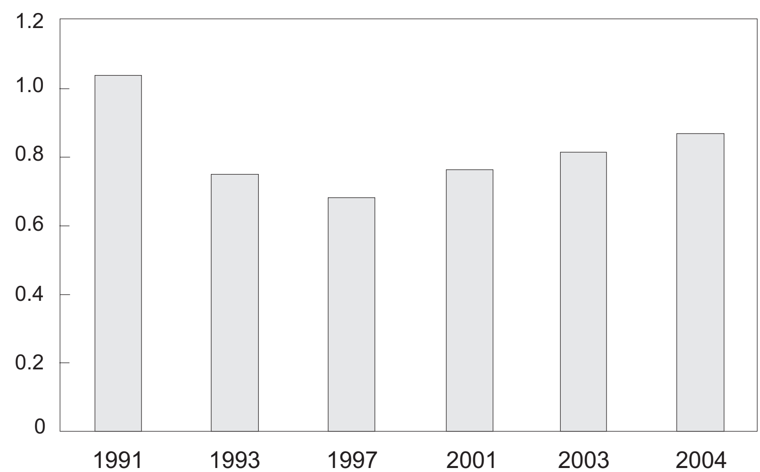
* Or nearest date for which data are available.

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

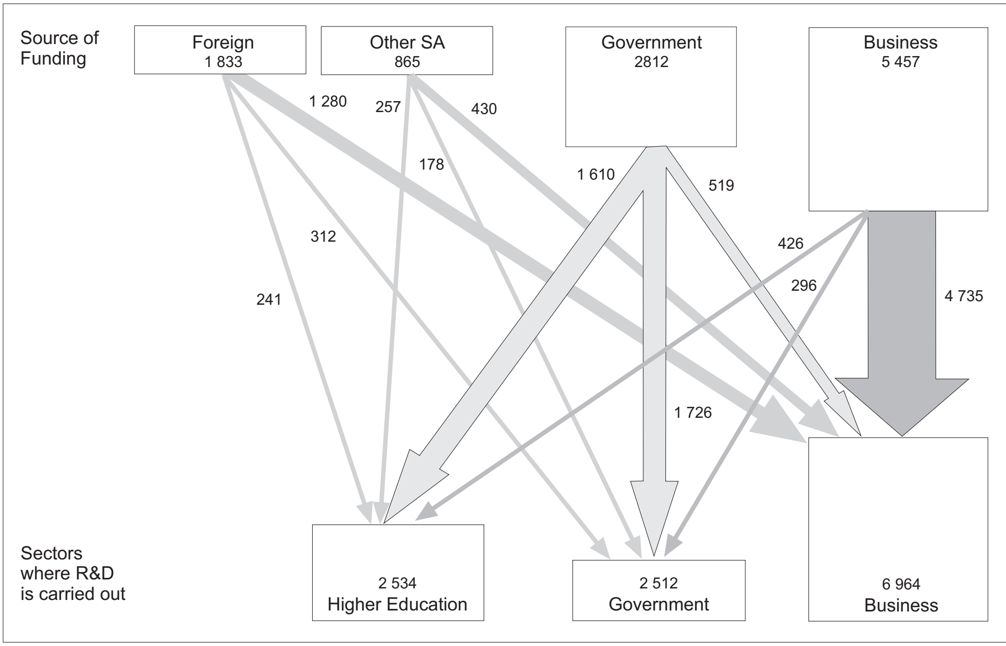


Source: Background report.

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.

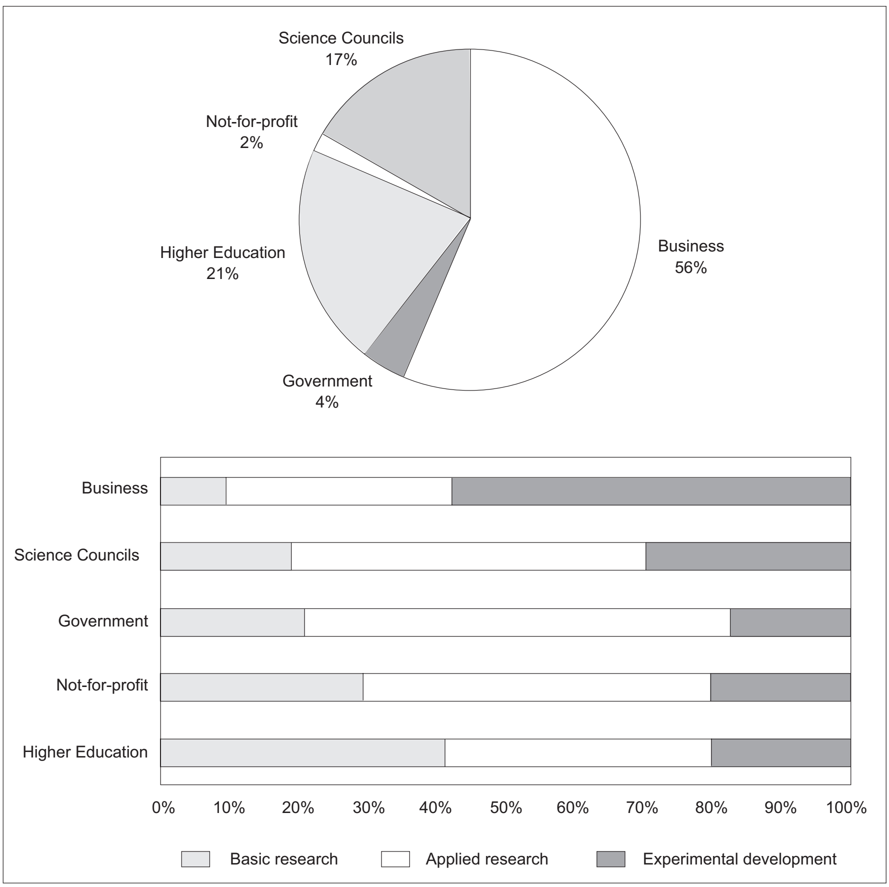
Government funds 33% of South Africa's R&D and performs 21% (Figure 2.2). Insofar as a declining share of government funding is normally taken as an indicator of development, this places South Africa firmly within the OECD funding pattern. The business sector in South Africa funds 45% and performs 58% 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.

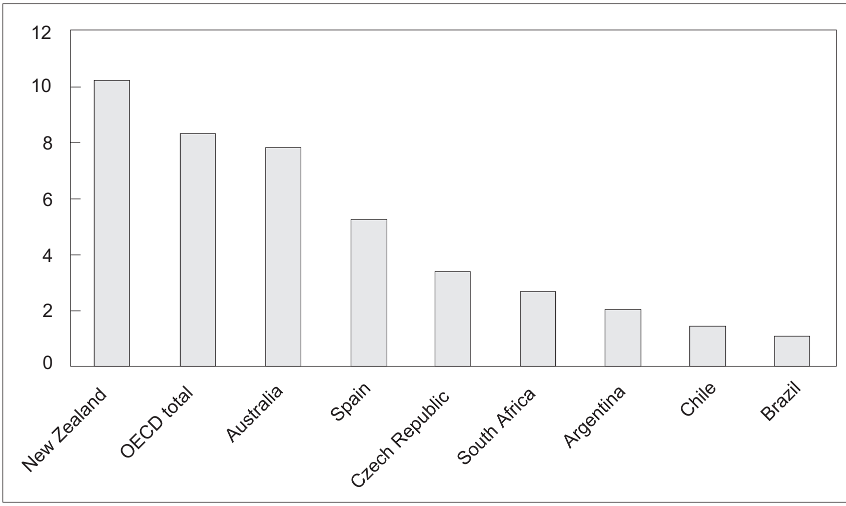
*Includes PhD students.

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.

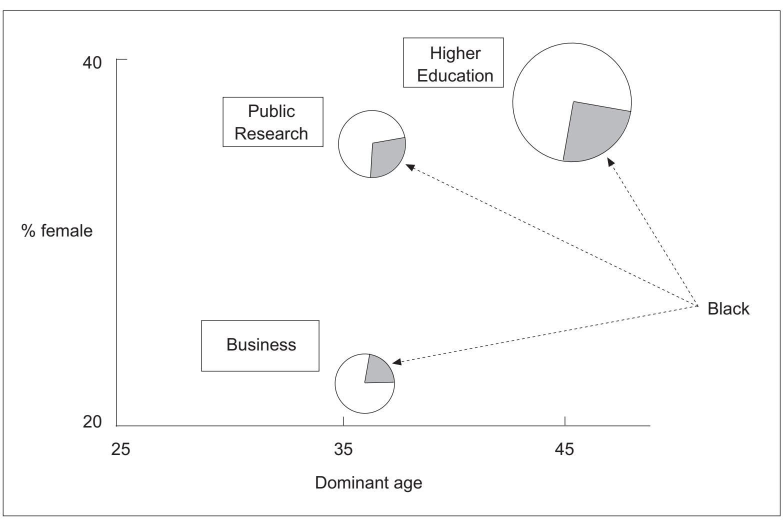
While South Africa's R&D expenditure is fairly high compared with other developing countries, the number of researchers, at 2.7 per thousand employees is low relative to developed countries and some of its peer countries (Figure 2.4), but higher than Chile at 1.4. Very R&D-intensive OECD countries such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

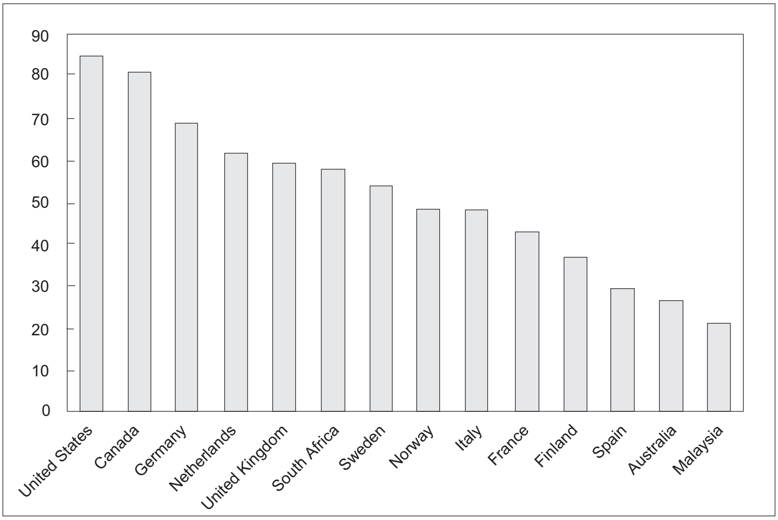
Against this background, the government has made human resource development in science and technology a high priority. Major challenges identified include:

- 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

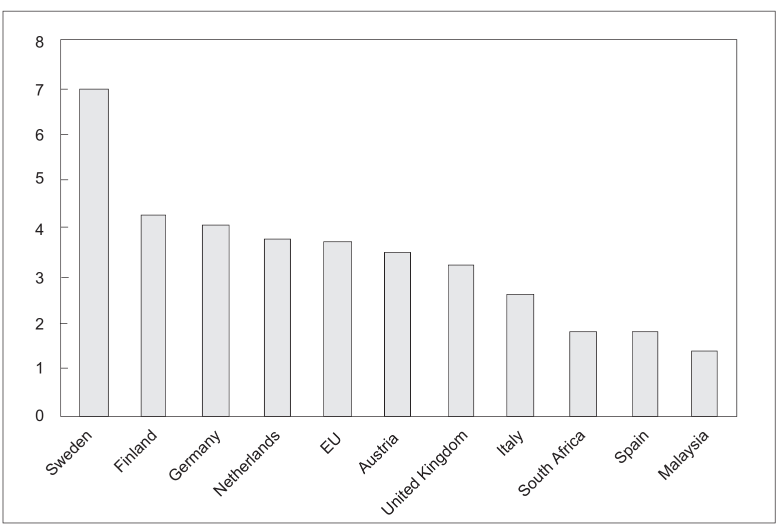
Innovation in industry is much harder to characterise than R&D. The first innovation survey, modelled on the European Union (EU) Community Innovation Survey (CIS), was done in 2001 and covered the period 1998-2000 (Oerlemans *et al*., 2003). Such surveys are in their infancy, and there are significant 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.

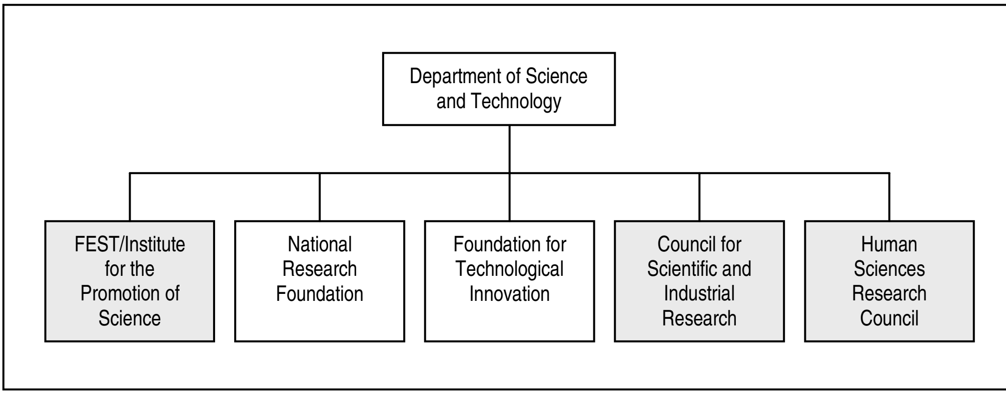
In 2002, the government endorsed the DST's national R&D strategy (DST, 2002) which made some of the institutional and governance proposals of the earlier White Paper more explicit. It identified six key weaknesses in the national innovation system:

- 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



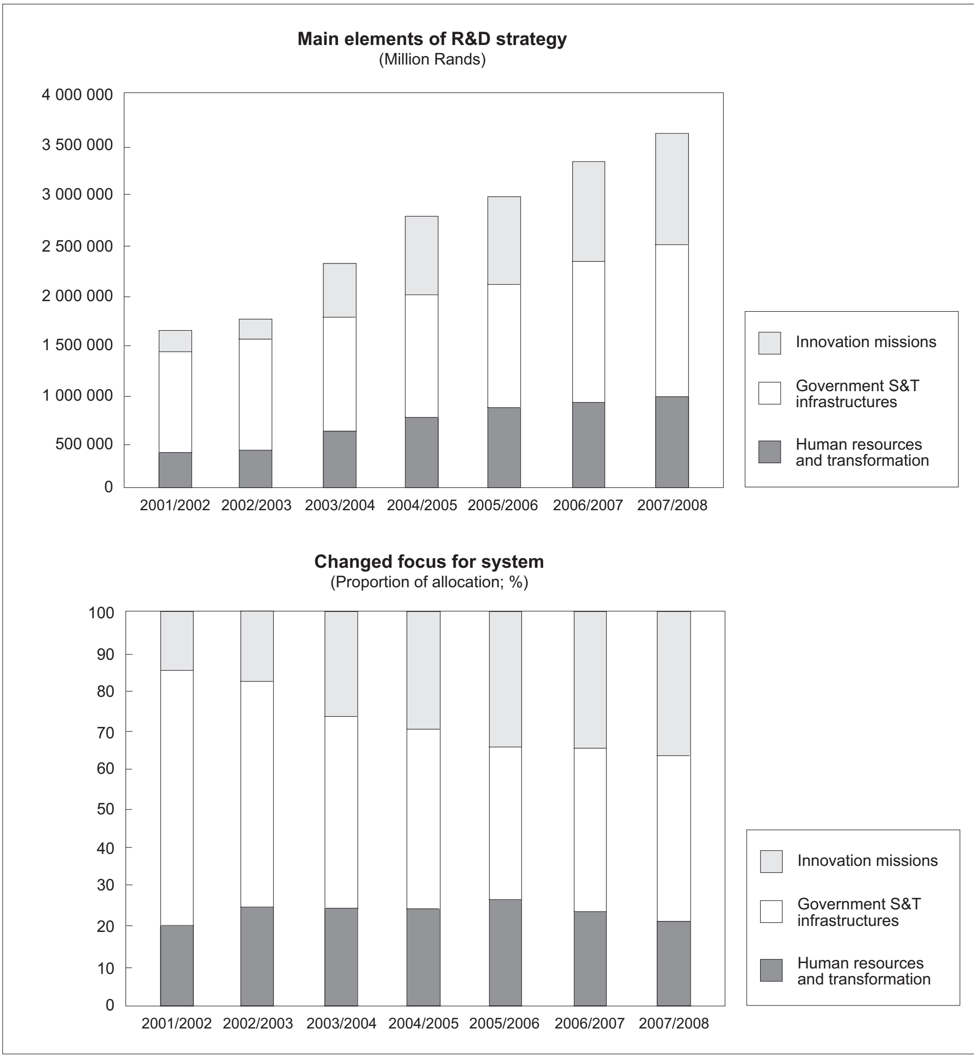
Note: Shaded agencies are research performers. The others are funding organisations.

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

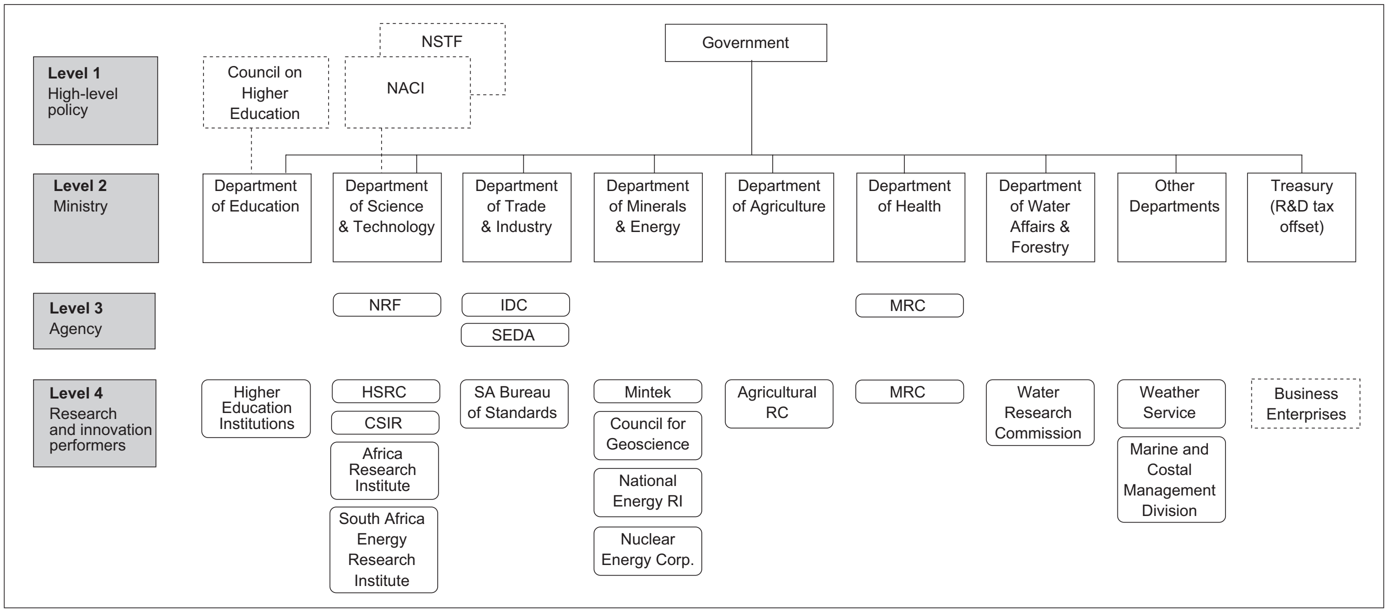
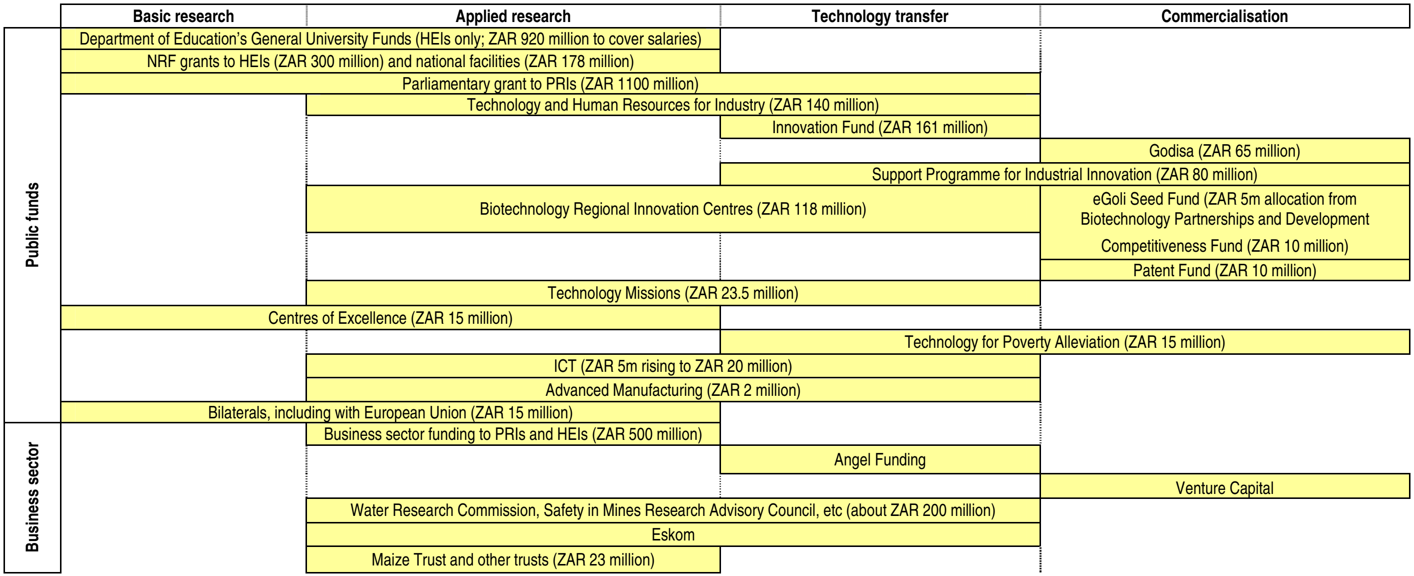


Figure 2.11. Funding for R&D and innovation in South Africa (2003/04)



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.

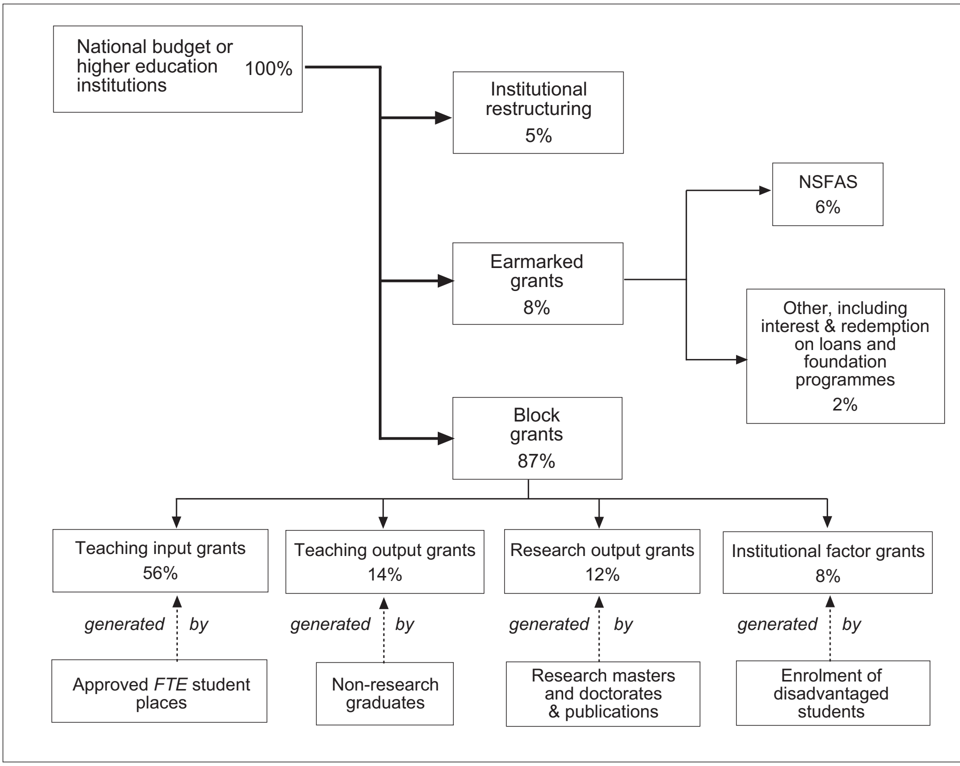
SPII has three sub-schemes, two of which involve grants. One, aimed at larger companies, is based on the idea of co-investment, repayable with interest. Here, SPII aims for a 19% internal rate of return, building the financial capability to recycle funds into new investments over time.

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.

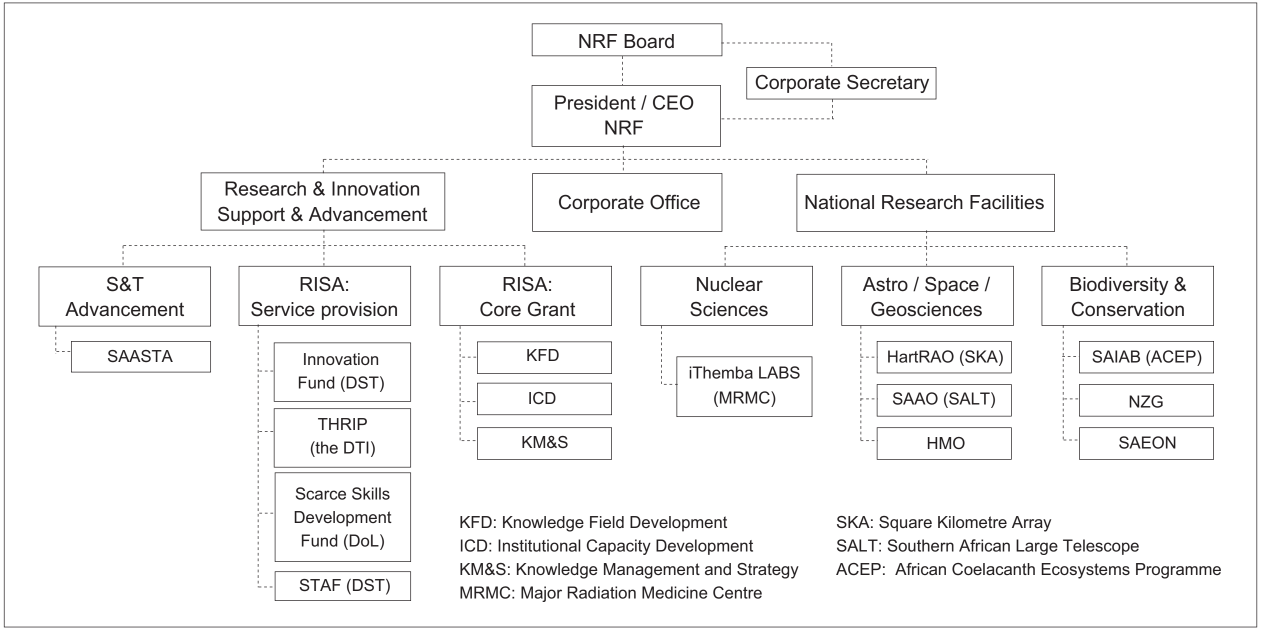
There is a separate category of grants for institutions with a large proportion of disadvantaged students. It is added to the Teaching Input Grant and is based on the proportion of disadvantaged students and the size of the institution, with small universities getting more per disadvantaged student than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

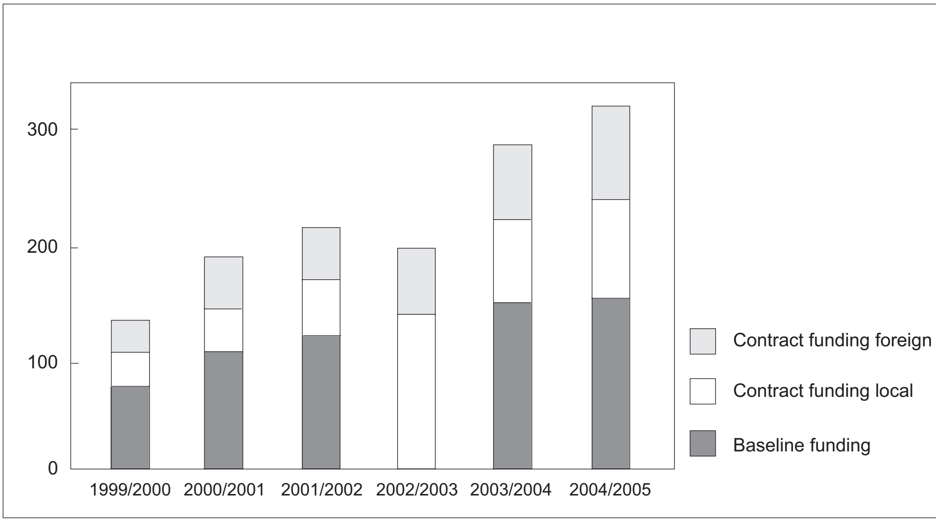
A total of 455 SMEs benefited from the work of the stations in 2004/05, of which 206 received training (DST, Annual Report, 2004/05). Each technology station has a small management element to identify and support companies and to make the necessary links to the university. The direct services to SMEs 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

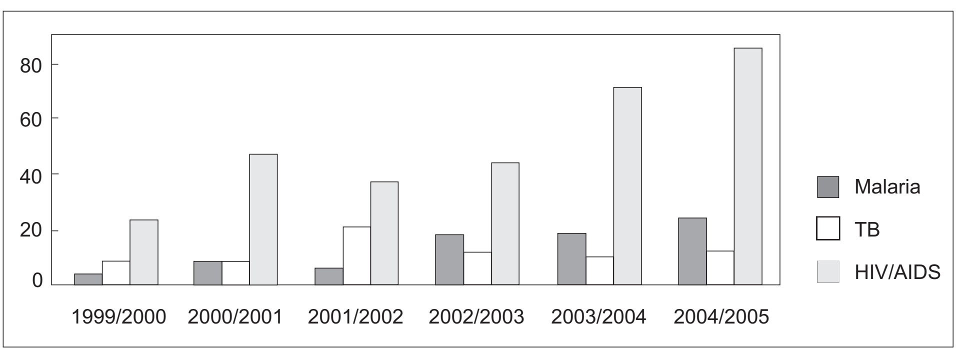
The Medical Research Council (MRC) was established in 1969 as a research facility of the Department of Health. It currently has a staff of 830, revenues of ZAR 335 million (2005) and produces about 600 peer-reviewed journal articles a year and two to five patents. It is the only one of the research councils 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.

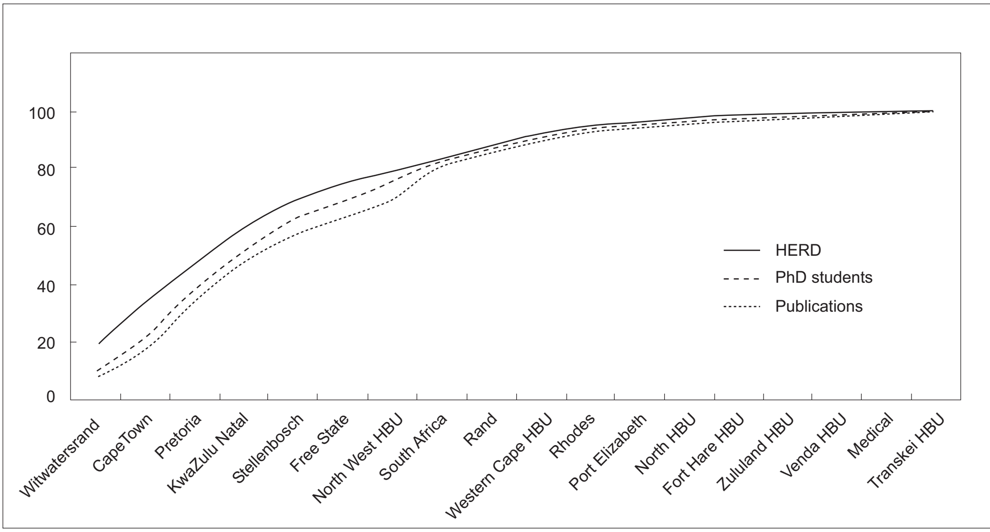
Table 2.13 shows the amount of R&D expenditure, number of publications and PhD students at South African universities. As in most systems, these values are concentrated in a small number of the most successful universities. Figure 2.16 plots the corresponding Pareto curves (cumulated percentage on the 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.

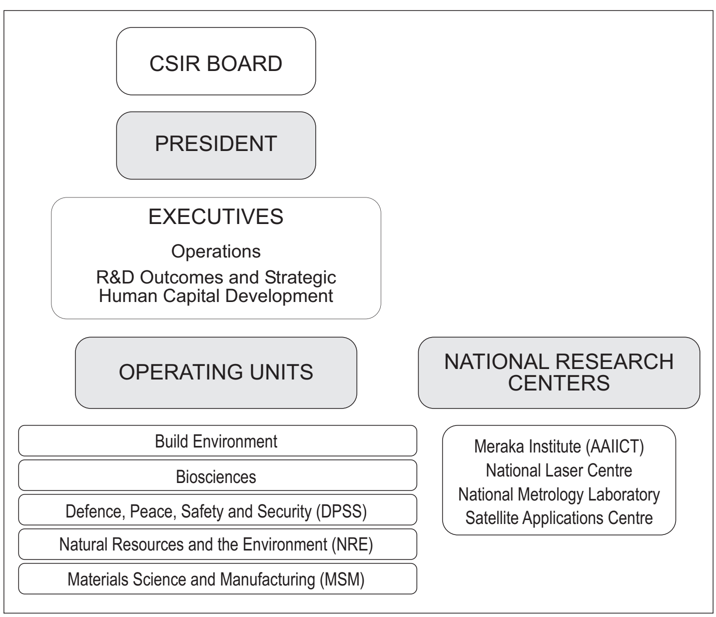
2.4.3. The public research institutes

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%

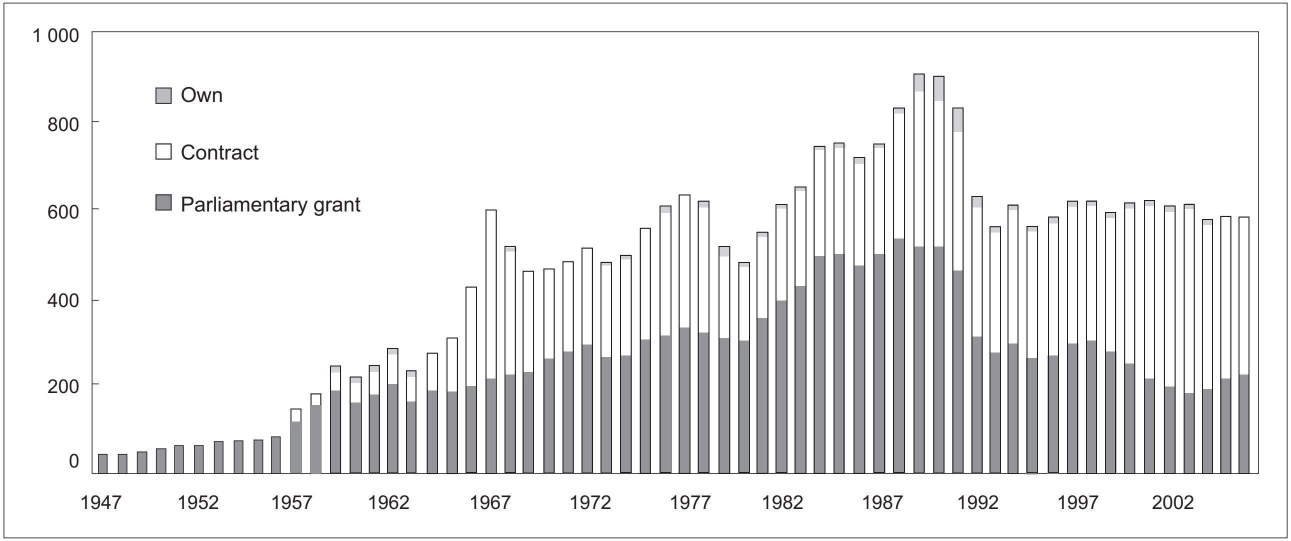
Figure 2.17. CSIR's internal structure, 2006



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.

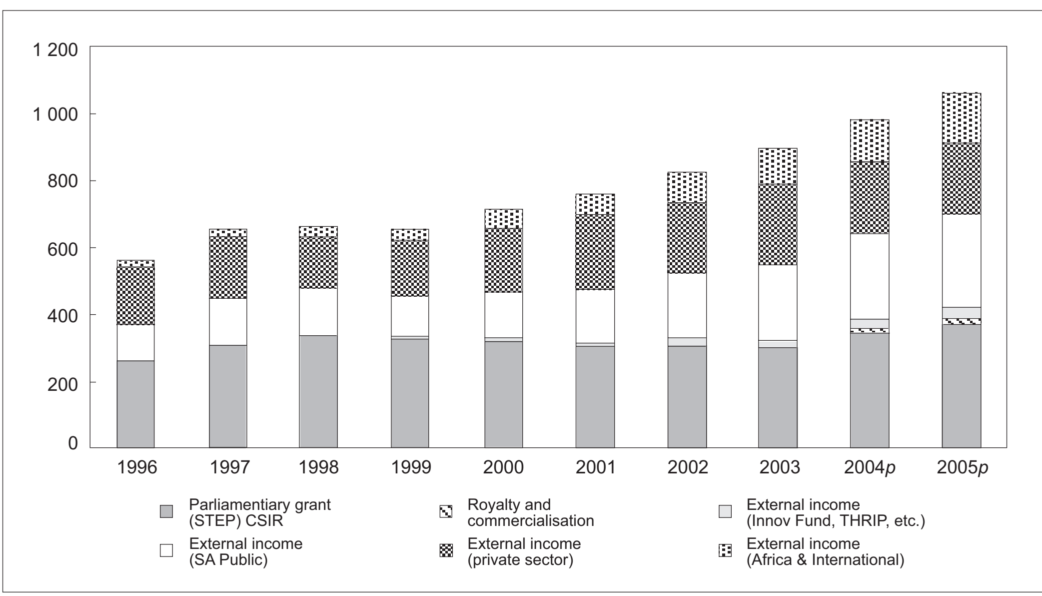
2.4.4. The Council for Scientific and Industrial Research

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.

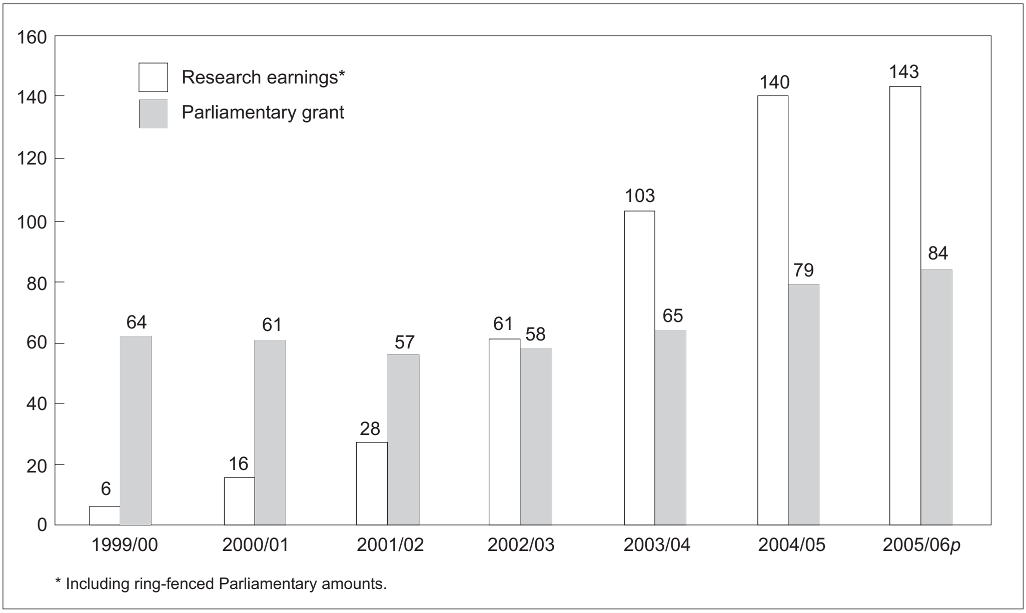
Matrixed across these are "cross-cutting units" for: Capacity Development; Gender and Development; Social Aspects of HIV/AIDS Research Alliance research network; Knowledge Systems; and Policy Analysis.

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.

Chapter 3

BUSINESS ENTERPRISES IN THE INNOVATION SYSTEM

The institutional focus of much policy thinking about innovation systems can easily lead to over-emphasis on the state institutions involved. This seems to have been the case in South Africa, as much description and discussion of the innovation system has focused heavily on components associated with government organisations and activities. Such a perspective downplays, or even ignores, some of the major roles played by business enterprises, not only in turning knowledge into improved livelihoods, higher incomes and delivered public services,[27] but also in generating the knowledge and human capital to undertake those tasks. The well-known shortage of people with strong mathematical and scientific skills entering the higher education system and remaining there long enough to become research and development (R&D) workers affects industry as much as the knowledge infrastructure. Given the large number of non-R&D industrial innovation activities for which such people are needed, industry is arguably even more affected by this shortage. However, while industry suffers from this human resource problem, it is also a key part of the solution.

South Africa's large proportion of business enterprise expenditure on R&D (BERD) in total R&D expenditure is a virtue and reflects industry's ability to build on existing strengths, especially in resource-intensive branches, and to develop bigger clusters of capability, as in the minerals-energy complex. This happens both directly and through various spillovers to the wider economy such as trained and experienced people and spin-out firms. The big companies tend to develop polytechnic capabilities and transfer many of these to their partners in supply chains, not least to small, medium and micro enterprises (SMEs). Maximising the benefits from large companies' presence implies active policies to encourage and exploit their human capital and knowledge development activities, both internally and via

27. Although the focus here is mainly on commercial business enterprises, the broad heading of "business enterprises" should be understood as referring to all kinds of enterprises that produce goods and services. This includes the production of public services, undertaken by state organisations and also increasingly by private enterprises under various types of public-private partnership arrangement.

their links with other companies and the knowledge infrastructure. Rather than devoting too many national resources to jump-start high-technology industries, an important policy thrust should be to build on existing industrial strengths. Partly, this entails deepening engineering and design capabilities, both for absorbing externally generated technological knowledge and for generating internal innovations. Interventions that capture technological learning from and with large firms are important extensions of conventional R&D policy that should have a major effect on South African innovation capabilities.

The main purpose of this chapter is to highlight the importance of the roles of the business enterprise component of the innovation system.

Section 3.1 tackles human resource development, perhaps the issue that will be central to all other aspects of the development of the science, technology and innovation (STI) system over the next decade. There is already a large body of evidence[28] about problems constraining the supply of human resources throughout the education system, the so-called "human capital pipeline" of the innovation system. However, a policy focus on this pipeline, though obviously centrally important, addresses only some of the processes by which human resources for science, technology and innovation are developed. Important other parts are associated with the activities of business enterprises.

Section 3.2 addresses several issues relating to innovation capabilities in enterprises. The central argument is that the effectiveness of the overall innovation system over the next decade will depend on the depth and diversity of innovation capabilities that are accumulated by, and deployed in, business enterprises. Greater emphasis will need to be placed on stimulating and facilitating the development of those innovative capabilities, and part of that entails recognising and reinforcing the important role firms play in creating the human resources at the heart of those capabilities.

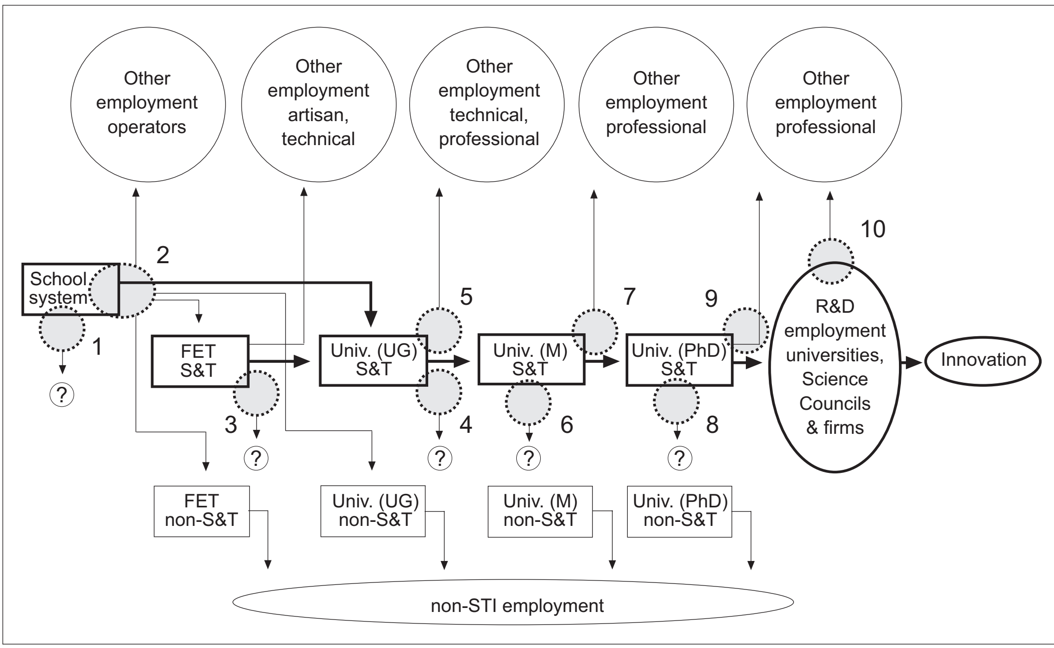
3.1. The human capital pipeline in the innovation system

Much of the discussion about human resources and the development of the national innovation system has centred around the idea of a pipeline running from school education through higher education at undergraduate and postgraduate levels to the employment of scientists and engineers in R&D activities (*e.g.* NACI, 2006, pp. 79-80). Despite achievements over the last decade in reconstructing, re-orienting and expanding what had been a grossly distorted education and training system, there is widespread agree-

28. For extensive reviews see, for example, HSRC (2003) and CHE (2004).

ment that it still falls far short of what is needed. From the perspective of those concerned with the national innovation system, the consequence is simply that far too few people, especially blacks, are reaching the end of the pipeline and engaging in R&D. The flow is below current needs and will probably decline further below future needs unless major changes are made.

Figure 3.1. The human capital pipeline in the innovation system



A large part of the shortfall is associated with relatively low participation rates in higher education. As indicated earlier, both for this and for demographic reasons, the university system needs to expand by up to one-third. However, it is not clear whether these expansion plans can be realised or how this will affect the numbers of people in scientific and technological disciplines and the proportion of those who will actually go all the way through the pipeline and contribute to innovation. The main reasons for this uncertainty can be outlined with reference to Figure 3.1.

- Dropout rates from the school system (at [1] in Figure 3.1) are high for many reasons, mostly associated with poverty and HIV/AIDS, and they may rise further in future.

- The number moving on from school to further/higher education in scientific and technological subjects is relatively low for several reasons [2]: a considerable number of school leavers move directly to employment; not enough, especially blacks, attain adequately high grades in science, technology and maths; a considerable number do move on to further/higher education, but not to scientific and technological subjects.
- Among those who do move on to further/higher education in scientific and technological fields, a considerable proportion drop out ([3] and [4]).
- Among those who graduate with first degrees in scientific and technological subjects, a large proportion move directly to employment rather than to postgraduate training ([5]). This is especially the case among black graduates for whom the opportunity costs of proceeding further are often particularly high, while employers' demand for graduates in order to comply with black economic empowerment (BEE) requirements is also high.
- At postgraduate level, drop-out rates remain high ([6] and [8]), and this is apparently particularly true in the case of black PhD students for reasons that seem to be both economic and "social".
- Among those who graduate at Master's or PhD levels, the numbers who move directly to employment outside R&D are apparently quite high ([7] and [9]). Again the issue of opportunity costs seems important, especially for black graduates. Moving directly to employment outside R&D offers more attractive prospects than proceeding from a Master's degree to doctoral training or from the latter to post-doctoral research.

The end result is that relatively small numbers progress through the pipeline to undertake R&D.

Considerable efforts are being made to address many of these difficulties. For example, with significant financial support from the private sector, a growing number of Dinaledi projects have been established to provide improved school level education in science, technology and maths. It is also striking that a considerable amount of postgraduate student training is associated with projects funded under THRIP and other schemes. However, despite this expansion (for example, quite recently in the number of Dinaledi projects), the overall scale of such initiatives seems quite limited. Also, particular attention needs to be given to the level of financial support for postgraduate students and post-doctoral fellows.

Three other points should be noted about the human capital pipeline perspective on the question of human resources and the national innovation system.

- Almost all the discussion about the pipeline focuses narrowly on R&D as the only activity in which human resources contribute to innovation. A wider perspective that encompasses various kinds of design, engineering and associated management activities suggests that the human resource issue is an even greater priority than when it is viewed solely from an R&D-centred perspective.
- The R&D-centred discussion is frequently narrowed further by concentrating on government bodies and universities as the focal points of the need for human resources. A wider perspective that gives more prominence to the role of R&D in business enterprises would add to the importance that must be attached to the human resources issue.
- Almost all the discussion centres on the pipeline running, as in Figure 3.1, through the education system as the key, or even sole, organisational mechanism for creating the required human capital. A wider perspective would give much greater attention to the role of business enterprises as creators of human capital for innovation and would open up ideas about ways in which that role might be reinforced.

3.2. Innovation capabilities in business enterprises

This section highlights the importance of business enterprises as key actors in the national innovation system in South Africa. Compared with other developing economies, a large proportion of national R&D is undertaken by business enterprises in South Africa. Business enterprise R&D appears to be quite heavily concentrated in the cluster of industries associated with the resource-based segment of the economy and in parts of the services sector, principally those concerned with financial, business and clinical research services.

Large firms appear to be playing roles in the innovation system similar to those played by large firms in technologically dynamic economies: acting as leading accumulators of knowledge resources, diffusing significant fractions of those resources more widely through the economy, especially to smaller firms, and contributing to the long-term evolution of the structure of the economy.

The need to shift the structure of the economy away from its past dependence on resource-based activities is widely debated. Recent studies in South Africa have stressed the need for a dual strategy: one focused explicitly on employment creation, the other on shifting towards more knowledge-intensive production by evolving the economy's existing innovative strengths rather than by trying to leap into supposedly high-technology industries for which the economy has limited strengths.

However, the innovative activity of business enterprises does not only rest on R&D. Various kinds of design, engineering and associated management activities are critically important, and in many firms it is these resources alone that support innovation and are the base from which more formally organised R&D emerges. These capabilities are also the basis for important knowledge-intensive parts of the services sector in which opportunities for growth seem high. However, the "engineering gap" threatens to constrain the scale and efficiency of the planned surge of investment-driven innovation and to limit the rate of the transformation towards a more knowledge-intensive economic structure.

Business enterprises are important as creators of human capital for the innovation system, not simply as employers of human resources. An important locus for the creation of such human resources is in association with imports of technology for large projects and foreign direct investment (FDI).

The following sections therefore raise questions about aspects of innovation policy concerned with: *i)* structural change in the economy; *ii)* the importance of engineering capabilities and engineering-based innovation; *iii)* the role of human resource creation in and by business enterprises; and *iv)* the fuller exploitation of imported technology.

3.2.1. The level and structure of business enterprise R&D

Considerable attention is often given to the ratio of R&D to gross domestic product (GDP) as a key indicator of the development of a country's innovation system, and a target of 1% seems to hold a particular fascination for many middle-income countries, including South Africa. However, even if one focuses only on the R&D component of innovation activity, two other indicators illustrate perhaps more significant features of the evolution of innovation systems in developing/emerging economies.

- Change in the share of total R&D activity that is accounted for by R&D performed by business enterprises (BERD). This share is thought to reflect more realistically than the total scale of R&D the extent to which the R&D-driven component of innovation has become effectively embedded in the economy. The path of change over time runs from a share of around 20% or less in developing countries to one of around 60-75% in the advanced economies, as reflected in the cross-section data for a selected group of countries shown in Table 2.1 in Chapter 2.

- Transformation of the technological structure of production activities in the economy – essentially a change from heavy reliance on resource-based industries towards those that are more technology-intensive or knowledge-based – is often interpreted as being more R&D-intensive (*e.g.* UNIDO, 2002).

Table 3.1. The structure of economic activity and of business enterprise R&D

Sectors (SIC categories)	(A) **Gross value added as % of GDP (2004)**	(B) **Business enterprise R&D as % of all BERD (2004/05)**	(C) **Ratio B/A**
Agriculture, forestry, fishing	3.1	2.7	0.9
Mining and quarrying	7.0	6.3	0.9
All primary industries	10.1	9.0	0.9
Manufacturing	19.1	44.1	2.3
Radio, TV, communication equipment, instruments	0.3	4.2	14.0
Transport equipment	1.8	10.3	5.7
Petroleum, coke, nuclear fuel, chemicals and plastics	4.5	16.6	3.7
Electrical machinery and apparatus	0.5	1.2	2.4
Non-metallic minerals	0.7	1.7	2.4
Metals and metal products	3.9	6.3	1.6
All other manufacturing	7.5	3.8	0.5
Electricity, gas and water	2.4	4.0	1.7
Construction	2.3	7.1	3.1
All secondary industries	23.8	55.2	2.3
Wholesale and retail trade	15.1	0.3	0.01
Transport, storage and communication	10.8	4.8	0.4
Finance, insurance, real estate and business services	21.5	28.3	1.3
Government and personal services	19.5	2.4	0.1
All tertiary industries	66.9	35.5	0.5
Total	100	100	1.0

Sources: For (A) Statistics South Africa (2005b); for (B) CeSTII (2006).

These two kinds of change are commonly linked. South Africa, however, demonstrates an unusual combination of these characteristics. A relatively high share of BERD in total R&D is combined with a heavily resource-based economy.

The share of BERD in total R&D seems to have risen through the 1980s and 1990s (Kaplan, 2004), and it has continued to rise over the last five years to reach 56% in 2004/05 (CeSTII, 2006).[29] One consequence of this trend is that the proportion of gross domestic expenditure on R&D (GERD) performed by business enterprises in South Africa is broadly similar to, or a little higher than, in several other countries with much higher GERD/GDP ratios such as Spain, New Zealand, Norway, the Netherlands and Canada. It is also around 1.6 to 2.0 times higher than the levels in countries with lower GERD/GDP ratios, including some with substantially higher levels of GDP per capita such as Portugal or Greece.

In other words, the high BERD/GERD ratio is a significant strength of the South African innovation system and a point that merits emphasis because the achievement seems to have been insufficiently recognised in the STI policy community.[30]

The fact that the economy has remained heavily dependent on resource-based industries is not immediately obvious. The combined value added of the primary resource-based industries (agriculture, fishing and forestry plus mining and quarrying) accounted for only about 10% of GDP in 2004 (Table 3.1, column A). In contrast, manufacturing and other secondary industries accounted for 24%, more than twice that share.

That is misleading, however, because of the strong interconnections between the narrowly defined primary industries and other segments of the economy. For example, the minerals-energy complex (MEC) spreads far beyond its core in mining *per se* (Fine and Rustomjee, 1996). It accounts for large parts of manufacturing: the coal-based petroleum industry and its closely associated chemical manufacturing, the basic and downstream processing of metallic minerals, the production of plant, machinery and transport equipment for these industries, the mainly coal-based electricity supply system, and the large share of construction industry output that they

29. The more recent increase may reflect in part an improvement in data capture.

30. For example, the National Strategy for R&D suggested in 2002 that private-sector R&D had been falling in the previous four years. Private-sector R&D and business enterprise R&D are not the same thing and, perhaps because of changes in R&D survey arrangements during the 1990s, one or both may have appeared to be falling in the late 1990s. The most recent R&D survey data for 2004/05 (CeSTII, 2006) seems both very soundly based and is much more optimistic about BERD.

use. all of which are industries with above-average R&D intensity (Table 3.1, column C). Beyond that, the MEC reaches into important parts of the services sector, for example to large parts of the transport sector which is needed to convey the large quantities of materials which the complex produces, uses and exports, as well as engineering and consulting companies that supply design, engineering and project management services for the system. Alongside the MEC other strongly resource-based value chains are important such as the large sugar industry and other agro-food industries, as well as the world-scale brewing and forestry-based pulp and paper industries.

It has not been possible to identify any analysis that has tracked the corresponding complex of business enterprise R&D associated with the pervasive economic activities of the resource-based segment of the economy. However, our guess is that it is substantial, accounting for very much more than the 9% of BERD that is directly associated with the primary resource-based industries (Table 3.1, column B).

In these respects, South Africa has managed to create a form of resource-based economy that is very different from what is found in many other countries. Three differences are striking: the structure of resource-based production is much more deeply embedded in the economy, the intensity of associated R&D is relatively high, and the development of that segment of the economy has been driven largely by major corporations that were mainly locally based and owned. In other words, the South African resource-based economy appears to have more in common with earlier stages of the Scandinavian model of resource-intensive industrialisation than with Latin American and especially other African models.

Table 3.1 also indicates that another area of R&D strength in the economy is in the services sector, in particular financial services and business services. The broad category, which also includes clinical research services, accounts for about one-fifth of GDP and for 28% of BERD. However, it is relevant to note here again that a significant component of the knowledge-intensive business services industry consists of companies supplying design, engineering and management services to the resource-based industries.

3.2.2. The role of large firms in the innovation system

For many decades economic activity in South Africa was highly concentrated and controlled by a small number of large enterprises. That degree of concentration has since declined. Nevertheless, a considerable body of opinion considers the present level of concentration excessive because it is a source of several problems. Most prominently, the restricted degree of competition is seen as leading to socially inefficient pricing behaviour, in particular the practice of import parity pricing.[31]

However, it is also important to consider another, more positive aspect of the role of large firms in the development of the economy – their role in the innovation system. In doing so, one must distinguish between creating and accumulating knowledge resources for innovation (*e.g.* by training, research, technological development, and acquisition of experience), and using and applying these knowledge resources in production (*e.g.* in starting, operating or improving production activities).

Small, medium and micro enterprises play an enormously important role in using and applying knowledge resources in production. In all economies they provide employment for a large proportion of the workforce. Numerous studies have demonstrated that this is especially the case in South Africa (*e.g.* DTI, 2004), and that it is critically important in the second economy both for semi-employment in the informal urban economy and for forms of employment that sustain rural livelihoods. Not surprisingly, therefore, support for the development of the SME sector has been a major thread running through several areas of public policy at national and provincial levels, including several areas of policy concerned with science, technology and innovation.

Here, however, the focus is on the creation and accumulation of knowledge resources. Large firms have been particularly effective in this respect in a wide range of industrial development contexts.[32] They are particularly well placed to accumulate knowledge resources, to invest in training and to achieve effective scale in implementation. Their scale also increases their incentives to undertake such activities, since it typically enables them to capture a relatively larger fraction of the benefits. For example, the expected returns to investment in training process design engineers depends on how frequently the firm's future projects will draw on design engineering skills, and large firms can usually expect much greater use of them than smaller firms. This was strikingly illustrated, for instance, in the intensive efforts of large Korean firms in the 1960s and 1970s to

31 Import parity pricing is the pricing of locally produced materials at the level of prices of their imported equivalents, which are almost invariably higher than the marginal costs of locally produced products. This is considered an important obstacle to the diversification of production downstream from several resource-based industries.

32 These include the United States in the 19th century, Germany through the same period and into the 20th century, and Japan in the mid-20th century (Chandler *et al.*, 1997), as well as Korea, Singapore and, contrary to common perceptions, Chinese Taipei since the mid-20th century (Amsden and Chu, 2003).

acquire and accumulate engineering capabilities for use in a rapid succession of investment projects.

A recent study of manufacturing firms in South Africa's Ekurhuleni district found that, compared with small firms: "Large and medium firms were much more likely to train, and more likely to use outside training providers." They were also much more likely to make use of the recently established levy-grant mechanism to support firms' training: "Ninety percent of large firms claimed the levy, compared with 61% of medium, 27% of small and just 8% of micro firms." (Machaka and Roberts, 2006)

In both developed and developing economies large firms are also the major players in accumulating knowledge resources through R&D. Drawing on the latest R&D survey, Kahn (2006) has indicated that large firms account for a high proportion of BERD: the top 12 R&D performing firms account for 58%, and the top quintile for 86%.

A significant number of these firms are parts of the economy's resource-based nexus. However, it would be misleading to presume that their R&D activity is narrowly focused on the technologies at the heart of their respective resource-based industries. Large corporations are typically multi-technological in their R&D and inventive activities. They develop knowledge bases across a much wider range of technologies than those directly involved in their core production activities. They do so primarily to support the management of their key supply chain interfaces, and consequently this extended knowledge base is associated with the technologies of related industries: those from which large firms buy inputs of materials, components, assemblies, engineering and other knowledge-intensive services, and capital equipment, and also those to which they sell, or might sell, their products (Patel and Pavitt, 1997; Granstrand *et al.*, 1997; Brusoni *et al.*, 2001).

Apart from serving the immediate interests of individual firms, this multi-technological capability plays two extremely important and wider roles in the economy. First, it provides part of the basis for inter-firm interaction in innovation, such as the user-producer interaction that provides a platform for networked innovation activities along value chains. Second, it provides a basis for diversification of the firm's own production activities. In other words, the multi-technological knowledge bases in large firms play a large role in the dynamic evolution of production by interconnected firms across industries; they do not merely support the existing production of individual firms in individual industries. The dynamic role played by the technological capabilities of large firms appears to have been important, for instance, in the emergence of diversified structures of production around resource-based industries in countries like Finland and Sweden, and in the evolution of individual firms into different industries.

There is, of course, nothing fixed and inevitable about this. In particular, the diversity of the knowledge bases of large firms varies across industries and in different economic contexts, as does the extent to which those knowledge bases actually contribute to the broader evolution of local economies. The lack of information makes it difficult to assess these issues in South Africa. However, two sets of information may be noted.

First, data on general global patterns indicates that large firms in industries in which South Africa has a strong presence have significantly diversified, multi-technology knowledge bases. Table 3.2 indicates the degree to which the world's largest firms have patented inventions in technological fields outside the core fields of their own industries. Firms in the metals, mining and petroleum and paper industries have an above-average propensity to patent in non-core fields, and those in the chemicals industry are very close to the average (column C). Also, firms in the aerospace, materials and machinery industries, where South Africa has a potential or emerging innovative presence, also have an above-average proportion of their patents in fields outside the core fields of their industries (column B). An important feature of these non-core knowledge bases of firms is that they include substantial segments relating to generic technologies such as information and communication technologies.

Table 3.2. The technological diversification of the world's large firms

The proportion of firms' patents outside their core fields of technology, by industries, %
(the world's 500 largest firms – 1991-96)

(A) Industries with limited or no business enterprise innovative presence in South Africa		**(B) Industries with potential or emerging business enterprise innovative presence in South Africa**		**(C) Industries with strong business enterprise innovative presence in South Africa**	
Photography/photocopy	65	Aerospace	74	Metals	66
Motor vehicles and parts	64	Materials	69	Mining and petroleum	58
		Machinery	62	Paper	57
Across industry average (48)					
		Rubber and plastics	45	Chemicals	47
				Food, drink and tobacco	43
Electrical/electronics	39				
Pharmaceuticals	30				
Computers	25				

Source: Mendonca (2006).

Second, anecdotal information suggests that these patterns occur in South Africa. Mining companies, for instance, undertake R&D in a wide range of technological areas. In the past at least, this has given rise to one of the most striking high-technology South African businesses: Lodox Systems (Altman, 2007). The company has broken into advanced country markets with full-body radiography equipment for health-care applications. The technology originated in, and was spun out from, the De Beers diamond mining company where it had been developed to screen personnel to prevent theft of diamonds secreted in the body. Large companies in financial and retail services also undertake a wide range of ICT-related R&D, and it is interesting to note that the first anchor tenant on the Innovation Hub science park in Pretoria is the large South African paper company, Sappi, which has established one of its major technology centres there to pursue technology development in a range of directions.

Finally, beyond training and R&D, large firms are typically very effective accumulators of experience, a rarely discussed but critically important form of knowledge for innovation. They are usually better able than smaller firms to invest explicitly in experience-accumulation activities, *e.g.* by secondment of engineering and management personnel to other organisations where they can acquire it, and also by actively managing the rotation of personnel through successions of experience-enhancing activities and projects.

There is, however, another side to this story of intra-corporate accumulation of knowledge-resources via training, R&D and experience acquisition. Large firms rarely appropriate the full returns from their investments in accumulating knowledge resources, and large fractions of these resources typically leak into the rest of the economy. They flow to suppliers and customers and also more widely through a variety of channels, among which the movement of highly skilled people is often particularly important. In effect, as well as being important accumulators of knowledge resources, large firms also act as substantial diffusers of those resources into their economic environments.

An important part of this knowledge-diffusing role is concerned with SMEs because large firms frequently act as sources of knowledge for the smaller firms that are their suppliers and customers, and as sources of knowledge assets for the establishment of new small firms (spin-outs). This last role runs counter to the more common emphasis on small firms as knowledge creators in the modern economy. It is indeed the case that in recent years the organisation of innovation in advanced economies has shifted, such that, in some industries and some areas of technology, small firms have come to play a larger role in more organisationally distributed forms of innovation. Even here, however, large firms, and not just the more commonly discussed spin-offs from universities and other public research organisations, play an important role in the emergence of new small firms. They do so both deliberately via relatively formal spin-off arrangements, but also passively or involuntarily as people leave larger firms, taking with them their accumulated know-how and experience to set up new small firms.

These kinds of knowledge dispersal from larger firms to smaller start-ups seem also to be occurring in South Africa. For instance, in the Innovation Hub in Pretoria, most of the 50 tenant companies have their origin in some form of spin-out from other, usually fairly large, businesses, not from the nearby universities or research institutes. Sasol has established a joint venture with an American firm to enable it to pursue its downstream diversification in the chemicals industry. The joint venture company, Merisol, established research centres at the Port Elizabeth Technikon and the University of Cape Town to help extend the range of applications of phenols. Alongside the knowledge accumulated for the company's internal purposes, the research network has led to the spin-off of parallel technologies for commercialisation by smaller companies, including Gradchem Solutions, a small company set up in 1999 by engineers who were previously employed by Sasol (Godfrey, 2006).

Large firms disperse knowledge both as more or less steady trickles over time and as phases concentrated around major changes in the economic environment of enterprises. The latter type was important in South Africa during the second half of the 1990s. Over the previous two or three decades, large companies accumulated considerable in-house stocks of technological capability to support the execution of innovation and investment activities. For example, the mining houses undertook substantial in-house and collaborative R&D and also developed large pools of in-house engineering expertise. However, as the economy opened to international markets in the mid-1990s, they faced pressures to specialise in their core competencies and to outsource other activities to specialised suppliers. They massively reduced their in-house technological capabilities. However, these capabilities did not evaporate; nor did all of them emigrate to Western Australia and other hubs of knowledge-intensive services that supply the global mining industry. Instead, a large proportion was spread throughout the economy to create and strengthen a range of South African engineering service firms (Segal and Malherbe, 2000). Similar dispersions of large firms' knowledge assets also took place in other areas (see Box 3.2).

To sum up, this report argues that the activities of large firms in creating, accumulating and dispersing knowledge, perhaps especially in industrialising economies, play critically important roles as vehicles for building up knowledge capital for innovation across wide areas of the economy in which they are embedded.

However, this picture of the positive role of large firms in the development of national innovation systems does not imply that such a role will automatically arise from the mere existence of large firms. On the contrary, their existence creates only the basis for a potential role, and the extent to which it has been played in industrialising economies has been shaped by very specific institutional factors. The literature about development in East Asia highlights the significance of some of these: particular types of social contract between the state and private business, particular forms of relationship between the policy bureaucracy and private enterprise, particular forms of state-facilitated collaboration among firms, and specific forms of relationship between public and private technological organisations.

In South Africa also, it was a specific configuration of such institutional arrangements that shaped the strong knowledge-accumulating role of large firms in the apartheid era. As yet, however, only a beginning has been made in building a new set of institutional relationships that would provide a context in which business enterprises, especially large ones, can be induced to intensify their accumulation and particularly their dispersion of knowledge assets within the national innovation system. Moreover, possibilities for proceeding further seem to be constrained by views of large firms' innovation activities as homogeneous and entirely focused on serving their private interests. This may be too narrow. In particular, when the knowledge dispersion dimension of their activities is combined with their own diversification activities, it may contribute to the kinds of dynamic evolution of the structure of the economy that are widely recognised as being in the public interest. The challenge for policy is to distinguish between the private and (potentially) social forms of innovative activity, and to find ways of encouraging firms to extend the latter.

3.2.3. Design and engineering in innovation

Design, engineering, entrepreneurial and management capabilities play a significant role in the innovation system (Box 3.1). Broadly, the services provided by these capabilities are organised in three ways in innovation systems.

Box 3.1. The role of design, engineering, entrepreneurial and management capabilities in the innovation system

The activity at the heart of almost all innovation is the creation of a set of specifications (or designs) of the change to be made. These may consist of complex designs in computer-aided design facilities. They may be drawn in the dust on a workshop floor. They may also consist of specifications for procedures and organisational arrangements.

For modern types of technology, the creators of these designs and specifications are various kinds of engineer, such as a university-educated graduate working in a software design office. But the creators of some kinds of designs and specifications may be quite different, for example a farmer designing the planting configuration for crops on a small holding. Other actors may identify the needs or opportunities for innovation for which the designers and engineers provide the specifications. Entrepreneurs play that important role, but again a broad view of who they are is necessary. They may be the classic entrepreneurial individual who creates a small firm, an engineer or manager in a manufacturing company who identifies a local market opportunity to exploit a well-established technology or a provincial official who exploits an opportunity to bring simple technology and financial resources together to create new rural health clinics.

Even for quite simple innovations, various actors may have to be co-ordinated and scheduled in order to integrate the various inputs needed for innovation. Hence managers are often involved, and again these may span a wide spectrum.

The design, engineering, entrepreneurial and management (DEEM) actors play three key roles in innovation systems. First, they generate the specifications for changes in the production of goods and services by drawing on existing knowledge without any direct input from R&D. For example, engineers designing the plans for exploiting new mines draw on available design principles, methods and data, and they apply these, plus their experience, to the varying requirements of different mining situations, introducing advances and improvements over previous plans as part of the practice of engineering.

Second, and probably much less often, DEEM activities take place on the basis of recently developed knowledge, perhaps created by their own (R&)D, perhaps licensed from more distant R&D performers, or possibly drawn from immediately preceding and closely located R&D. In these roles they contribute to the process of translating knowledge outputs from R&D into the concrete realities of implemented innovation.

Third, in addition to these two kinds of supply-side role, they play an equally important role running in the other direction: from the production of goods and services to the execution of R&D. When their existing knowledge base is inadequate to meet the demand for innovation, they actively call on R&D to supply new knowledge. Moreover this is not a vague demand for innovation in general. Instead, design, engineering, entrepreneurial and management activities serve to concretise specific technical configurations or performance requirements that help to shape the process of technological development.

Vertical integration within business enterprises. This involves locating these capabilities within the business enterprises that use the services they provide. For example, manufacturing firms employ their own product design engineers or process development engineers rather than buy in design and engineering services. The emergence and roles of such vertically integrated design and engineering activities is well illustrated by the case of Multotec Process Equipment, a machinery supplier to the mining industry in South Africa (Box 3.2).[33] It illustrates how innovative activity typically develops in business enterprises in industrialising economies, It frequently starts with quite minor forms of innovation based on in-house design and engineering, and gradually deepens to encompass types of innovative activity based on R&D. In other words, design, engineering and related capabilities constitute a seedbed for the later development of more formally structured R&D-based innovation. In Multotec the in-house design, engineering and related resources played three key roles: they generated innovation in their own right, they acted as the link forward between knowledge from R&D and the implementation of continuous innovation, and they linked backwards demand for innovation and new knowledge from the market to suppliers of new knowledge, either inside or outside the firm.

Vertical integration within government providers of public services. Government departments and agencies at national and local levels also employ their own in-house design and engineering capabilities to support the provision of public services across public health, transport, defence, security, and so forth. They do so primarily to contribute to the existing provision of those services, and increasingly to manage the process of contracting specialised suppliers for inputs to service provision. These capabilities play roles similar to those in business enterprises: they implement innovations in their own right; link new or existing knowledge to innovation; and articulate demands for innovation from identified needs in their markets back to suppliers of more R&D-intensive sources of knowledge and innovation.

33. In industrialising economies, a very large part of the diversification of production into new kinds of industry draws on existing stocks of knowledge that are engineered into the specific configurations of products and processes for particular markets and environments. Structural change in such economies depends much more heavily on engineering than on R&D. Consequently, for example, a very large part of the diversification of production by large Korean firms drew on design, engineering and related project implementation capabilities (Amsden, 2001).

Box 3.2. Deepening innovation capabilities in manufacturing

The intensification of innovation at Multotec Process Equipment (MPE)

From engineering-based problem solving to product technology development

MPE, a Johannesburg firm employing about 75 people, manufactures machinery for the mining industry: cyclones and spirals for the separation of materials mostly for use in mining gold, platinum, diamonds and coal, although some are used in chemicals and there are potential applications in areas such as foodstuffs. They rate themselves the second largest supplier of heavy mineral spirals in the world and the largest supplier of coal spirals. Total turnover grew by about 60% between 1999 and 2004. The firm dominates the local market, and exports mainly to Australia, Russia and Norway have developed gradually, aided by the internationalisation of the South African mining industry, and account for approximately 30% of output. The company is part of a larger group, with majority ownership held by a German firm employing 700 people worldwide. The manufacture of its products does not require advanced manufacturing capabilities, but since the mid-1990s the cyclone division has engaged in a series of incremental product developments as well as more radical redesigns. This stream of innovation requires a combination of advanced computer modelling (computational fluid dynamics) together with experimentation and testing of the different designs. The firm's innovation-centred strategy contrasts with that of competitors which, producing under licence or as local subsidiaries of international firms, have a fixed range of products and do not undertake the same level of in-house design and development.

Demand-side pull factors underpinned the early evolution of innovative activities in MPE, in particular the specific demands of South African mines. Historically the firm's senior managers did not see themselves as pursuing an R&D-centred strategy. Instead, in the 1990s they decided to provide a strong service function to customers. This required an engineering capability to provide support and problem-solving, and this led the firm to a stream of incremental innovations to meet specific customer needs. MPE emerged as the leader in making innovative products to order rather than off-the-shelf products. To maintain the firm's market position, innovation became increasingly integral to the business. Only through continuous improvements could MPE stay ahead of local and international firms that sought to copy its products. At the same time, this path of continuous innovation was critical in supporting increasingly export-intensive growth.

Supply-side "push" influences reinforced this process. Some were internal to the firm: it progressively built up a team of in-house design engineers to support its service support strategy. They were able to develop an extremely experienced engineering team unusually rapidly in the late 1990s because of retrenchments in the big upstream industries. Recruitment included, for example, the lead process engineer who until 1994 had been head of Iscor's research and development. With this strong base of human capital, the team was rapidly able to move forward with development and design improvements. Building on this emerging R&D, the company reached back into the innovation system to interact with universities and to collaborate with the Council for Scientific and Industrial Research (CSIR) in fluid dynamics modelling. In 2003 supply-side capability was reinforced by the acquisition of a full-scale test rig that was essential for testing innovative prototypes. This enabled MPE to deepen its innovative activity by developing a new generation of more efficient cyclones. The company also reports that its innovative capability has been supported by the existence in South Africa of computing power, mainly the skills and capabilities of people employed in modelling and product design, which was both readily available and cheap. …/…

Box 3.2. Deepening innovation capabilities in manufacturing *(continued)*

By 2004 MPE had moved through several types of learning. One was the recognition that innovation in general, and R&D in particular, were key drivers of the firm's commercial success. Until recently MPE did not identify R&D as a separate function and had no R&D section. Even in 2004, the firm identified R&D expenditure as only about 1.5% of turnover. Yet it employed seven qualified process engineers, and several design and engineering activities were not accounted as R&D, including ongoing product development and customisation. The scale of the full range of innovative activity rooted in design and engineering was clearly much larger than the formal R&D. The firm had evidently entered the knowledge-intensive part of South Africa's manufacturing industry.

Source: Adapted from original research reported in Roberts (2004).

Specialised knowledge-intensive service suppliers. The capabilities for design, engineering and related activities may be organised in specialised supplier organisations: design and architectural consultancies, engineering service suppliers, project management and procurement contractors, suppliers of medical testing and trials services, and so forth.

Across all kinds of economies, the relative importance of these externalised modes of organising design, engineering and related service activities has increased significantly over the last two or three decades, while in-house, vertically integrated forms of organisation have sharply diminished in scale. Specialised suppliers of design, engineering and related management services constitute a rapidly growing component of the knowledge-intensive business services (KIBS) sector.

One consequence of this global change has been that organisationally dispersed forms of *innovation* processes, and not just dispersed forms of *production* processes, have become much more common. By extending well beyond innovation-centred interaction between suppliers and customers in value chains, innovation has become a more dispersed and networked process, with specialised suppliers of various kinds of innovation-generating services often linked together in highly complex webs. This has happened, for instance, in pharmaceuticals, where large companies no longer execute the full range of activities from basic research to product marketing, but rely on a host of knowledge-creating organisations to supply specialised inputs to innovation. Similarly, in the automotive industry, substantial parts of R&D and innovation have moved upstream in the supply chain as vehicle manufacturers have adopted the principle of "co-makership" with the first-tier suppliers that essentially design and deliver sub-systems to them. The same kind of organisational dispersal of innovation has taken place in the resource-intensive industries that are especially important in South Africa.

These trends have various implications for the development of national innovation systems in industrialising economies, one of which seems well recognised in South Africa: the need to foster innovation that is implemented via networks as well as in individual firms (*e.g.* Kruss, 2006). Two other implications may be important for South Africa as well: the existence of opportunities to exploit specialised segments of globally dispersed innovation; and the intensified importance of accumulating design, engineering and related capabilities within user firms.

3.2.3.1. Opportunities in specialised segments of globally dispersed innovation

In recent years, many kinds of business processes have been vertically disintegrated, with some elements outsourced internationally to locations with lower-cost supply capabilities. This has provided opportunities for countries with low-cost, adequately skilled labour to capture segments of the market via various kinds of globally organised business process outsourcing (BPO) arrangements. With active government support, South Africa is achieving growing success in this market.

A similar opportunity arises within globally dispersed innovation processes. South Africa is already exploiting this market in areas such as clinical trials and knowledge-intensive mining services. However, such market opportunities cannot fully be exploited simply on the basis of existing knowledge resources but require specialised engineering firms to upgrade their skills base to encompass elements of higher-level design and project management tasks from which the operating companies have withdrawn and to broaden the scope of their competencies in order to offer more comprehensive packages of services.

Another form of globally dispersed innovation processes takes place within the organisational structure of multinational corporations (MNCs), which increasingly network their innovative activities. Subsidiaries in developing countries with a relatively strong skills base are increasingly being drawn into these intra-corporate networks. As yet, this does not appear to have been an important feature of inward FDI in South Africa. It can become a much more important component of the national innovation system. However, the right to participate in such internal innovation networks is won through internal competition within the MNC. It depends upon the generation and demonstration of subsidiary capabilities and is not automatically granted.

3.2.3.2. Accumulating design, engineering and related capabilities within user firms

It follows that, as well as stimulating R&D, policy should centre on strengthening design, engineering and related capabilities in firms. These must be endogenous to the innovation system for three reasons.

First, in addition to supplying services for major investment projects, these kinds of design and engineering capability provide a stream of incremental innovation during the operation of existing facilities, as illustrated by Multotec (Box 3.2). Even in heavy industries with less frequent product innovation, these capabilities provide the basis for continuous streams of process improvement that have a major impact on productivity and costs. This requires in-house capabilities that are deeply embedded in the details of the specific markets and technologies of individual firms.

Second, even for larger and more intermittent investment projects, efficiency is not necessarily achieved by outsourcing the whole process to specialised supplier firms. Evidence from the global chemicals industry suggests that project implementation is typically more efficient when it is based on partnership arrangements that draw on substantial in-house engineering and project management capabilities in the facility-operating firms (Box 3.3). Unless these capabilities are accumulated, the basis for engaging efficiently with the international market for engineering services will be limited.

Third, these design, engineering and related capabilities have an independent economic life of their own. Firms providing these services constitute a specialised sector of knowledge-intensive economic activity, often with the potential to expand into export markets in their own right. However, a key constituent of these capabilities is detailed experience in the relevant user industries.

Over the next decade, it will therefore be important to extend the scope of policy attention well beyond the R&D activities that contribute to innovation and to give greater attention to strengthening the capabilities of business enterprises in areas concerned with design, engineering and investment project management.

Box 3.3. Organising design and engineering in investment projects

Design, engineering and project management services - Do or buy?
Some evidence from the global chemicals industry

Established firms in large, project-intensive process industries have substantially decreased over the last 20 years the extent to which they undertake detailed engineering and construction management activities; most now buy in these services from specialised engineering firms and project contractors. However, most have retained a core capability in basic (conceptual) design and engineering and related management areas. There are several reasons why firms maintain these capabilities. They include the importance of controlling, and also learning from, the implementation of investment projects that embody new knowledge from their own R&D. Within that, their ability to engage interactively in closely partnered implementation with specialised contractor firms seems to result in more efficient project implementation than either of two other ways of organising projects: those in which the operator takes sole control of project implementation and those that are exclusively led by contractors on a totally turnkey basis.

This is illustrated by an analysis of data compiled by Independent Project Analysis, Inc., covering projects carried out worldwide in the chemicals industry. For the period 1985-97, more than 3 000 projects worth over USD 5 million are covered. The table below suggests that two types of project show the least efficient overall performance: those for which contractors have full responsibility from the very early stages of project definition, with almost no input from the owner, and those that were implemented entirely by the operators. The best performers are the partnered projects in which contractors are brought on board early and the lead is taken by whichever party has the most appropriate overall capabilities.

Cost growth over expected values		Relative engineering to construction time*		Start-up time	
Rate %	Project type	%	Project type	No. of months	Project type
10-15	Contractor-led	102-104	All operator		
5-10	All operator	96-98	Contractor-led	2.5-3.0	All operator
0-5	Partnered	90-92	Partnered	2.0-2.5	Partnered Contractor-led

This appears to be one important reason why younger firms in these kinds of project-intensive industry in industrialising countries should aim to acquire and accumulate over the longer term core competencies for undertaking the types of design and engineering activity that are needed in-house as a basis for effective partnering with specialised suppliers.

* A measure of the reworking needed to bring the plant to operability.

Source: Data adapted from Brusoni (2005).

3.2.4. The "engineering gap": a looming crisis?

If this report had been written five years ago, the above question would have seemed unnecessary. A review of trends in the demand and supply of engineers and technicians over the 1990s indicated no sign of an imminent problem. The demand for engineers, as reflected in employment levels, showed considerable shifts between industries but the overall total showed only "erratic fluctuations around a moderately declining trend" (Steyn and Daniels, 2003).

When set against declining aggregate demand, some trends on the supply side were a bit worrying but not alarming:

- Despite roughly stable engineering enrolments in universities, the number of graduates had declined significantly since the mid-1990s.
- Despite substantially rising engineering enrolments in technikons, the number of national diploma graduates had fallen, and the number of graduates with higher diplomas or BTech degrees had fallen sharply since the mid-1990s.
- Although the number of Master's graduates in engineering had risen in the universities, it had fallen significantly in the technikons.
- The number of university doctoral graduates in engineering in 2000 was no higher than in 1991, having fluctuated over the intervening years.
- Although there had been substantial increases in the number of graduating engineers from historically disadvantaged groups (except at the doctoral level), they remained hugely under-represented.

However, a lot has changed since then. A huge change has taken place in the expected rate of industrial and infrastructural investment, generating a surge in demand for engineers in design, engineering and project management activities, plus associated technicians and skilled artisans.

It has only been possible to assemble fragmentary information about these changes. A study of the skills needed for innovative large investment projects in the petrochemical and chemicals industries identified an increase of 20% over only the 2003-04 period in expected investment-driven demand for construction manpower, together with a likely shortfall in available skills in terms both of the quantities provided by training institutions and their quality (NACI, 2003). Subsequently a report on civil engineering in South Africa traces out other aspects of rising demand (Lawless, 2005). It notes for example that:

- Actual spending on civil engineering construction during 2003-04 had already risen above an earlier optimistic scenario and showed every sign of continuing to outstrip that rapidly rising projection (Lawless, 2005, Figure 2, p. 6).

- The proportion of consulting firms that required new qualified engineering staff had risen dramatically to more than 75% over the 2001-04 period (Lawless, 2005, Figure 2.12, p. 40).
- In the supply chain providing manufactured goods for the construction sector, firms had already seen demand outstrip their ability to supply, especially in design-intensive areas (Lawless, 2005, p. 56).
- In the government sector, restructuring and downsizing of in-house engineering and related capacities had resulted in demand for engineering services massively exceeding available supply, just at the time when that demand was in any case increasing, especially in sectors of expanding infrastructure development (*e.g.* water supply) that focused on poverty reduction in rural and urban areas (Lawless, 2005, pp. 61-63).

These concerns were articulated before the announcement of the Accelerated and Shared Growth Initiative with its further additions to expected investment, and also before the announcement of a number of major new mining projects. They are primarily about civil engineering but may also apply to other areas of engineering, such as the Pebble Bed Modular Reactor project. Others have noted similar problems. For example, a Development Bank of Southern Africa (DBSA) report on the state of infrastructure noted, with respect to rural and municipal road networks, that "only about half the skilled resources required to address the issues involved are available, and it could take a decade to develop the human resources necessary to address all the needs" (DBSA, 2006).

It seems, then, that a very large gap is opening up between the demand for various kinds of engineering activity and the supply of engineering capabilities. Unless it is rapidly closed, this engineering gap is likely to have several implications.

- First, at the outer margin, some projects will simply not be implemented, or will be delayed.
- Second, at the next margin, projects will be poorly implemented, reducing the productivity gains.
- Third, there will be another margin of projects for which the shortage of engineering, technical and craft skills for post-start-up operation and maintenance will limit the operational effectiveness of the facilities created.

- Fourth, with these resources stretched increasingly thin, the intensity of efforts to search out directions of diversified production is likely to be constrained.

Such difficulties are already evident in several areas. For example, senior managers of a mining engineering company explained that the international market for their services was expanding very rapidly, especially in other African countries but, they said, “We have a huge skill shortage. This company could do twice the export business if we had the people.”

In a different area, the DBSA report cited above noted an extensive set of shortcomings with respect to the construction, operation and maintenance of infrastructure facilities. With particular attention to infrastructure to serve the poor and marginalised, the report noted that “institutional capacity is the primary constraining factor. Delivering new infrastructure and operating it are complex activities but competent skilled persons are in short supply, especially away from the major urban centers.”

It seems very likely that over the next decade the looming engineering gap will limit the rate at which new technology enters the economy via major investment projects. Given the scale of investment involved, even quite a small constraint on implementation is likely to have a large negative impact on the rate of innovation, perhaps creating a chasm between engineering and implemented innovation that will have much greater economic and social significance than the more frequently discussed chasm between R&D and implemented innovation.

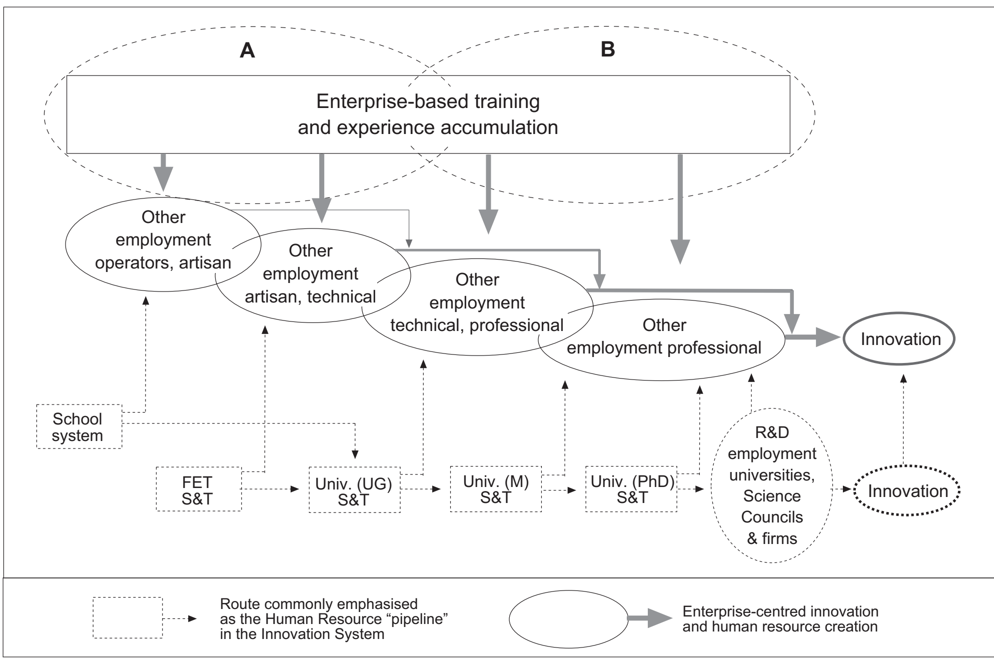
3.2.5. Intensive and pervasive enterprise-centred learning

A striking feature of the global knowledge economy is not simply the greater demand from business enterprises for higher skills supplied by the education and training system. It is also the extent to which business enterprises have enhanced their own activities to strengthen their internal knowledge resources. Their investment in creating human capital takes a wide variety of forms that complement and build upon the education and training provided by school and further/higher education; and it spans the whole spectrum of skill levels from operator/artisan skills to higher professional capabilities.

The mechanisms used vary widely: in-house training, commissioning special training programmes from external suppliers, seconding personnel to other organisations, and intensive knowledge-management operations to capture explicit information and to exchange wider forms of experience. Particularly striking has been the creation of various kinds of corporate universities to support these efforts. Examples include the Pohang University of Science and Technology set up in 1986 by POSCO (a steel company) in Korea, or VALER the corporate university established in 2003 by CVRD (a mining company) in Brazil.

In South Africa various kinds of corporate knowledge accumulation appear to have been quite intensive in the apartheid era but were substantially run down in the early 1990s. Subsequently, the government has taken steps to help rebuild this activity via the Sector Education and Training Authorities (SETA) and the associated training levy, primarily focused on supporting training in artisan/technician areas illustrated in area (A) in Figure 3.2.

Figure 3.2. Enterprise-based training and learning in the innovation system



This suggests there may be an important gap in the system of incentives and support for investment by enterprises in strengthening their human resources in the technical/professional fields, illustrated in area (B). These resources are not simply important components of the private innovation systems of the individual firms that invest in their creation. They typically diffuse as externalities to other firms, especially smaller ones, and they can contribute in important ways to the dynamic evolution of the structure of the economy in socially desirable directions. It may be important to consider whether new mechanisms are needed to induce higher levels of corporate investment in these kinds of capability. Among such mechanisms, it may be increasingly important to consider how the full potential of inward technology flows might be more fully exploited.

3.2.6. The international dimension: exploiting inward technology flows

Government policy concerned with developing the national innovation system has focused strongly on domestic sources of innovation and particularly on domestic R&D activities. However, although no meaningful data exist on the issues, it seems likely that most innovation in the economy draws primarily on imported technology. Most of this takes place in association with fairly substantial innovation-cum-investment projects for setting up new production or infrastructure facilities or for introducing new products. In turn, these take place within two kinds of organisational framework: as innovation projects undertaken by locally owned companies and as projects implemented through inward direct investment by multinational corporations.

3.2.6.1. Strengthening capabilities with imported technology: "local" investment projects

In most cases, these projects involve the acquisition of technology embodied in the imported equipment and services used to set up new production activities. They also usually transfer the knowledge necessary for the use and operation of the facilities and the knowledge for augmenting domestic innovative capabilities. International experience indicates that it is possible to organise projects in ways that include knowledge transfer components that substantially strengthen domestic innovative capabilities.

This was, for example, a common feature of projects when heavy process industries were developed in Japan and later in Korea, and intensive efforts were made to build into investment projects opportunities for acquiring training and experience in design, engineering and even technology development activities. These typically involved the organisation of R&D projects in the local firms, but these were designed to generate knowledge about the technology that was being imported, rather than to generate knowledge for globally novel innovations (see, for example, Ozawa, 1974; Amsden, 1989, 2001; Enos and Park, 1988; Kim, 1997). In some cases, the use of technology-importing investment projects as vehicles to create new innovative capabilities was organised as distinct technological learning projects and was treated as a bank-funded investment to create human and organisational capital (see Box 3.4). A common feature of such initiatives was some form of government support for firms (not necessarily funding) to make the necessary investments; government-backed development banks have also played an important role.

Box 3.4. Bank-funded investment in innovation capabilities

Investing in engineering capabilities: Petroquisa's Copesul project in Brazil

In the late 1970s, Petroquisa, a subsidiary of Petrobras, the Brazilian petroleum company, planned to construct a new petrochemical plant, the Copesul plant. This was a standard industrial investment project. Petroquisa put up the majority of the equity capital, and debt financing was provided by the Brazilian National Economic Development Bank, the World Bank and the Inter-American Development Bank. The core project involved the normal components of procurement and construction (with substantial elements of local sourcing), plus training in plant operation and start-up.

More unusual was the component concerned with the engineering for the plant. Petroquisa sought to organise this component in a way that would augment the country's engineering capabilities in this area of technology. The development of these capabilities had reached the point where a step-change was needed to create competence in qualitatively different kinds of capability from those that had already been developed. The planned change was from extensive capabilities for detailed engineering of chemical plants, where local sourcing was already nearly 100%, to capabilities for basic engineering and technology development where there was no existing Brazilian supply capability. This new platform of capabilities could not be created in an academic environment or by any amount of experience accumulation in the qualitatively different activities of detailed engineering.

Petroquisa therefore built into the engineering component of the project a specific technological learning sub-project to achieve this step-change. It had the following features.

- It was designed as a training and experience acquisition sub-project to be implemented with the international company supplying engineering services for the plant. This was built into the invitations to bid for the engineering contract, and the sub-project was an explicit element in negotiations with potential suppliers.
- The arrangements for training and experience acquisition were designed in a way that did not impose risks (*e.g.* of delay or higher costs) on the main plant project.
- To provide a nucleus for the training and experience acquisition project, Petroquisa assembled a team of 20 experienced engineering staff in the basic engineering department of its R&D facility, CENPES. This group spent four months strengthening its engineering competence in order to create a core of absorptive capacity before the start of the training and experience-acquisition part of the sub-project.
- Staff from two Brazilian engineering firms were included in the core team to ensure that the augmented capabilities would be acquired by a small network of organisations – not only by the plant operator (Petroquisa) but also by specialised engineering service suppliers.

…/…

Box 3.4. Bank-funded investment in innovation capabilities *(continued)*

- The core of the training activity involved 20 engineering staff undertaking training courses for a total of ten months in the European offices of the engineering suppliers. This involved parallel engineering of parts of the process plant being constructed. The subsequent experience acquisition involved a simulation of the whole design process for a similar plant.
- Further elements of the package were designed to ensure that the Brazilian organisations acquired not just a one-off injection of capability to design an existing state-of-the art plant, but a basis for further development of the core technology. This required further training in the development of experimental units in CENPES, the provision of the relevant design and data programmes, plus rights to subsequent upgrades and improvements over ten years.

Perhaps the most striking feature of this sub-project was that it was treated as an investment project in its own right – an investment in creating knowledge and capabilities alongside the investment in the overall plant. Feasibility studies of the returns that would accrue from the subsequent application of these capabilities were conducted and the expected returns were deemed adequate to secure additional project funding from two of the development banks that funded the main plant project. In effect, bank finance was used alongside one project to invest in generating spillovers for subsequent projects undertaken both by Petroquisa and by the specialised engineering service suppliers.

Source: Sercovich (1980) and bank project appraisal documents.

It has not been possible to find examples of such initiatives in South Africa, and the impression is that they would not be supported by government or by the national development bank; the Industrial Development Corporation has covered the conventional components of physical capital, but not components designed to create knowledge-intensive human and organisational capital. This is a different issue from the commonly discussed need for improved venture capital facilities to fund the commercialisation of innovations. It is necessary to finance investment in the underlying knowledge capital that is needed to create such innovations in firms, and not only to finance the products of that innovation-generating knowledge capital, important as that is.

This suggests that current approaches to supporting the development of the South African innovation system leave a large gap in terms of exploiting the potential of major technology-importing investment projects in order to augment domestic *innovation* capacity, and not just *production* capacity. The planned expansion of investment provides an enormous window of opportunity to deliberately accelerate the accumulation of capabilities and experience on the part of younger engineers and project managers who will shortly have to replace the ageing senior cohorts in these fields.

3.2.6.2. Strengthening capabilities with imported technology: inward FDI

Issues relating to investing in knowledge capital arise particularly in connection with technology imports associated with inward FDI. FDI projects are not just one-off events centred on the initial investment in subsidiaries. They are dynamic processes that run over many years, during which their roles in relation to the host-country innovation system may change substantially.

Table 3.3. South African foreign direct investment: inward and outward

FDI flows as a percentage of gross capital formation – selected regions/countries (1980-2004)						
Regions/country	1980	1990	2000	2002	2003	2004
Inward flows, ranked by year 2004						
World	2.2	4.4	19.3	10.2	8.0	7.2
Latin America and Caribbean	3.7	4.4	20.6	15.4	12.9	15.5
East Asia	0.7	3.5	17.3	8.9	8.1	10.1
Developing countries	1.2	4.1	13.3	8.3	7.5	9.1
South-east Asia	5.4	11.9	12.1	6.1	5.3	7.7
Developed countries	2.5	4.5	21.4	10.9	7.9	6.1
Africa	0.3	2.7	3.9	5.3	6.3	5.5
South Asia	0.5	0.6	2.4	3.2	3.2	3.7
South Africa	**0.0**	**-0.4**	**4.4**	**4.5**	**2.7**	**1.7**
Outward flows, ranked by year 2004						
World	2.4	5.2	16.8	9.5	8.0	8.7
Developed countries	2.8	5.9	20.6	12.0	10.3	10.3
South-east Asia	0.7	2.2	5.6	5.1	4.2	8.4
East Asia	0.3	3.8	10.7	3.7	1.6	5.1
South Africa	**3.6**	**0.1**	**1.3**	**-2.4**	**2.2**	**4.6**
Developing countries	0.6	1.7	5.4	2.5	1.5	4.2
Latin America and Caribbean	0.6	1.1	2.2	2.3	3.2	3.9
Africa	1.1	0.8	0.3	0.0	0.4	2.4
South Asia	0.0	0.0	0.4	0.8	0.6	1.2

Source: UNCTAD, World Investment Report (2005).

This dynamic perspective on FDI is perhaps less visible in South Africa than in other countries because of the relatively limited recent experience of inward FDI. Even since the mid-1990s, inward FDI has been among the lowest in the world as a proportion of total gross fixed capital formation (Table 3.3). One consequence is that during recent years few MNC operations have developed their technological behaviour much beyond the initial phase of establishing production operations. Hence these inward technology flows are commonly perceived as consisting almost entirely of established technologies for routine operating skills, and that they are associated with very limited innovative activity within South Africa. They give every appearance of adding only to the country's production capacity, not to its innovation capability.

However, this may be misleading. It is clear from experience in other countries that the technological activities of MNC subsidiaries change over time, and in some contexts they become very substantial performers of R&D. A particularly illuminating case is the development of MNC subsidiary behaviour in the Brazilian automobile industry. In the early 1990s, as the Brazilian economy was opened to the international market, most of the auto industry subsidiaries ran down the R&D and engineering activities that had been built up during the import-substituting era. This prompted widespread comment in the country about the inevitable demise of innovative activity in the MNC-dominated Brazilian industry. However, by the later 1990s most of the assemblers and some of the MNC first-tier suppliers began to change their strategies, gradually increasing their design and engineering activity. They have now become significant actors in the global engineering and technology development networks of their corporate parents and affiliates. Key factors in this transition appear to have been a mixture of the regional scale of the markets served by Brazil, the high quality of locally available design and engineering expertise, and supporting education and research organisations.

Such paths of change are not given but can be significantly influenced by the host country. Singapore is striking in this respect, since it has used various kinds of policy initiative that are feasible in other contexts. Numerous forms of facilitation, support, inducement and development of the host country context for FDI played an important role at different stages in influencing the behaviour of subsidiaries that now undertake important innovative activities locally.

In Ireland also, MNC subsidiaries play a large R&D-performing role in the national innovation system, and Ireland has also used a battery of measures to increase the innovative capabilities of MNC subsidiaries and their suppliers in Ireland. These include supplier development schemes and the involvement of small, university-based centres in supporting the MNCs and their supply chains with training, innovation projects and human capital. In recent years, production-focused instruments have been strengthened by the creation of Science Foundation Ireland, which invests in creating centres of research excellence in niches of ICT and biotechnology and which, together with other parts of the state system, targets inward investment in research and innovation. Client executives at the Industrial Development Authority are explicitly tasked with meeting the continuing needs of the MNC subsidiaries for development support, as are their equivalents in Enterprise Ireland, who look after indigenous companies. This strengthens the position of Irish subsidiaries in international competition.

These kinds of experience illustrate the need to take a strategic perspective on the technological behaviour of MNC subsidiaries (Mytelka and Barclay, 2004). This involves going beyond policy efforts intended merely to attract FDI to measures that will induce changing patterns of technological behaviour by subsidiaries and contribute positively to the development of the host country's innovation system.

Even at the level of training in basic operating and technical skills, the potential impact of MNC subsidiaries can be very large. This is illustrated by the example of Daimler Chrysler in the Eastern Cape, which undertook a massive training effort despite the almost total absence of policy initiatives at local, provincial or national level to support and prepare for this (Lorentzen, 2006b). Lorentzen suggests that such policy initiatives continue to be poorly developed and rarely discussed, either at the level of basic operating and technical skills or across higher technical skills, professional design and engineering capabilities and even technology development and research competence. This is an important gap because it seems likely that inward FDI to South Africa will increase considerably from its current relatively low level.

But efforts to use MNCs as vehicles to add to local capabilities must be a matter of finding and then exploiting areas in which an MNC's private interests overlap with South African local, provincial and national developmental interests. It may be productive to envisage cost-sharing schemes to cover the costs of extending MNC activities beyond what they would undertake in their own interests, as the government of Singapore did with respect to the costs subsidiaries incurred in providing technical support to local supplier companies. Other possibilities can be imagined, as illustrated in Box 3.5, which outlines a set of conversations with human resource and engineering managers in electronics subsidiaries in Thailand. Provided that suitable cost-sharing could be arranged, the managers seemed willing to consider doubling the scale of their planned training programmes for automation and related engineers, not for employment in their own operations, but explicitly for employment in the industry at large.

Box 3.5. Cost-sharing with MNCs in developing innovation capabilities

Deliberately generating knowledge-based spillovers: insights from the electronics industry in Thailand

The MNC-dominated electronics industry in Thailand underwent a transition in the technological base of its operations in the early 2000s. Firms upgraded their process technology to much more automated and equipment-intensive production. As one element in this transition, most MNC subsidiaries entered a new phase of human resource development to create new teams of process and automation engineers, equipment and instrument testing technicians, IT engineers, and so forth.

While this depended partly on recruiting people with higher levels of basic education and training, it also involved a range of company training programmes to build up those skill levels. Some of the necessary courses were designed in collaboration with technical colleges and universities, but the main parts of the programmes consisted of in-house training to build the kinds of expertise that could only be acquired in the firms themselves. This was organised partly within the subsidiaries and partly at other affiliates and parent companies in the corporate groups. The companies planned these programmes on a scale that would meet their requirements, including a margin for labour turnover. They therefore accepted that a proportion of the skills they created would leak out to the benefit of other firms. The result was a set of company plans to operate training programmes for a succession of entry cohorts of 15-25 people.

In order to explore whether these programmes might be organised in ways that *deliberately* generated skill spillovers into the economy, rather than merely letting them arise as *accidental* trickles through labour mobility, the human resource managers in three of the MNC subsidiaries were asked two questions as part of a longer interview in 2000 about the skills base required for process upgrading and innovation in the local industry. The questions and summarised answers are reproduced below.

- **Question 1.** What would be your response if the government asked you to double the number of trainees put through your planned programmes, not with the expectation that you would employ the additional numbers, but specifically that you would not? The aim would be to create an excess of trained people beyond your own planned needs who would then move to employment elsewhere in the local industry, *e.g.* among your suppliers and other electronics firms.

  Answer 1. We could not possibly do that. How could we justify the costs of acting, in effect, as an unpaid technical college for the government? Of course it would be good for us and everyone else if there was a larger pool of these kinds of skilled people available for the industry as a whole, but the costs of your suggestion would be much higher than anything we could accommodate in our corporate social responsibility budget.

…/…

Box 3.5. Cost-sharing with MNCs in developing innovation capabilities *(continued)*

- **Question 2.** How would you respond if the suggestion was accompanied by a proposal to provide funding to reimburse your company for the costs of extending the scale of the training programme beyond what was required to meet your own needs?

  Answer 2. That would be an interesting idea. We have collaborated on skill development activities with governments in other places like Singapore, though not along the same lines. We would be cautious about the bureaucracy that might follow from government involvement, but we would certainly take such a proposal seriously. After all, we ourselves would benefit. In particular it would be good to speed up the emergence of a local industry to supply maintenance services and process equipment, instruments, etc., in the way that happened earlier in Singapore.

The idea was dismissed in subsequent discussions with government officials: Why should we subsidise the multinationals? They get a very good deal here as a result of various tax breaks. Why should we add to that? It was not accepted that there would be no intended subsidy for the MNC's own activities, just cost-sharing in an area where interests overlapped.

Source: M. Bell, unpublished interview notes.

South Africa is increasingly part of a global knowledge system in which there is a pervasive shortage of higher-level skills and professional expertise. It will become more and more important to use a wide array of inventive and imaginative approaches to ensure that the country competes for this global knowledge pool from the strongest possible position. Imaginative ways of inducing MNCs to act as a vehicle for enhancing the knowledge resources and capabilities of the national innovation system must be part of that effort.

Chapter 4

INSTITUTIONS, POLICY IMPLEMENTATION AND GOVERNANCE

This chapter examines two components of the innovation system: education and research (or knowledge infrastructure) and the political system (or policy and governance).

For the first of these, it focuses on research and development (R&D) by higher education institutions and public research institutes (the science councils). It draws on international experience to highlight the importance of balance in the system: first, between university R&D and business enterprise R&D; and second, between the different roles and activities of public research institutes. However, it is important to recognise that the latter is a variable that needs to be tuned to the particular structure of economic actors and activities in the economy.

With respect to the second component, the focus is on certain issues relating to implementation and its effects. First, different aspects of policy appear to be stimulating the emergence of a considerable diversity of organisational vehicles for innovation. Although some of this may appear "untidy", organisational creativity is valuable for tackling the new challenges facing the South African innovation system. Second, there is a widespread impression that, at various levels in the system, resources are being spread too thin across activities, and that this may inhibit the emergence of critical mass in a more focused set of programmes, organisations, research fields and sectoral sub-systems. Third, the connection between the articulation of high-priority, strategic missions and their implementation seems to be excessively fluid. This loose connection suggests that, five years after the R&D Strategy Report of 2002, it may be time to take another look at involving innovation strategy and priorities. Finally, selected aspects of the governance of the research and innovation system are reviewed, drawing on international experience to highlight areas in which in South Africa's practice seems to match that of international leaders, and others in which there appear to be significant limitations.

4.1. The knowledge infrastructure

This section discusses the role of the public research institutes (PRIs) and the universities in knowledge generation and use. Higher education research plays a very significant role in the development of national innovation and R&D capabilities, but probably more through its contribution to human capital formation than through its contribution to new knowledge. This is a main reason for expanding the research capacity of higher education to meet the growing needs of the economy. However, on current trends, this capacity seems more likely to collapse than to maintain the steady state of the past decade or to expand to meet needs. Bold measures will be needed to manage this difficult period.

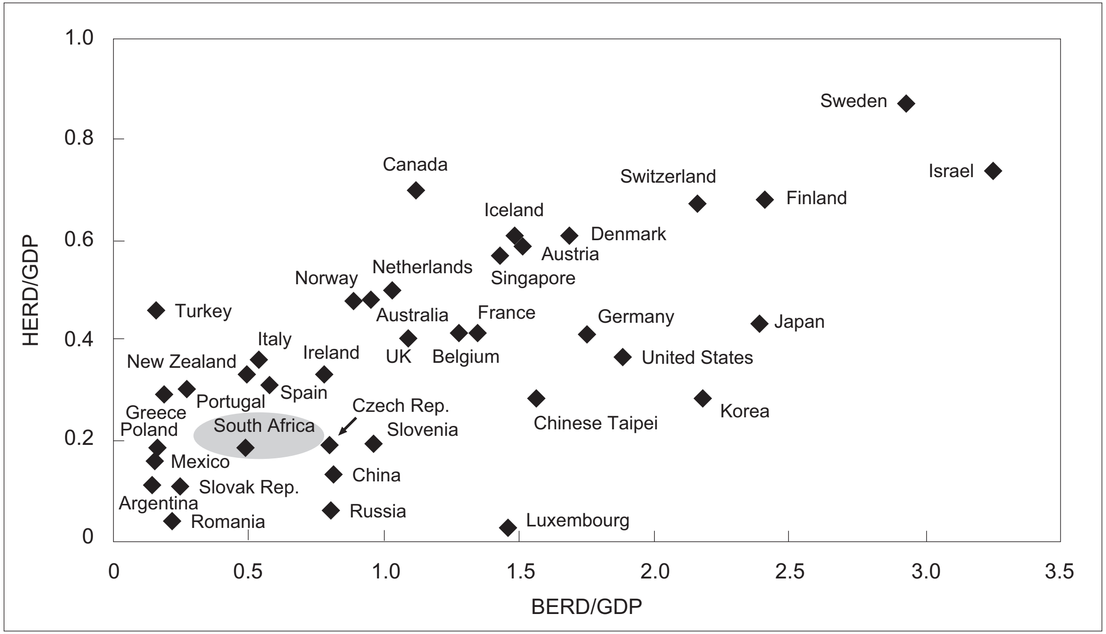
To make higher education research a useful component of the innovation system it is important for the universities not only to have a significant amount of fundamental research capacity but also to devote much attention to strategic and applied research in areas of social and industrial relevance. Programmes that link higher education to industry are important focusing devices[34] that signal where the higher education system should increase its activities and are also useful sources of information for the universities. The fact that important strengths of the higher education research system are concentrated in historically white universities is politically uncomfortable. However, these capabilities are fragile and the costs of rebuilding them if they are allowed to dwindle are very large.

The PRIs provide a crucial complement to the universities. They provide R&D and technology transfer services that have more direct industrial applications,[35] typically helping companies move a little beyond what their internal capabilities would otherwise permit, reducing risks and increasing the rate of innovation. Universities generally lack the skills to do this. Given some stability in its terms of reference and core funding, there is every prospect that the Council for Scientific and Industrial Research (CSIR) in particular can play a useful role in extending the reach of the knowledge infrastructure in supporting industrial development. Growing interaction between CSIR and the universities provides, therefore, a further focusing device for higher education research and a further way to exploit university research, as well as underpinning CSIR's capability building, which will over time need to become increasingly research-focused.

34. Nathan Rosenberg used the term in his book *Perspectives on Technology*, Harvard University Press, 1976, in the context of mechanisms (especially market mechanisms) that influence the direction of industrial innovation.

35. As elsewhere in this report the word "industrial" is used to refer broadly to any form of production of goods and services.

Figure 4.1. HERD/GDP vs. BERD/GDP, 2003



Source: OECD, MSTI (2006); value for South Africa is from the 2004 R&D Survey.

4.1.1. Higher education research

4.1.1.1. The scale of research

There is considerable variation among OECD countries in the proportion of total R&D (GERD) that is performed in the higher education sector (HERD). It ranges from less than 20% in Korea, Finland and Japan to around 30% or more in Spain, Norway and Canada. This makes it perilous to use cross-country comparisons of this ratio as a basis for arguing that HERD in any particular country is under- or over-funded. Nor does the relationship between HERD and per capita GDP in OECD countries make it possible to identify relevant targets easily. There is, however, one reasonably regular statistical relationship that does merit closer inspection: the trend in the relation between BERD as a proportion of GDP and HERD as a proportion of GDP (Figure 4.1). This is exactly what one would expect to see if the outputs of R&D in the higher education system are important for business enterprise R&D. South Africa sits towards the bottom left in the figure, together with a number of developing nations and the low R&D performers among developed countries, such as Italy. The EU and OECD average values are in the middle of the picture while the high R&D performing outliers (Sweden and Finland) are at the top right.

The interpretation of this relationship requires care because it almost certainly does not reflect the traditional linear model of innovation that informed the massive expansion of research and education systems in OECD countries over the past half century. That model implies that there should be a link between HERD and BERD because outputs from the basic research component of HERD drive the later stages of R&D and these in turn drive economic growth. There is no credible evidence for this. On the contrary, as in the South African innovation survey, countless surveys of OECD firms show that their main sources of technology are internal knowledge and other firms. Public sector research in general, and higher education research in particular, accounts for a small share of their total knowledge inputs to innovation.

Research in the higher education sector produces far more than the kinds of "basic" knowledge outputs that were once thought to drive the linear model. It also produces people-embodied research skills and people-embodied knowledge, not only doctoral graduates but also research-trained graduates at all levels. Across a range of differing organisational arrangements in OECD countries, doctoral studies in both universities and public research institutes are an increasingly important element both of the research process and of the production of research-trained knowledge workers for the economy as a whole. Knowledge and human resource outputs arising from research in these institutions are inextricably linked. But the latter seem to lie at the heart of the relationship between HERD/GDP and BERD/GDP.

Business enterprises in increasingly knowledge-intensive economies recognise that they need research-capable manpower in order to make the best of their own internal stocks and flows of knowledge and to establish the best possible connections to the stocks and flows of knowledge outside the firm. There is also clear evidence that larger firms that employ well-qualified manpower use this absorptive capacity to establish partnerships with universities and research institutes and place a high value on what they obtain from these relationships (Cohen and Levinthal, 1990). They also use it to acquire and absorb knowledge from a variety of sources in other countries.

The implication is clearly that South Africa needs a correspondingly stronger R&D effort in higher education to generate the human capital and absorptive capacity needed to undertake these activities. The widespread perception that South African industry often succeeds through a "fast follower" strategy reinforces the need for this absorptive capacity. New research-based knowledge is of course important – in some industries more than in others – but it appears to be a less important driver of growth than human capital. However, for both reasons, South Africa needs to move upwards and not only to the right in Figure 4.1 above.

In trying to do so, South Africa faces a number of significant constraints, including, but not only, the well-known human resource pipeline constraint. Available statistics on the numbers of researchers in the higher education sector at the start of the 1990s are conflicting (Table 4.1).

Table 4.1. Full-time equivalent researchers in the higher education sector, 1991-2004

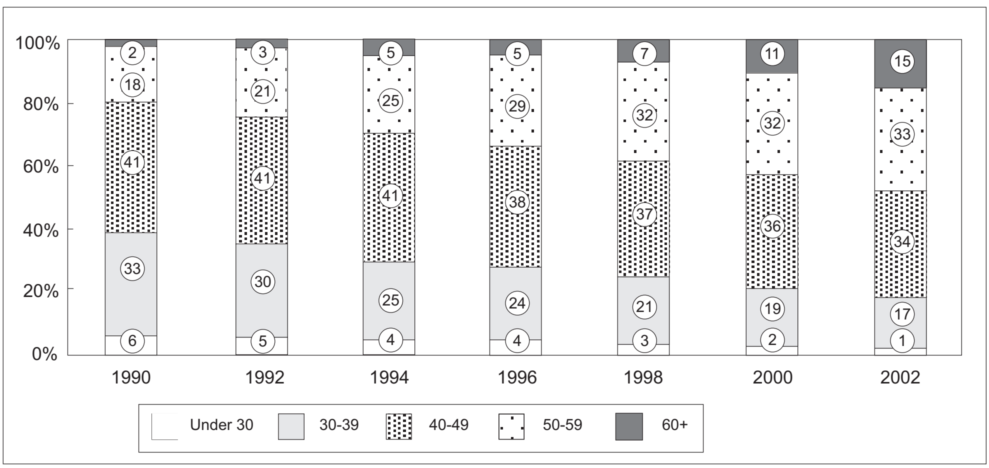
Year	FTE higher education researchers	Source
1991	5 984	1991 South Africa S&T Indicators*
1992	3 631	2004/05 National R&D Survey
2001/02	3 424	2001/02 National R&D Survey
2004	3 374	2004/05 National R&D Survey

*1991 SA Science and Technology Indicators, cited from Paterson *et al*. (2005, p. 16).

What does seem clear is that the number of higher education researchers has stagnated for some years. There has also been a slight decline in the proportion of university faculty with PhDs, from 41% in 2000 to 37% in 2003. Over the period, the proportion in the technikons rose from 5 to 7%. The number of articles by South African authors in scientific journals remained stable between 1991 and 2003, whether one counts total output, output in journals accredited by the Department of Education or only ISI journals (at about 7 000, 5 500 and 4 000 articles a year, respectively). In a world where scientific output is growing, this means a decline in world share from 0.7% in 1987 to 0.49% in 2000. As Paterson *et al*. argue:

> *"South Africa's scientific output has been stagnating for the past 10-15 years. Stated differently, the scientific output of public science has reached a steady state. The output is typical of a system which has reached its limits. Unless the system changes structurally, no substantial growth is likely. In fact we would predict that no amount of incentives and rewards will affect this situation in the short term."*[36]

Figure 4.2. Age of authors of South African journal articles, 1990-2002



Source: Paterson *et al*. (2005).

The demographics of ageing means that even this steady state may not be sustainable. In 1990, 20% of South African journal articles were written by people over 50 years old. By 2002 this figure had risen to 48% (Figure 4.2). As retirement and death take their toll on a research system that does not renew itself, output will collapse. The proportion of black (and, one assumes, comparatively young) authors of journal articles only rose from 4% to 11% between 1990 and 2002. While these authors' productivity should increase as they age, the gap is significant. Doctoral enrolments have been rising since 1997/98 but completion rates have fallen, leaving only a

36. Paterson *et al*. (2005, p. 15).

minimal increase in the annual rate of doctoral graduates, now about 1 000 a year. South Africa's social and economic development requires significant expansion of the higher education research system, but major interventions will be needed even to maintain the current situation.

4.1.1.2. The focusing of research

A number of new instruments have been put in place recently to strengthen research in the higher education sector. These include three programmes aimed at increasing human capital within the sector:

- The Research Chairs Programme.
- The Prestigious Post-Doctoral Fellowship Programme Pilot (ZAR 150 million per year).
- The Professional Research Development Programme (ZAR 15 million per year).

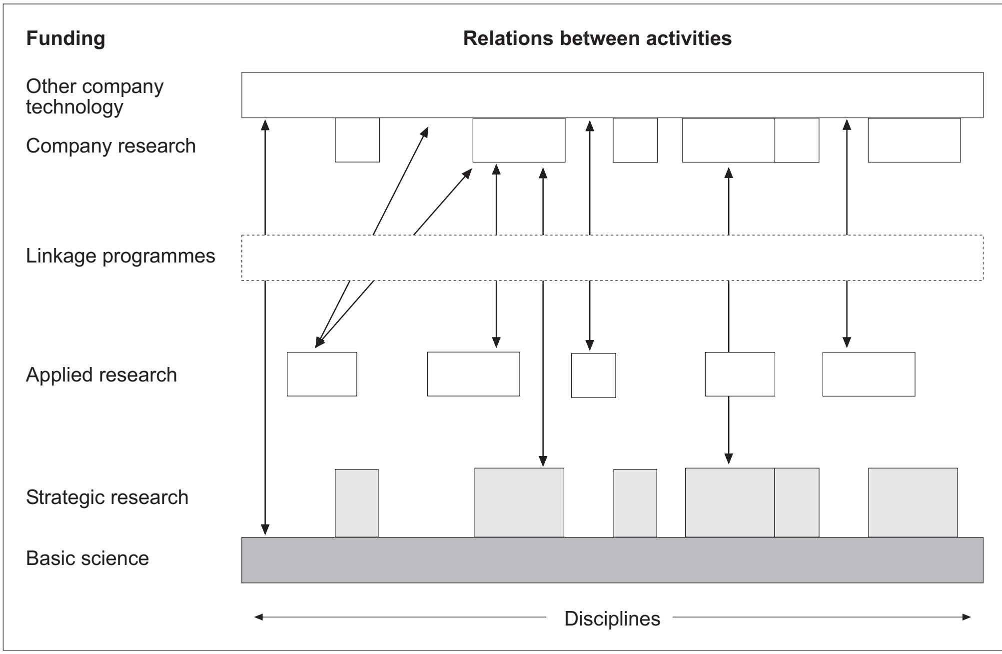
Funding under these programmes is largely driven by criteria of academic quality and they therefore tend to strengthen higher education research in general, without reference to the economic and social relevance of the additional capacity. However, some kind of focusing device is needed to induce growth and development of academic research in areas of social and economic need.

Figure 4.3 indicates how such focusing of state-funded science may be combined with the diversity that criteria of academic quality are likely to encourage and the selectivity that criteria for social and economic priorities impose. The figure takes its inspiration from the policies of the former Swedish National Board for Technological Development (STU), and concentrates on pure and applied science; it takes no account of the many other important linkages involved in innovation and the development of more routine technological capabilities.

The Swedish STU argued that there is a need to do a certain amount of fundamental science (the dark grey box), spread broadly across most, if not all, disciplines and irrespective of whether there is any direct productive or user requirement. This research (which STU called Programme 1):

- Enables university teachers to stay up to date.
- Provides the nation with the minimum amount of scientific capability needed to create a growth node if more capability in a particular discipline or problem area is needed in the future.
- Provides answers to some policy questions.

Figure 4.3. R&D activities in a mature innovation system



The lighter grey areas mirror those where industry performs research in addition to technology development, design and routine production. These elements of strategic work (STU's Programme 2) are funded specifically in order to provide human and knowledge resources to industry, but in other respects they may be indistinguishable from fundamental or curiosity-driven research and may be described by some as strategic basic research. The availability of funding in these areas acts as a focusing device for actors in higher education and public research institutes and for this reason, in many countries, industry plays a significant role in selecting the areas to receive funding and has some say in which topics are funded within these disciplines. It is necessary to make a strategic choice of areas, based partly on existing needs and partly on the prospective requirements of industry. This prospective analysis needs to be updated regularly and to be conducted in partnership with industry, for example through foresight studies.

In the South African system, the following instruments have this focusing function:

- The Innovation Fund.
- The Centres of Excellence and Equipment Programme.
- The National Biotechnology Strategy.
- The Advanced Manufacturing Technology Strategy.
- The Technology and Human Resources for Industry Programme (THRIP).

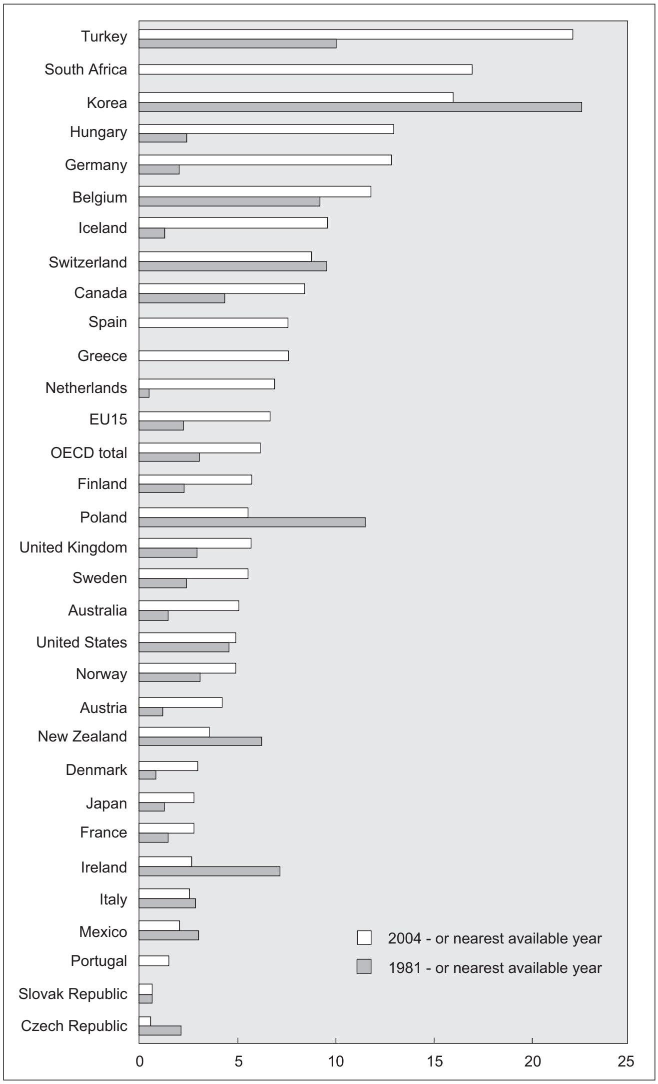
Section 4.2.2 will suggest that, under these mechanisms and in other areas, the extent of focusing has probably been inadequate in recent years, with resources consequently spread thin over too many areas and activities. Of note here are three further points: *i)* the importance of the historical role of THRIP and of the recent decision to develop a specialised mechanism that will provide a similar focusing role with respect to the needs of the small, medium and micro enterprise (SME) sector and the second economy; *ii)* the importance of excellence in HERD; and *iii)* the need to establish new, more widely dispersed nodes of excellence in the university system.

The role of THRIP

Among the focusing mechanisms for HERD that are listed above, the THRIP programme appears to have played the major role as a focusing device. It has done so in two important ways. Not only has it provided a vehicle for (generally large) companies to provide signals and incentives to the higher education research system, but it has done so by closely combining the generation of new knowledge with strong emphasis on the development of human capital in areas relevant to major parts of the South African economy. The willingness of South African industry to fund research at universities is undoubtedly influenced by THRIP as well as by a number of historically strong relationships between key South African companies and certain universities (such as the long-standing and strong links between the mining industry and the University of Witwatersrand). This degree of connection between industry and the university sector is very high in international terms and constitutes an unusual asset (Figure 4.4).

Figure 4.4. Proportion of HERD funded by industry, 1981 and 2004

Percentages



Source: MSTI, 2006/2; SA Innovation Survey, 2004/05.

The conclusion to the recent debate about the role of THRIP with respect to larger companies and SMEs therefore seems correct. On the one hand, by continuing to involve larger companies (with a stronger emphasis on additionality) it not only helps to address the impending crisis of funding and capability in the universities, it maintains effective signalling about needs and opportunities between medium-to-large industry and the universities, increases the scale of industry-relevant human resource development, and raises the attractiveness of South Africa as a location for R&D by increasing the relevance of the knowledge infrastructure to large areas of industry. Finally, via the various forms of knowledge spillovers described in Chapter 3, it indirectly disseminates knowledge and human resources more widely in the economy.

For its part, the commitment of the National Research Foundation (NRF) and the Department of Trade and Industry (DTI) to develop a new funding mechanism specifically focused on the SME sector and the second economy will help to meet a different set of important needs in the innovation system. This explicit focus will of course target a set of beneficiaries in a sector prioritised in terms of black empowerment, even if one-quarter of all SMEs currently appear to be white-owned and two-thirds of SMEs in the formal economy are white-owned (DTI, 2004). This is one of several manifestations of a difficult tension between the need to create and maintain (and therefore fund) excellence in the higher education research sector and the need for equity (within and outside that sector). This is particularly challenging because of the role of excellence in scientific research.

The importance of excellence in science

Science is fundamentally elitist. Scientific discovery and output is extremely skewed, so that a small proportion of researchers produce most of the important publications (the so-called Lotka effect).[37] Collaboration and co-authorship are increasing in science not because academics necessarily see this as desirable in itself – after all, they dilute the individual researcher's credit – but because they are increasingly necessary to achieve results in many fields, because it provides access to global research networks and membership of "invisible colleges" and access to certain types of funding. Excellence is a precondition for participating in partnerships. Similarly, the evidence is that technologically competent companies, including major multinational corporations (MNCs), seek partnerships with the world's best researchers. Sasol's funding of researchers in Scotland as

37. This underpins a research-related strand of the broader arguments for differentiation in the higher education sector that were emphasised in the "size and shape of higher education" debate in South Africa in 2000 (*e.g.* CHE 2000a and 2000b).

well as research in South Africa is well-known local evidence that this is the case. So also is the international funding of clinical research and trials in South Africa because it has excellent facilities and skills for such work. Excellence in the knowledge infrastructure is therefore a necessary precondition for knowledge-related foreign direct investment (FDI), the retention of potentially footloose company R&D activities, and the export of R&D services.

This raises several questions about designing a new SME-focused research and human resource development mechanism to complement THRIP. Two seem especially important.

- While scientific excellence in universities, alongside strong innovative activity in larger firms, is an important basis for vibrant sectors of knowledge-intensive SMEs operating at the international technological frontier, how large is the likely contribution of such sectors to the overall aims of widespread black economic empowerment, massive expansion of employment, especially for unskilled and semi-skilled human resources, and rapid erosion of the second economy? There does not appear to be any clear answer.[38]
- Are different kinds of excellence needed to support the achievement of these aims, and if so are universities the best kinds of institutional vehicle for mobilising and managing them? Section 4.1.2 points to international experience that suggests that they are not.

Developing new nodes of higher education research excellence

Scientific knowledge, team building and development of a track record are a cumulative and gradual process, and it is therefore costly and time-consuming to build a centre of research excellence. As noted earlier, success in this area is one of the positive legacies of South Africa's past. The higher education sector has several excellent nodes of research capability as measured against a global yardstick and many more that are good. However, the capacity to sustain such levels must surely be threatened by the "ticking bomb" of researchers' age profile, and there is the further problem that most of the excellence is concentrated in the universities that were privileged under the old regime. In spite of the increasing proportion of black students at these universities, the scientific leadership remains predominantly white and male, and it is politically uncomfortable to focus funding on these universities while waiting for time to take its toll and for a new generation of researchers, more representative of the national demographics, to take over.

38. One report noted that, as of 2002, the first two rounds of funding by the Innovation Fund had created 55 new jobs and six new firms. (NACI, 2002).

It is also unrealistic to expect new centres of excellence to emerge in historically disadvantaged universities almost exclusively through their success in competing for funding with the long-established centres. The concept of a "level playing field" seems inappropriate when the teams have had such unequal opportunities to build the ability to play competitively. Consequently, spreading the distribution of excellence, or at least spreading the distribution of opportunities to develop it, seems to call for a dual mode of research funding. One relatively small component would focus selectively on the time-consuming business of creating new centres of research excellence and would involve a much greater degree of positive discrimination than currently seems to exist. Another component would continue, perhaps even more selectively in the light of Figure 4.3, to sustain and develop global and national excellence in the institutions that already have the underlying bases for achieving it.

4.1.2. Public research institutes

The concerns that led the DTI and the NRF to develop a new SME-centred mechanism parallel to THRIP are extremely important, yet most OECD countries have found that the university system is not a good means of providing this kind of support. Universities generally lack the hands-on understanding of production and of running a business required to tackle the needs of small firms and generally deal well only with small, technology-based firms that have high absorptive capacity. Most other small firms struggle to speak the language of the professors and are too distant from them even to make contact. The OECD countries therefore tend to develop substantial, dedicated small-firm support services, usually covering a range of developmental support from finance through management to production skills. Technology is usually incorporated in some way, but more specialised technological support is normally provided through non-university higher education institutes such as technikons (see Box 4.1), polytechnic research institutes such as CSIR, and, to a diminishing degree, through more specialised institutes like the Council for Mineral Technologies (Mintek). In Europe, at least, branch-focused institutes and other specialised technology institutes tend to merge into larger polytechnic organisations able to help their customers with an increasingly wide range of problems.

Box 4.1. TETRA: the bridge between the Flemish polytechnic schools and SMEs

The TETRA programme, managed by IWT-Flanders, aims at improving technology research, technology translation and technology transfer from higher (non-university) education institutions to the private sector, especially SMEs. A second objective of the programme is to improve the research and educational context at higher education institutions.

It has been running since early 1997 and has supported up to 2003 about 159 projects, selected from 448 proposals for a total of EUR 36.5 million. Project duration has typically been two years.

An eligible project has to be relevant for a group of at least three companies (and usually more) which pay only a small fraction of its cost. Every project has a users' committee with the project leader, representative(s) from the scientific partner(s), representatives from each interested company and the IWT advisor.

Apart from the higher education institutions themselves, 1 125 organisations (universities, research institutes and companies) have been involved in the users' committees of the approved projects. Following a positive evaluation, the Flemish government upgraded the programme in 2004:

- Universities and higher education institutions can now jointly submit projects.
- The annual budget of the programme has been increased to EUR 6 million.
- The subsidy rate for qualified projects has been set at 90%.
- The maximum project cost now amounts to EUR 0.5 million.

As noted in section 4.2.1 below, some of these kinds of organisational vehicles for innovation support and implementation in South Africa are emerging, and this report suggests that such experimentation and organisational development needs to continue. This section explores several aspects of international experience that may contribute to such organisational innovation, catering not only to the need for support for SMEs but also in a variety of industry contexts.

Internationally, there are three types of research institute:[39]

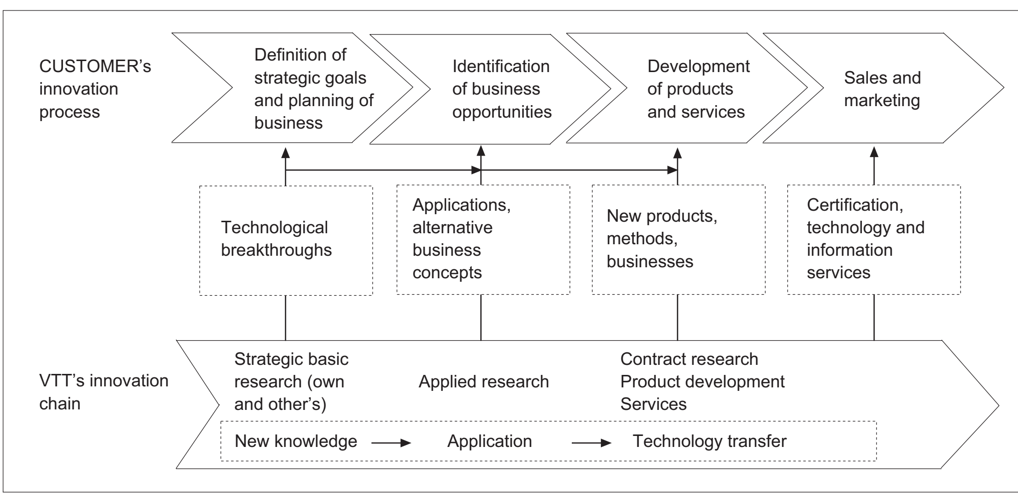
- *Research associations,* which originally tackled common problems within one or more branches of industry and then became institutionalised in the form of institutes. Some of these are still membership-based.

39. International observations on institutes are largely drawn from Arnold *et al*. (2007).

- *"Technology-push" institutes*, sometimes set up in the more recent past, in order to promote industrial development more widely. SINTEF in Norway is an older example. Fraunhofer in Germany and IMEC in Belgium are also in this category.
- *Services-based institutes*, generally focusing in their early years on measurement, testing and certification. Like the SP Technical Research Institute of Sweden, these have generally moved upstream into research. VTT in Finland is a mixed case, as a policy decision transformed a services-focused institute into a technology-push institute.

Most institutes involved in industrial applications operate a three-stage innovation model, relying on core funding and other types of subsidised activity to feed the development of new capabilities or technology platforms. Figure 4.5 illustrates the process of gradually developing these platforms together with the more technologically capable members of industry and finally using the knowledge as a basis for providing consulting and other technical services as the institute matures. VTT says its effort is split roughly 30/40/30 among the three stages.

Figure 4.5. VTT's innovation process



Source: VTT.

At CSIR, there has been a long-term trend away from high levels of state subsidy for the institutes and towards a model in which the state provides a core subsidy intended to fund capability development and leaves the institute to earn the rest of its income on the market.

The relevance of the different types of institute varies with stages of development and economic structure. Thus, Denmark's GTS institutes work in an economy composed primarily of SMEs. They offer many testing and certification services and much of the rest of their work deals with helping firms with product and process development rather than research. Only 8% of the GTS staff have a PhD and the level of core funding is also low: about 10% of turnover. In contrast, the Fraunhofer institutes work in a strong and developed industrial context with many large firms. They focus on applied research, are closely linked to universities, and work about equally for large firms, small firms and the state. About 30% of Fraunhofer staff have a PhD and the core funding is about 30% of turnover.

Institutes' activities change over time and with economic development. The Norwegian research institute system was set up in the late 1940s, when Norway was an underdeveloped and almost entirely resource-based economy, with the specific intention of developing products and processes for industry. As the economy developed and the absorptive capacities of Norwegian firms increased, the institutes shifted towards applied research. They can be considered to be in transition from the GTS model to the Fraunhofer model. About 30% of the staff of SINTEF, the large polytechnic institute into which most Norwegian industrial research institutes have been merged, have PhDs. SINTEF's core funding is very low (perhaps 10%) but it receives substantial hidden subsidies in the form of synergies with two universities, making the effective rate of core funding an estimated 20%.

There is considerable variation in how proactive the institutes are in supporting companies. CIDAUT, Spain's Research and Development Center in Transport & Energy, for example, actively leads SMEs in the Spanish automotive components sector into new technologies and helps them design new products. In Italy, the well-known branch-focused institutes of Emilio Romagna play a similarly proactive role (Rush *et al*., 1996).

Common characteristics of these kinds of research institutes are:

- The use of core funding to develop capabilities (knowledge, technology platforms, specialised test and certification equipment, and approvals) not easily accessed by the private sector.
- The use of those capabilities to reduce innovation risks for companies, allowing them to go a step beyond what they could otherwise achieve in terms of technological development.

As indicated earlier, CSIR is currently operating a model that is slightly more oriented towards engineering and design than that of most northern European industrial research institutes, but one that appears to be relevant in South Africa and that complements the role of higher education research. Like the other institutes discussed, CSIR is developing closer links with the universities, and these should be further encouraged because: *i)* they improve the quality and scope of CSIR's support for innovation in industry; *ii)* they allow CSIR to function as a focusing device, for example by co-operating on PhD projects in areas that will build future knowledge platforms for the institute; *iii)* they encourage a sensible division of labour so that both institutes and universities focus on activities in which they have comparative advantage.

4.2. Policy implementation

Major influences on the shape of the national innovation system over recent years have stemmed from policy changes in the early years of democratic government, in particular the combination of economic liberalisation and radical reductions in large areas of public support for R&D and technology-intensive production. But, as noted in Chapter 2, there have subsequently been broad policy developments aimed at further transformation of the system. For instance, the Department of Arts, Culture, Science and Technology/Department of Science and Technology (DACST/DST) has progressed from the overall White Paper on Science and Technology in 1996, to the more focused National Strategy for Research and Development in 2002, to the more narrowly defined strategies for specific areas of technology such as the National Biotechnology Strategy[40] and, in conjunction with the DTI, the Advanced Manufacturing Technology Strategy (AMTS). The DTI itself has also developed a range of policy frameworks that directly influence the development of the innovation system, in particular the Integrated Manufacturing Strategy (IMS).

The following section outlines some of the ways in which such DACST/DST and DTI policy initiatives have been followed to, or at least towards, implementation, in order to explore three issues:

40. The initiation of the Biotechnology Strategy actually predates the National Strategy for R&D in which it was incorporated.

- The development of an increasing diversity of organisational vehicles for innovation.
- The possible need for sharper priorities in resource allocation and tougher choices between alternatives among the wide array of actions being taken and funded by government.
- The fluidity that appears to exist in the linkage between formulating and implementing strategy, with particular reference to the National Strategy for R&D, and the need to look again at the strategic priorities and key missions of nearly five years ago.

4.2.1. The emerging diversity of organisational vehicles for innovation

As discussed in Chapter 2, a strong innovation system based on a dense structure of organisations and organisational interconnections had been built up to support the economic and political aims of the apartheid regime. Large parts of that system were later downsized, dismantled and realigned. More remarkable, perhaps, has been the subsequent path of organisational creativity in building new structures to support new aims. In connection with industrial innovation, for instance, there has been a high degree of organisational responsiveness, experimentation and inventiveness in building new organisational vehicles for innovation. These developments respond, among other things, to four different strands of policy:

- Economic policies, mainly trade policies, which have stimulated more innovative activities on the part of industrial enterprises in some industries.
- Policy initiatives on the part of the DTI and the DST intended primarily to stimulate innovative activity in the universities and science councils and their interaction with industrial enterprises.
- Strategies intended to link developments in priority areas of technology to innovation in industry (*e.g.* biotechnology or advanced manufacturing technology).
- Steps to implement the DTI's Integrated Manufacturing Strategy within the broader frame of the Microeconomic Reform Strategy.

4.2.1.1. Economic policy and innovation by industrial enterprises

The liberalisation of economic policy in the mid-1990s, especially in the area of trade policy, brought a mixture of new competitive pressures and market opportunities to bear on the industrial sector. One early policy response was the Motor Industry Development Programme. This combined strong economic incentives to intensify innovation and upgrading with strong support for developing and implementing innovation. Most of the support was organised through the Automobile Industry Development Centre (AIDC). Established in 2000 under the Gauteng Province Blue IQ initiative, and subsequently extended to KwaZulu-Natal, the AIDC addressed the whole of the industry's domestic supply chain. It acted as a vehicle to provide comprehensive multi-functional support in areas such as skills development and training, supplier and supply chain development, up-grading activities in specific segments of the supply chain (*e.g.* tooling), as well as facilitating business access to government investment financing and other support programmes. Within that spectrum, it supported and facilitated a range of technology-related activities spanning the industry's diverse technological structure. At one level, for instance, it was associated with a project to develop applications of CSIR's world-leading technology for the production of lightweight die-cast components. At another, through the Tirisano Programme, it achieved considerable success with cluster-centred initiatives to upgrade basic skills, technical efficiency and lean manu-facturing practice in small firms located in the lowest and least sophisticated tiers of the supply chain structure.

Other industry sectors sought to upgrade the technological basis of products and processes and to intensify their innovative efforts via mechanisms developed by their own business associations. In contrast to the AIDC, these often focused on particular segments of an overall value chain. For example, the Southern Africa Stainless Steel Development Association has provided a collective framework for assisting fabricators and manu-facturers with technical research as well as domestic and export market development, and it has facilitated the creation of a multi-stakeholder forum involving Mintek and the CSIR to address technological and other issues.

In other industries, competitive pressures and opportunities in the changing economic environment induced business enterprises to develop new collaborative arrangements with universities as vehicles for innovation. This often, but not always, led them to the well-established research universities. For example, faced with increasing competition from Japanese suppliers, Aberdare Cables, a South African manufacturer of fibre optic cables, and Corning, a supplier and part owner of Aberdare, approached the

Department of Physics at the University of Port Elizabeth to set up an optical fibre characterisation research programme in 1999 (Paterson, 2006).

The search by enterprises for university-centred organisational arrangements for innovation meshed into other initiatives arising primarily on the university side of the relationship with support from a different set of policy initiatives.

4.2.1.2. Policy to stimulate innovative activity in the university sector

As noted in Chapter 3, the DTI and DST have developed a range of initiatives to provide financial support for various kinds of interactive innovative activity involving universities or science councils and business enterprises, principally the Innovation Fund and THRIP. Drawing on the valuable studies of knowledge networks in Kruss (2006), the report focuses here on the university sector to illustrate the considerable flexibility and diversity of the organisational vehicles developed for collaborative innovation. Their flexibility and diversity is striking both with respect to the network arrangements within which higher education institutions (HEIs) are embedded, and with respect to organisational arrangements created by the HEIs themselves as bases for their networked relationships.

The types of network in which universities have been involved have included a wide range of partners that have contributed directly to innovative activity: government departments at national and provincial levels, other HEIs, the science councils, international academic collaborators, industry associations, large corporations (both local and foreign-owned), and small start-ups. These organisations have interacted in various ways. In many cases, projects have involved several business enterprise collaborators or several HEIs. Among the latter, several projects have linked together more basic/strategic research capabilities in established universities with more applied and engineering-oriented capabilities in technikons and historically disadvantaged universities. The array of arrangements reflects a vibrant structure of organisational interaction and is an important component of the country's innovation system.

A striking feature is the development by HEIs of varying organisational mechanisms as vehicles for collaboration. These seem to have been aimed at resolving one or more of three common problems: *i)* bridging the interface between academic activities, which tend to be structured along disciplinary lines, and practical problems that tend to require multidisciplinary solutions; *ii)* capturing academic benefits from collaboration, especially training and learning opportunities for students, while insulating other academic activities from more alien and short-term influences of business collaboration; and *iii)* finding ways of disconnecting administration and management from the responsibilities of academic staff without burying the need for speed and flexibility beneath inflexible academic bureaucracy.

Some projects do not address these organisational issues and collaboration involves relatively simple and direct relationships between academic groups and business enterprises. For others, efforts were made to address at least some of these issues essentially by linking the organisational mechanism specifically intended to support university-industry interaction and the academic structure. For example, at the former Technikon Pretoria, the French South African Technical Institute in Electronics (which later became the Incubation Centre for Technological Innovation) had considerable success in using its own personnel to forge research collaboration with industry and in engaging postgraduate students in these activities, although it had much less success in involving the academic faculty (Paterson, 2006). Other cases have involved more organic development of new and evolving mechanisms for collaboration (Kruss, 2006).

Such kinds of organisational invention in the HEIs are part of a broad extension of their activities towards more explicitly use-oriented R&D. Sometimes described negatively as “mission creep”, this seems to be entirely consistent with global trends towards forms of knowledge production that are more closely connected to its use, as well as being executed via new kinds of organisational vehicle.

4.2.1.3. Strategies to link technological development to industrial innovation

The National Strategy for Research and Development identified a number of national innovation missions, among which two have so far been particularly important in stimulating the development of new organisational vehicles for innovation: the National Biotechnology Strategy and the National Advanced Manufacturing Technology Strategy (DST, 2002). The Biotechnology Strategy has led to the creation of Biotechnology Regional Innovation Centres (BRICs) which act mainly as funding and facilitating bodies concerned with commercialisation and cluster development in three regions of the country. The design of AMTS, instead, included the development of new organisations that would perform innovative activities.

The AMTS emerged from two lines of policy: the DST’s National Strategy for Research and Development and the DTI’s Integrated Manufacturing Strategy, the latter being a component of the government’s wider Microeconomic Reform Strategy. The report initiating the AMTS expressed the intention to create innovation centres and innovation networks to support innovation across a wide range manufacturing technologies (CSIR, 2003).

Innovation centres should, it was suggested, take two forms: technology competence centres and sector support centres. As the names suggest, the former would focus R&D programmes on specific areas of technology that might be relevant to several sectors, while the latter would be more technologically diverse, focusing on particular segments of industry. As an illustrative example, it was suggested that one sector support centre might involve an expansion of the scope of the Automotive Industry Development Centre towards greater emphasis on R&D. Another example would involve the creation of a National Textile and Clothing Innovation Centre, again with R&D as a central function. Innovation networks would be more spatially dispersed. As with the centres, they would differ between sectorally oriented organisations (*e.g.* a Chemical Industry Network) and technologically focused organisations (*e.g.* an Advanced Materials Network).

4.2.1.4. Implementing the Integrated Manufacturing Strategy

The DTI's Integrated Manufacturing Strategy also led to another strand of innovation-related organisational development: the Customised Sector Programmes (CSPs). These are designed as multi-functional action programmes for addressing the competitive challenges facing various groups of priority industries. Specific initiatives concerned with technological innovation were important components of these programmes. As illustrated in the case of the CSP for the metals sector (the Metals Sector Development Strategy, DTI, 2005), some of these involved mechanisms to undertake relatively complex R&D activities such as the Light Metals Development Centre and the Precious Metals Development Centre.

In several cases, however, the technologically dual structure of many South African industries called for initiatives to help build more basic foundations for innovation via skills development and incremental upgrading of products, processes and the organisation of production. This led for instance to the National Tooling Initiative which was embedded in one of the DTI's customised sector programmes (Intsimbi). It involved the creation of a network of non-profit organisations that would develop new and upgraded programmes to provide training in modern tool, die and mould-making technologies in nine provinces, as well as providing commercial loans to help recapitalise the industry.

Box 4.2. The National Casting Technology Centre

The Metals Sector Development Strategy (MSDS), developed within the framework of the DTI's customised sector programmes, outlined several organisational developments to support upgrading and innovation in various parts of the sector. One of these was a National Casting Technology Centre (NCTC) to help strengthen the competitiveness of the foundry industry. The plans appear to have been developed through a significantly bottom-up process, and so effectively reflect the nature of this industry's demand for technological and related support. The excerpts from the MSDS below give an indication of the nature of that demand and of its priorities.

"The NCTC will be driven by the needs of the local foundry industry and … its governing body shall largely comprise individuals and institutes representing the industry. Core to its initial activities will be the aim of improving the competitiveness of the South African foundry industry, through the development of skills training, dissemination of foundry technologies, research and statistics on movements in the local and international foundry industry. The core functions of the centre will encompass (in order of current need and priority):

- Casting Technology Training and skills development: … the NCTC will have equipment available to:

  Introduce trainees to the practical aspects of foundry operations … also able to offer localised and on-site training … aimed at the more practical applications of foundry knowledge and technology …. facilitate vocational training for university and early stage diploma students … facilities … would be made available for postgraduate research and development. … Will also actively encourage the countries' foundries and academic institutions to participate in foundry skills development programmes which may not take place on the NCTC site.

- SMME/BEE development: … key to the NCTC will be … programmes that assist SMEs to:

  Become sustainable businesses with access to good quality skills development and training … as well as the Skills Development funds. … Also the NCTC would be in a good position to identify and further encourage and improve skills of the potential BEE individuals … success of any SMME or BEE enterprise is reliant on the quality of skills within that enterprise. … The NCTC will be excellently positioned to develop and nurture excellent BEE talent in this regard.

- Foundry Support: … the NCTC will act as a reference facility for those individuals and companies:

  Offering specialised consulting based services to the foundry industry, the NCTC could provide assistance with the use of on site equipment in the following roles:

  - ✓ Product development (focusing on casting activities).
  - ✓ Trial production runs for new products and developments.
  - ✓ Component and materials testing.

- Research and development: … if the foundry industry can address its immediate and pressing problems with regards to skills development, technology implementation and SME development, then it would at some stage require services that involve intensive R&D capabilities. It would be up to the NCTC to develop and promote these capabilities to the local industry … new casting technologies and processes, the development of new casting materials, or … new products to meet specified physical and design criteria. However, the NCTC would need to be guided by its members' requirements in developing this aspect of its capabilities."

Source: DTI (2005).

A particularly striking initiative to strengthen the non-R&D basis for innovative activity was outlined in the CSP report initiating the Metals Sector Development Strategy. This noted that industry opinion considered that the performance of the AMTS "does not fully meet their requirements … (and) … needs to gravitate towards implementation" (DTI, 2005). It then outlined plans for a National Casting Technology Centre (NCTC). As indicated in Box 4.2, this was to be very firmly demand-driven by the industry, with an emphasis on *i)* basic skills development to support incremental upgrading in foundry operations, with an emphasis on black economic empowerment (BEE) aims, and *ii)* facilitating relatively incremental product development, trial runs and testing. Only at a later stage might it become relevant to facilitate and support the development of R&D capabilities and activities. In other words, in terms of the three institutional types outlined earlier, industry demand here pulled the structure towards service-based rather than technology-push types of organisation.

4.2.1.5. Organisational development and diversity: an overview

The above observations suggest that the response to several strands of government policy has been the development of a rich structure of organisational vehicles for innovation. Following a slight elaboration of the VTT framework in Figure 4.5, one can perhaps distinguish four broad strata.

- *Organisations undertaking strategic research* to generate new knowledge bases in advanced areas of science and technological development and serving to keep relevant parts of the industrial science, technology and innovation (STI) system well informed about the global frontier and well supplied with at least small numbers of specialists in those areas.

- *Organisations undertaking directed research* in areas that are defined primarily in terms of globally significant directions of technological development, but for which specifically South African needs or opportunities, or potential future needs, are identified.

- *Organisations undertaking applied research and technological development* with application envisaged fairly immediately, often associated with the fine-tuning or upgrading of established technologies, perhaps already in use in South Africa.

- *Organisations primarily providing services* to help firms exploit existing knowledge through the acquisition of various kinds of product design expertise, process engineering know-how and production skills that will enable them to upgrade their operations through incremental innovation.

Individual organisations do not fit neatly within these groups. In many cases they cut through them vertically. Such multi-level engagement in innovation is also evident in public organisations. Sometimes this involves two adjacent layers (as in the case of some universities), but other organisations are much more vertically integrated; CSIR, for example, is active on all four levels.

The broad features of this organisational structure do not seem to have been systematically reviewed. In particular, questions do not appear to have been raised about the part of this structure that consists of public organisations. For example, as noted in Box 4.3, the 2003 review of the CSIR encouraged the organisation to ensure that it covered all four strata, but it did not explicitly question whether this degree of vertical integration (*e.g.* compared to a greater degree of specialisation in a smaller number of strata) was appropriate for the current South African context or consistent with experience elsewhere. Given that the terms of reference for the review centred narrowly on the single organisation rather than the system sub-structure in which it was embedded, such questions could probably not have been raised.

Such questions seem also to have been absent in broader reviews. For example although the organisational structure for STI funding was considered in the *Evaluation of the Implementation of the South African Innovation Policy* (NACI, 2002), that study did not examine the structure of organisations more directly involved in performing and supporting innovation. The later *System-wide Review of the Science Councils of South Africa* (DST, 2006) did address some aspects of organisational structure but these were limited in two ways. First, even with respect to public organisations, the review was only partially "system-wide". It focused on the science councils without examining closely related innovative activities in either the HEIs or the nexus of organisations providing non-R&D support for innovation in business enterprises. Consequently, it was unable to address wider issues of vertical organisational integration, specialisation and overlap. Second, even within the science council component of the innovation system, the treatment of organisational structure only concerned the boundary lines between the *substantive content* of R&D performed by the different councils, not the kinds of STI *function* discussed here and also earlier when referring to organisational arrangements in several European countries in connection with Figure 4.5.

Raising questions about the functional structure of organisations that perform and support public innovation therefore seems overdue. Five observations may stimulate debate in this area.

First, the diversity of recent organisational developments outlined above seems to be evidence of a vibrant and creative phase of organisational invention and evolution. This seems entirely appropriate since South Africa needs to continue transforming the organisational and institutional basis of its innovation system in the context of a unique complex of economic and socio-political circumstances, as well as common global challenges. This calls for creativity in devising innovative organisational forms specifically fitted to those circumstances. A phase of apparent organisational "untidiness" is inevitable and even desirable.

Second, however, although it would be premature to impose limits on this diversity, aspects of the emerging structure need regular monitoring. Obsolescence and mistakes will inevitably occur. Evolution involves not only the emergence of new and adapted forms of organisation, it also involves the decline or extinction of inappropriate ones.

Third, one feature of the current structure seems striking: the convergence of several technology-push organisations (universities, science councils, and organisations such as advanced manufacturing centres) around broadly similar R&D functions at the second and third strata of the structure. This raises questions about whether greater functional differentiation and specialisation might be developed.

Fourth, an important process of demand-driven organisational development at lower strata seems to be emerging across quite wide areas of industry, perhaps especially with respect to non-R&D-centred organisations at the fourth level. This bottom-up evolution of the system seems to merit support and further development. This might be achieved in several ways. For instance, greater demand-driven coherence between the different strata might be reinforced by providing organisations in the lower strata with a significant degree of control over parts of fund allocation for development or research performed in higher strata in order to generate a more articulated pull on higher tier technology-push organisations. Also, demand pressures on public organisations from business enterprises might be enhanced; in other countries co-funding mechanisms between the state and industry have been widely used to try to ensure that there is an effective pull on the public system. The Norwegian tradition of user-driven R&D funding takes this notion a step further. The Research Council of Norway provides subsidies directly to companies to enable them to buy research or other technological services for specific projects from organisations in the knowledge infrastructure. The intention (which is reasonably well achieved) is to establish a customer relationship between the company and the research-performing or service-providing organisation.

Fifth, possibly the most important strand of organisational evolution involves deepening the levels of innovative activity in business enterprises. In many areas, the key issue will be to induce firms to start undertaking themselves the kinds of activities included in the fourth stratum. In others, it may be more relevant to concentrate on trying to reinforce the progression upwards from design, engineering and incremental upgrading towards more formally organised technological development and applied research. The development in public organisations of programmes in the various strata may need to place a high priority on incorporating particular kinds of function that support these evolutionary trends *in* business enterprises, rather than only on providing services *for* them.

4.2.2. Priorities, choices and critical mass

Among the most difficult issues facing any innovations system actor is the selection of priorities among different areas of scientific, technological or innovative activity and the choice of the scale of resources to allocate to particular activities. This problem is complicated by scale economies and critical minimum scales of capability and activity. Aims backed by the allocation of even marginally sub-critical levels of resources may not be just marginally under-achieved but be very substantially under-achieved or perhaps not achieved at all; those backed by larger allocations than are required for effectiveness absorb resources that might be better deployed elsewhere.

In the private-sector component of a national innovation system, powerful market signals and other pressures help to shape how these difficult issues are resolved. In the public sector, however, influences on resource allocation are much more diverse. This is partly because some elements of public sector allocation have a longer time horizon. They also deal with achieving social rather than commercial goals, and the signals and pressures are often less visible and immediately pressing.

This section examines the issue of public resource allocation. It is important to stress the impressionistic character of the comments made, although they are based on a wide range of documentary and interview sources. Consequently, rather than providing answers, this section raises questions regarding resource allocation at three levels of the innovation system:

- Projects, programmes and organisations within science and technology (S&T) fields.
- Projects, programmes and fields within organisations.
- Different sectoral innovation systems within the overall national system.

Specific examples illustrate points of argument, but are less directed at the specific projects, programmes or fields of science or technology than at the overall issue of selectivity and concentration in resource allocation and the general questions that may arise about diversity, fragmentation, critical mass and effectiveness.

4.2.2.1. Resource allocation within S&T fields

There appear to be quite widespread concerns that in particular fields of research, development or other innovation activities the available resources are often spread too thin across projects, programmes and organisations. The consequence is that the scale of an activity is too small to achieve really effective impact, or more precisely, too small to achieve the intended aims. For example, a participant in the field of materials research has described the situation as one in which individual activities are often sub-critical in size (Box 4.3).

Box 4.3. Fragmentation in research: the case of materials research

In a paper prepared for a Human Science Research Council (HSRC) study of knowledge networks (later reported in Kruss, 2006), Professor Rob Knutsen of the Centre for Materials Engineering, University of Cape Town, included a short overview of the state of materials research in South Africa around 2003-04. Excerpts are reproduced below.

"Probably the most honest way of describing materials research in South Africa at present is that it is fragmented. There are pockets of activities at various HEIs scattered throughout the country, but the sum total of materials research activity is much less than 10 or 15 years ago.

"… there still exists some excellent research activities, although on their own they are often sub-critical in size. Notable exceptions include the Polymer Institute at the University of Stellenbosch, which has grown from strength to strength and is a sizeable operation on its own that is involved in a broad spectrum of polymer research.

> "It is reasonable to question the current level of fragmentation. The NRF has attempted several times to encourage not only inter-institutional collaboration, but also collaboration with the same institution and sometimes within the same department. The reaction has been slow and sometimes the resistance is obvious. Activities that are sub-critical in size do not guarantee sustainability of the research operation … (but) … there is light at the end of the tunnel in that concerted efforts are being made by DTI, through the National Advanced Manufacturing and Logistics Technology Strategy, to embrace the existing knowledge base in South Africa to develop knowledge networks to foster innovation."

Source: Knutsen.

The review team encountered views that similar difficulties were arising within the activities undertaken under the Biotechnology Strategy. Worries were expressed that, by the time resources were divided among the BRICs and then spread among the participating organisations and the individual projects, the scale of effort in individual activities was less than the critical mass needed to achieve the overall impact desired. Similar concerns were voiced about the dispersion of efforts across organisations, research groups and projects concerned with vaccine development within the South African AIDS Vaccine Initiative (SAAVI). If these kinds of concern are valid, the implications are important in such significant areas of innovation.

4.2.2.2. Resource allocation within organisations

It was not possible to identify analyses demonstrating the existence of a scale effect on achieved impact. However, in some situations it seemed pertinent to question whether resources were being spread too thin. For example, there are several indications that efforts have been stretched in various ways at CSIR in recent years (Box 4.4). This example is particularly interesting because the CSIR Review in 2003 offered a clear opportunity to raise questions about diversity and critical mass. However, this was not done, and in its main recommendation the review panel asked the organisation to stretch its activities wider. It emphasised that, while rebuilding its science-based activities, the organisation should "at the same time, seek, by all means, to retain, and indeed improve upon, the considerable progress that the CSIR has made in terms of generating external income". In other words, the message was that the organisation should not choose between activities intended to strengthen its science and technology base and those at the more applied downstream end of the spectrum. It should make sure to cover both. This vertically linked profile of activities might be highly desirable, but can it be executed effectively across an unchanged array of technological fields?

Box 4.4. Policy diversity and critical mass at CSIR

One dimension of the diversity of the portfolio of CSIR activities has been extensively examined over recent years: the emphasis it should give to activities to strengthen its science and technology base, on the one hand, and to more immediately income-earning applied, consultancy and technical service activities, on the other. The 1997 CSIR Review suggested the latter should be intensified while the 2003 Review suggested that greater emphasis should be given to the former.

However, much less attention seems to have been given to another kind of diversity: the spread of CSIR activities and resources across different scientific fields, technologies, problem areas and application domains. The 2003 Review did suggest that there was a need to align resource allocation more closely with national needs, but it did not raise questions about the diversity of needs to be addressed with the available resources. The review did consider the "market spread" of the organisation's activities within and across its business units. However, the action suggested was to consolidate existing activities into larger business units, not to select among activities and concentrate so that they could achieve greater scale.

…/…

Box 4.4. Policy diversity and critical mass at CSIR *(continued)*

Discussions with a group of CSIR staff indicated that they had taken the 2003 review very seriously. Steps had been taken towards organisational consolidation by pooling the activities of individual units; efforts had been made to strengthen activities linked to the science and technology base; and new activities more closely aligned with national priorities had been added to the portfolios of the business groups. However, it was hard to identify any significant activities that had been deliberately discontinued or scaled back.

The overall portfolio of projects, topics, fields and problems seems to have been considerably extended although information is lacking to assess the consequences in terms of the scale of individual activities. However, there must be a question to ask about whether resources are being spread so thin that critical scale is being compromised in some areas.

As an illustrative example, the Materials Science and Manufacturing Division encompasses the following eight competence areas.

- ✓ Metals and metals processing
- ✓ Polymers, ceramics and composites
- ✓ Fibres and textiles
- ✓ Manufacturing science and technology
- ✓ Energy and processes
- ✓ Sensor science and technology
- ✓ Emerging science initiatives and industry themes
- ✓ Materials science and manufacturing agencies

This is a very wide spread of activities, especially when one bears in mind that most of the competence areas relate to broad fields of technology that have potential application across several industries. Also, from 2004/05 to 2005/06 the combined grant and contract income available for work in this area remained virtually unchanged (it actually fell slightly from ZAR 114.9 million to ZAR 114.5 million). It may therefore be asked whether all the individual activities in the Materials Science and Manufacturing Division can continue to reach the critical thresholds needed to achieve the intended high-quality contributions to the science base as well as major innovation impacts in firms and industries.

Similar questions arise at higher levels in the organisational structure, such as with respect to resource allocation across large-scale national programmes, "big science" projects and "big technology" initiatives at the level of the NRF or the DST as a whole. The DST for instance has recently launched or strengthened R&D programmes in oceanography and Antarctic sciences, in astronomy (the Square Kilometre Array Project and the Southern African Large Telescope) and in R&D support for the development of new energy technologies (both for the Hydrogen Economy and the Pebble Bed Modular Reactor – PBMR). This is a challenging portfolio of large and expensive projects. It is not clear that critical mass can be achieved in all, especially given the acute shortage of people with engineering and R&D skills.

It is clear from looking at individual programmes that there is strong capacity to devise strategies and plans. What appears to be missing, however, is an equally strong ability to balance the needs of different parts of the innovation system and therefore the portfolio of state actions.

4.2.2.3. Resource allocation across sectoral innovation systems

It is increasingly recognised that the resource allocation problem in national innovation systems is not just about allocation across fields, projects or organisations. It is also about fostering the emergence of constellations of competence centred on particular sectors of economic activity, sometimes discussed in terms of innovation clusters or sectoral innovation systems. The experience of OECD countries suggests that such constellations of competence have frequently emerged where dynamic sectors of the economy have co-evolved with fields of academic excellence: the chemicals industry in Germany and the pharmaceutical industry in Switzerland with those countries' academic strengths in chemistry; the automobile and electrical power equipment industries in Sweden with academic excellence in mechanical, electrical and electronic engineering; or the electronics and the information technology industry in California with academic strength in computing and materials science.

Several South African universities have achieved outstanding positions of research excellence. Box 4.5 shows South African universities among the leading 1% of all universities in several disciplines. Simply to appear in such a list demonstrates very high performance, and to appear in the first or second quartile is outstanding. It is therefore striking that in two of the discipline categories (clinical medicine and plant and animal sciences) six South African universities are located in the top 1%, with three or four in the first two quartiles of the top 1%.

It seems fairly clear that, in at least the first two of these fields (clinical medicine and plant and animal science), resources are sufficient to permit the achievement of research excellence. However, from an innovation perspective it is also important to ask whether enough resources are being allocated to facilitate the emergence of wider constellations of competence (or sectoral innovation systems) around these core areas of academic excellence. For example, with a core of academic performance like that in clinical medicine, one might envisage a nexus of related technological capabilities, including some combination of potential strengths such as medical instrument and equipment engineering (perhaps centred on the success of Lodox Systems), the emerging strengths in clinical trial services for pharmaceutical development, and more general hospital services exports. To succeed in this would almost certainly involve difficult choices, such as whether and how much to focus research and industrial efforts in areas sufficiently similar to be mutually supportive, as in Singapore's initiative to create a biomedical, life sciences and health services platform as a key hub for the next phase of that country's technology-driven economic development.

Box 4.5. Scientific excellence at South African universities

Pouris has analysed the citations to South African academic publications over the last decade and has found that the citation-based performance of South African universities is among the global leaders, *i.e.* their position among the leading 1% of all universities in each of 22 disciplines. South African universities appear in the top 1% in nine of the 22 fields. Six universities appear in this group. The author ranks those universities by their quartile within the 1% leaders in each discipline as in the table below.

Quartile ranking among the leading 1% of world universities in each discipline, 1995-2005

Scientific discipline	UCT	Pretoria	Orange Free State	Witwatersrand	Natal	Stellenbosch
Clinical medicine	1	2	4	3	2	2
Plant and animal science	2	2	3	4	2	3
Social sciences	2			2	4	
Environment/ecology	2	3		4		
Geosciences	3			2		
Engineering	3			4		
Chemistry				4		
Materials science				4		
Biology/biochemistry	4					

Source: Pouris (forthcoming), adapted from the original.

A further consideration is how many focus areas can be supported. It may be useful to bear in mind that, in other countries, economic development has often been driven by international technological and scientific excellence in a relatively small number of key sectoral systems; in Finland and Sweden, for example, it was driven by perhaps only three or four during any one phase of growth. In Japan in the post-1950 period, economic development was driven primarily by five or six sectoral systems producing products for which elasticity of demand in international markets was expected to be particularly high. Later, in Chinese Taipei, growth was driven by an even smaller number of sectoral systems of innovation and production, perhaps only three or four during any one phase. In Singapore the number of sectoral drivers during each phase of growth has been even smaller, only two or three depending on how one defines the boundaries.

In South Africa the PBMR programme perhaps illustrates some of the difficulties that may arise if too many major sector-level programmes are implemented simultaneously, at least when they draw on qualitatively similar bodies of underlying technological and engineering capability. This large R&D programme is part of the process of developing, designing and constructing a technologically novel (Generation 4) demonstration nuclear power plant by 2012. The expectation is that this will be followed by the design and construction of a number of commercial plants within Eskom's capacity expansion programme. At the same time, it is envisaged that if this moves forward successfully it will lead to export markets for technology, design/engineering services and perhaps items of plant, instrumentation and so forth. In other words, the PBMR project is currently in the developmental phase of building a new, technology-intensive industry in South Africa, in fact a new sectoral innovation system.

By 2006 this sector development programme had demonstrated strikingly one of the problems of an excess of projects for the resources available. The project's demands for scientific and technological resources were already impinging on other important areas of the science, technology and innovation system. As noted earlier, it is a significant contributor to the growing gap between demand and supply of design and engineering capabilities and probably helps to restrict the ability to achieve important investment-related objectives in other areas of the economy. It is also impinging on R&D capacity at other points in the innovation system. For example, CSIR has recently lost more than 20 engineers and scientists to the PBMR programme, presumably making it more difficult to achieve other important goals such as its contributions to major DST missions like the Advanced Manufacturing Technology Strategy. These cross-system effects are especially concentrated on a particular constellation of physical science and engineering capabilities: mechanical, electrical, electronic and chemical engineers, physicists, nuclear engineers, and so forth.[41] This therefore cuts across other priorities, such as the Advanced Manufacturing Technology Strategy and the Metals Sector Development Strategy, as well as investment programmes in the electrical power industry, the mining and downstream metals industries, the chemicals

41. Outside this particular constellation, other major sectoral development initiatives might have much less significant cross-system effects. For instance, a programme to facilitate the emergence of a life science and medical services innovation system might make demands on a constellation of capabilities which might more easily be met.

industry, the transport infrastructure, and export activities in services sectors like mining engineering.

If the resulting impression that decisions are often being made in ways that result in resources being stretched too thin over activities is correct, there is a need for a more effective overall mechanism to agree priorities, perhaps in the style of the Finnish Science and Technology Policy Council.

4.2.3. From strategy to implementation

One can trace in the STI-related activities of the DST and the DTI a fairly clear progression through successive stages of policy development, from the formulation and publication of broad strategies to implementation through programmes and projects. Such a process is not always tidily articulated such that all aspects of strategy developed in one period can be traced forward to implementation in a not too distant later period, and all implemented programmes in later periods can be traced back to their origins in earlier broad strategies. Nor does the process necessarily take place in a neat straight line. For example, the Biotechnology Strategy was incorporated into the R&D strategy, rather than emerging from it.

Some untidiness is inevitable and even desirable. Circumstances change, and a dirigiste system designed to ensure inflexible connections between strategy formulation and implementation would obviously be misplaced. But there are nevertheless important merits in maintaining strong connections between them. This section uses a few examples to explore how that balance has been struck in South Africa in recent years, focusing mainly on the Missions in Technology of the 2002 National Strategy for R&D. The degree of flexibility seems very high, with a considerable mismatch between stated strategic priorities and major implemented programmes. It may therefore be time to revisit the question of strategic priorities, though in a different way from the approach of 2002.

4.2.3.1. Inappropriate articulation between strategy and implementation: some illustrative examples

Two kinds of inappropriate articulation are visible in the implementation of major mission-type R&D initiatives.

- The *non-implementation of programmes* defined as priorities in national strategy. Two of the technology missions identified in the National R&D Strategy seem to be examples: one concerned with technology and knowledge related to resource-based industries, the other with technology and innovation for poverty reduction.

- The *implementation* of major programmes not previously identified as strategic priorities. The launch of major R&D and engineering activities for the PBMR programme appears to be an example.

Technology and knowledge to leverage resource-based industries

The National Strategy for R&D identified this area as the focus for one of its major technology missions. It argued that the resource-based industries were not priorities in their own right but "springboards for further development" of new, more knowledge-intensive growth paths that would be linked to, and derived from, those sectors. The industries were described as having:

> *"the potential to break out of the commodity pricing cycle by adding value in new ways, linking to new markets and by changing or enhancing the integration of logistics for export penetration. All of these areas are ripe for technological and institutional innovation."* (DST, 2002)

However, by the time of this OECD review, action to develop and implement this broad strategy had not been taken. There was a pale reflection of it in the Advanced Metals Initiative which incorporated three technology development networks (the Precious Metals, Light Metals and New Metals Development Networks). But these supported relatively small and focused R&D projects. There was no overall portfolio of R&D directions or other activities intended to achieve the broad kinds of innovation and knowledge creation envisaged in the National Strategy.

According to the DST, this mission was not implemented owing to an explicit decision and a judgement that "the industry was considered mature". That perspective seems to miss the apparent concern in the National Strategy with leverage and with developing directions out of these industries rather than within them. Incidentally also, it sets aside the experience of other countries, such as Australia, that have fostered an array of dynamic knowledge-intensive service industries around supposedly mature resource-based industries. It also fails to draw on the research-based insights noted earlier concerning the potential for diversification from innovative strengths in resource-based industries, and the window of opportunity to exploit the diversification potential of these resource-based industries during the current upswing of the commodity cycle.

Technology and innovation for poverty reduction

The National Strategy for Research and Development identified "Technology and Innovation for Poverty Reduction" as another of the four main technology missions. However, the review team is not aware of any substantial elaboration of the content of this mission or of any integrated approach to action under such a framework. Indeed this field was noted briefly as a weakness of the national innovation system in the background report for this project (NACI, 2006).

This does not mean that action to reduce poverty is not being taken in the innovation system. On the contrary, there are numerous examples of R&D projects and programmes that are clearly intended to do so. These include R&D projects concerned with improving access to health care, water, power, housing and so forth; the reorientation of agricultural R&D towards the problems of smallholder production and sustainable rural livelihoods. More broadly, STI activities that enhance employment opportunities in the first economy can be seen as contributing indirectly to poverty reduction in the second.

However, there appears to be no overall framework to co-ordinate and set priorities for what the innovation system can do to reduce poverty or to locate the main problems and limitations. More important, without such a comprehensive framework, it is virtually impossible to assess the adequacy of resource allocation to these innovation system activities relative to others.

The Pebble Beach Modular Reactor programme

South Africa's strong nuclear capabilities under the apartheid regime were subsequently massively scaled back. The 1996 White Paper on Science and Technology described the field of atomic energy as having been the subject of "large-scale rationalisation" (notably the closing of the enrichment programme), and activities had been reoriented towards commercial applications. Three years later, nuclear power was barely visible in the report of the Energy Sector Working Group in the National Research and Technology Foresight project (DACST, 1999). The working group identified ten research and technology challenges for the medium term and a further eight for the medium to long term. PBMR technology was not included among these 18 priorities, although it was identified as the last of three further areas of technology that the group felt required "further consideration". The technology was not mentioned in the National Strategy for Research and Development in 2002. It was not included in the four technology and innovation missions (Sections 5.5 and 8.1) nor in any of the six established or planned centres and networks of excellence (Section 6.4).

However, as noted earlier, by 2006 the PBMR R&D programme had emerged as a large-scale activity in the process of developing, designing and constructing a new, technology-intensive industry in South Africa; and the scale of this development programme was having a major impact on the innovation system as a result of its demand for scientific and technological human resources.

These three examples thus indicate a very high degree of flexibility between strategy and implementation. In effect, half of the four major technology missions in the 2002 National Strategy seem not to have been developed and implemented.[42] On the other hand, an R&D programme that was not part of the National Strategy four years ago has been implemented on a larger scale than any of the priority missions of 2002, and probably with much larger cross-system effects.

This degree of mismatch between identified strategic priorities and implemented programmes suggests that it may be time both to revisit the National Strategy and to consider the effectiveness of existing co-ordination and governance mechanisms.

4.2.3.2. Another look at strategic innovation missions

The 2002 National Strategy identified the priority technology missions in several ways, some of which would now be thought inconsistent with approaches in other countries. Some of the missions were identified in terms of sectors of the economy and society in which intensified innovation was needed (around the resource-based industries and in connection with poverty reduction). Others were defined in terms of types of technology (advanced manufacturing, information and communication technology and biotechnology). Also, although none of the missions was explicitly identified in terms of the kinds of science and technology functions that would be needed to connect fields of technology to innovation in particular sectors, the wider context of the mission statements implied that the focus was primarily on R&D.

The sector-centred component of the approach is consistent with the growing emphasis in other countries on the importance of sectoral differentiation in innovation policy. As one example, a recent report on new approaches to innovation policy in the United Kingdom captured this view:

42. The proportion may possibly be larger because the status of the sub-mission concerned with ICT is not clear.

> *"We need a textured innovation policy that recognises one size does not fit all sectors. The recipe in the pharmaceutical sector will not work for financial services or for public services. This leads to a requirement for us to gather sounder intelligence and analysis of the sources and contribution of innovation across different economic sectors."* (National Endowment for Science, Technology and the Arts, 2006)

On the other hand, it is increasingly emphasised that specific technologies are only one of many inputs to innovation, and that the categories of technology commonly identified in policy statements (*e.g.* biotechnology, nanotechnology) are much too heterogeneous to serve as focal points for meaningful priorities, partly because the segments of such fields that are most important for innovation vary widely across sectors. At the same time, it is increasingly recognised that R&D is only one of many interconnected functions that contribute to innovation (*e.g.* OECD, 2005).[43]

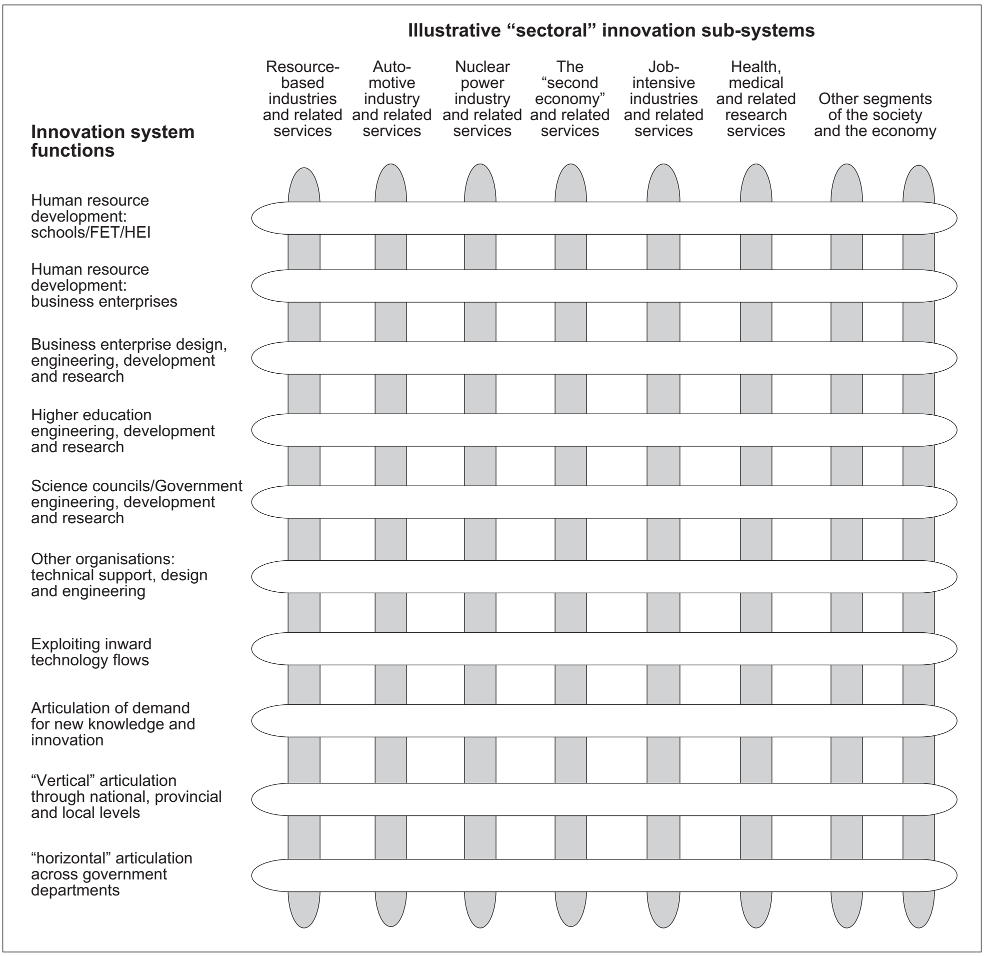
Consequently, it appears that an approach to revisiting the 2002 strategic priorities might appropriately be located in the tradition of the South African innovation system perspective, and could begin from innovation strategy rather than R&D strategy. It might also place much more consistent emphasis on the sectoral dimension, identifying innovation priority missions as centred in selected segments of society and the economy, including the appropriate nexus of interacting suppliers and services.

But then, as illustrated in Figure 4.6, such sectoral priorities (columns) would be simultaneously defined in terms of the relevant array of priority functions (rows) required to intensify innovation in each sector. Recalling earlier parts of this report, these might be identified in terms of: *i)* different types of a human resource creating function; *ii)* technical support and knowledge transfer, design, engineering and related functions as well as R&D; and *iii)* functions concerned with exploiting flows of technology from international sources. Such an approach would encourage systemic thinking in the process of setting priorities. Further, also in light of earlier comments, key functional elements of innovation strategy would identify not only supply-side functions, but also functions concerned with articulating demand for innovation in the sectoral segments of the innovation system. Explicit identification of the mechanisms for vertical articulation between national, provincial and local levels would also be important, taking note, for instance, of the kinds of issues identified in relation to the South African

43. See also the neat summary of this point in a chapter about higher education research in a recent South African Council on Higher Education report: "The R&D system is a subset of the national science and technology (S&T) system, which in turn is a subset of the national system of innovation (NSI)." (CHE, 2004)

automotive sector by Morris *et al*. (2006).[44] Explicit recognition of specific sectoral needs for cross-cutting integration across government departments would also be important, an issue explored in more detail in the next section.

Figure 4.6. Framing strategic priorities for innovation: an illustrative outline



44. The current NACI study of the profile of local and provincial innovation systems being undertaken by Jo Lorentzen should make a valuable contribution to understanding these vertical relationships in the national system.

4.3. Research and innovation structures and governance

Research and innovation governance in South Africa appears to lag good international practice in at least two respects. First, there is no forum or arena at the highest level of government that plays a strong integrative role across the whole of government, not least in balancing the various policies and instruments that in practice combine to make up innovation and research policy. This is compounded by the normal difficulties of co-ordination across different ministries, despite the innovative use of clustering. Second, there is limited separation between customers and contractors in the public research system. Important strengths include good capacities for strategic intelligence.

Raising the importance and profile of innovation requires greater strength in terms of implementation. It would be useful to set up a Nordic-style innovation agency inside or outside the NRF to achieve this. This could create continuity and a counterweight to intra-ministry planning. Such an agency could play a useful co-ordinating role by implementing policies for multiple ministries, as do the Research Council of Norway and the FFG in Austria.

4.3.1. International experience

Since behaviour and learning are central to an innovation system perspective, so are the ways in which these are institutionalised and their governance. OECD countries have devoted increasing attention to the question of governance of research and innovation in recent years, in an effort to understand how to make the best use of public research and innovation resources (OECD, 2005).

Studies of governance of research and innovation suggest that there is no single optimal pattern. A simple model of organisation and governance of research and innovation is used here (Figure 4.7).[45] It is a generic model that does not represent any particular national practice. The scheme has four levels of policy co-ordination:

- *Level 1* is the highest level. It involves setting overall directions and priorities across the whole national innovation system. It may be achieved through advice to government or by more binding means, such as decisions of a cabinet sub-committee.

45. This was developed in collaboration with Martin Bell, SPRU, in a project for the National Science and Technology Development Agency of Thailand in 2002.

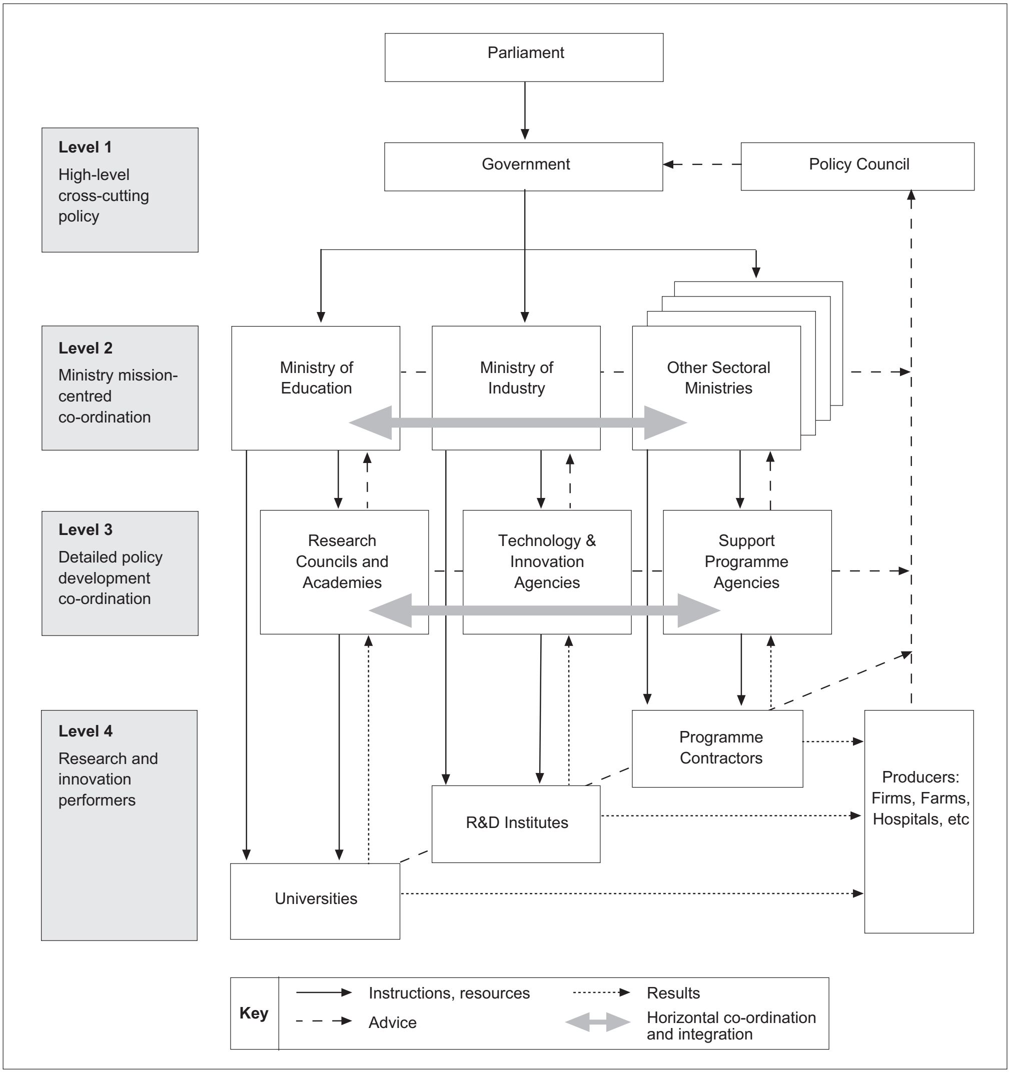
- *Level 2* is co-ordination among ministries whose sectoral responsibilities otherwise encourage them to pursue independent policies. In practice, this level of co-ordination may involve administrative aspects, policy issues or both. Sometimes an inter-ministerial group also functions as the Level 1 co-ordination mechanism.
- *Level 3* is more operational, with an attempt to make a coherent whole of the actions of funding agencies. This level, too, can involve administrative co-ordination as well as more substantive co-ordination of funding activities, such as co-programming.
- *Level 4* involves co-ordination among the bodies that actually perform research and innovation. Co-ordination at this level tends to be achieved through self-organisation rather than formal mechanisms.

Despite the apparent complexity of Figure 4.7, the network of flows of information and resources shown is actually much simplified as compared with what happens in reality.

Most of the vertical flows shown are formal. They amount to or concern *de facto* “performance contracts” between institutions at the different levels. The exception tends to be flows into the policy council, which are generally people-based rather than paper-based, and therefore informal. In many systems, especially in smaller countries, informal co-ordination is also achieved through the presence of members of institutions on the governing or internal advisory committees of other institutions. Such networks and interrelationships allow governance to play a number of important roles within the state’s rather complex activities in funding and managing aspects of research and innovation. Key research and innovation governance functions include (Arnold and Boekholt, 2003):

- Setting directions.
- A referee.
- Horizontal co-ordination.
- Co-ordinating production among knowledge producers.
- Intelligence.
- Vertical steering.
- Enhancing the profile of research and innovation.

Figure 4.7. Generic organisational structure for research and innovation policy



4.3.2. Strategic intelligence

South Africa has moved a considerable distance towards building a strong capability to undertake policy-relevant research on and analysis of the national innovation system. Part of this consists of the in-house capabilities of the main policy-making bodies (DST, DTI, the Department of Minerals and Energy, and others that influence innovative activity across the economy and society). Another in-house part lies with the staff of larger STI organisations such as the CSIR and the secretariats of advisory bodies such as the National Advisory Council on Innovation and the Council of Higher Education. A further important part consists of capabilities outside such bodies, mainly in academic organisations. This has three main components.

The largest is located in the Human Sciences Research Council and has several segments. Perhaps the core is the Centre for Science and Technology and Innovation Indicators (CeSTII). It is particularly important because it now has responsibility for the national R&D and Innovation Surveys following a disruptive decade-long phase of migration between several different organisations. In 2004 a Memorandum of Agreement between DST and Statistics South Africa formalised this arrangement as the basis for the official national science and technology statistics. Other segments of HSRC capability in this field are contained in a changing portfolio of substantial research programmes such as the Employment and Economic Policy Research Programme, the Education, Science and Skills Development Research Programme, and the Research Programme on Human Resource Development which undertook the flagship project leading to the excellent collection of studies published as the Human Resources Development Review 2003 (HSRC, 2003). Through a series of projects and commissioned studies over several years, these programmes have fostered a deepening base of expertise both within the staff of HSRC itself and among a wider network of collaborators.

A second component consists of small research groups in at least the following universities: the University of Stellenbosch (Centre for Research on Science and Technology), the University of Pretoria (Institute for Technological Innovation), Tshwane University of Technology (Institute for Economic Research on Innovation), the University of Cape Town (Programme for Science Studies in the South), and the University of Limpopo (Social Innovation Centre). These relatively formal groups blur into a third component that consists of individuals and small groups in universities and private consultancies. These play an important role as a wider network that not only contributes to projects undertaken by the other two components, they also undertake an array of studies on specialised aspects of innovative activity in South Africa: work in economics departments on clusters and industrial upgrading and innovation in the automobile industry (the University of KwaZulu-Natal) or on the details of innovative activity in Ekurhurleni (the University of the Witwatersrand).

All this activity is an extremely valuable resource. The core survey activities and associated analytical work at CeSTII now appear to be very soundly based, with strong capabilities of international standing at a senior level and a strategy to strengthen middle-level and younger cohorts. Given the importance of these activities as a basis for providing data and intelligence about the innovation system, and given the particular significance of accumulated experience at national and international levels in this field, it is important to maintain this stability and to further strengthen these capabilities so that they are not weakened by the normal patterns of personnel mobility.

Two other issues merit consideration. First, it appears that all three academic components in this field are dependent on specifically commissioned work from bodies like DST, the National Advisory Council on Innovation (NACI) and the DTI. This is excellent, and it is impressive that these bodies are able to draw on such strength of expertise. However, research that goes beyond what is thought to be of immediate importance by policy bodies plays a very important role in many other countries, and it might be useful to consider whether there are adequate channels for funding work that is independent of specific commissioning. Second, given the limited size of the apparent market for this kind of work, it may be spread too thin to achieve sufficient scale and multidisciplinarity. It might be useful to consider encouraging the emergence of somewhat larger centres of excellence to complement the work being undertaken in the HSRC, with two caveats: it would be important to provide preferential infant-industry support to encourage the emergence of such a centre among the historically disadvantaged institutions, and it would remain very important to leave open opportunities to support specialised high-quality work by individuals and small groups. The French Ministry of Research, the UK Economic and Social Research Council, the Research Council of Norway, the Finnish Ministry of Trade and Industry and VINNOVA in Sweden have all run programmes intended to build this kind of capacity.

4.3.3. Vertical steering and contracting

This section discusses vertical governance relationships among the institutions involved and the following section considers horizontal co-ordination and overall direction setting. The current South African structure was shown in Chapter 2 (Figure 2.10).

At the highest level, the Parliamentary Portfolio Committee for Science and Technology (comprising members of Parliament) oversees the activities of the DST. At Level 3, the NRF is the only sizeable agency in the system, in the sense that it deals with multiple programmes. It also has multiple principals. Like the Research Council of Norway and RANNIS in Iceland, the NRF spans the different skills and cultures involved, in that it is both a research council and an innovation agency. Most countries separate these functions. While there are strong theoretical reasons for preferring to have a single agency tackling both research and innovation, there is not much evidence to suggest that the unified model works in practice.[46]

At Levels 3 and 4 the use of research councils (actually, research institutes) is widespread. These typically receive a substantial grant from the responsible ministry and have a mandate both to set priorities for individual projects and to do research. The MRC spans Levels 3 and 4, not only setting internal priorities and performing research but also acting as a funding agency for external contractors (primarily in the higher education system). As a result, the small number of agencies (Level 3) is striking compared with current OECD practice, in which the research and innovation funding function is generally separated from project performance.

This reform looks back to the work of the Rothschild Committee in the United Kingdom in 1971, which criticised the high level of self-determination by the research community in relation to government-funded applied research:

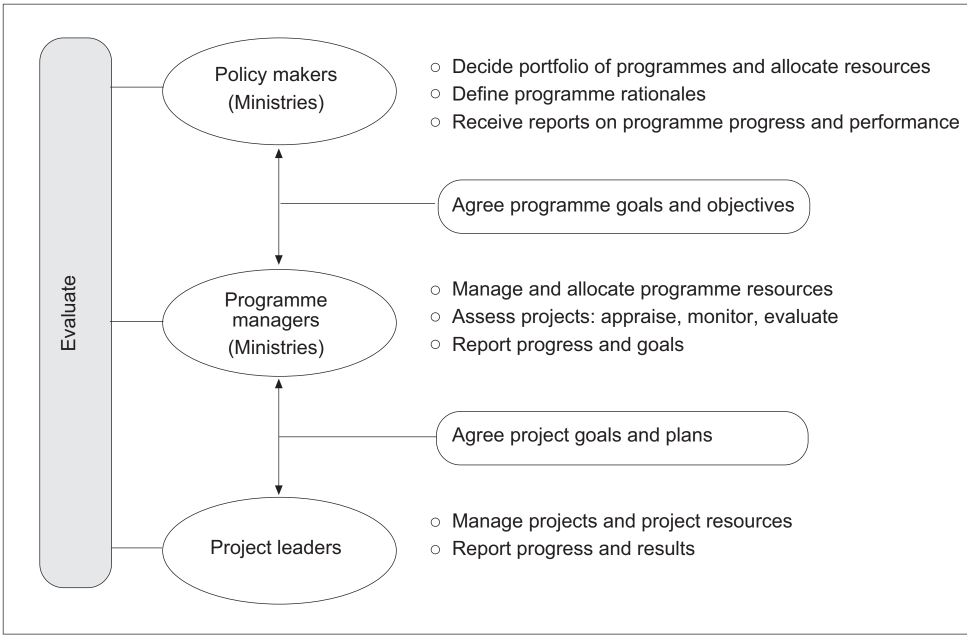
> *"This is wrong. However distinguished, intelligent and practical scientists may be, they cannot be so well qualified to decide what the needs of the nation are, and their priorities, as those responsible for ensuring that those needs are met. This is why applied R&D must have a customer"* (Rothschild Report, 1971).

The Rothschild principle of separating customers and contractors led the United Kingdom to break up the single Science Vote and allocate portions of the money to the respective customer ministries. More broadly, it reinforced the separation of functions in research and innovation policy, purchasing and performance that is seen in most countries today. Correspondingly, the new public management movement would seek a clear and contractually explicit distinction between the policy-making (ministry), customer (agency) and contracting (project-performing) levels of government,

46. The evidence from Norway is inconclusive (essentially because in the eight years prior to its evaluation, the Research Council's management failed to integrate the working of what in practice functioned as six agencies under a common roof (Arnold *et al.*, 2001), and the new organisation of RANNIS is too recent to provide useful evidence.

in order to increase transparency and to create markets at the interfaces between the layers (Figure 4.8).

Figure 4.8. Policy, programme and project management with evaluation



Source: Arnold *et al*. (1996).

In principle, a vertical division of labour has important benefits. It forces greater clarity about objectives, because these have to be written into contracts and communicated by the principals to their agents. It enables competition between research performers at the project level and between alternative agents or agencies at the programme level. A major drawback is that – if implemented in a literal way, so that the policy level makes policy in isolation or only based on the feedback obtained through reporting on existing programmes – the policy level is starved of the information it needs to make good policy. Where strategic intelligence is located in the system seems therefore to be important, though there are considerable variations in practice:

- Ministries clearly need analytic capabilities in order to make evidence-based policies and to act as intelligent customers in dealing with agencies and others.
- Agencies – especially multi-functional ones like the NRF – need analytical capabilities in order to tune their activities, identify and exploit synergies across their multiple tasks (for example, encouraging links between more fundamental and more applied research) and to codify what they learn in direct interaction with research institutions and companies.
- There needs to be an extramural market for analysis and policy advice in order to provide criticism, ensure the openness needed in a democracy and provide capacity that ministries and agencies cannot afford to maintain in house.

Finland maintains such a balance in research and innovation, and is widely regarded as a role model for balanced yet determined policy making and implementation. Sweden lacks capacity at the ministry level. Hence *de facto* policy making is split among agencies, and there is little overall policy direction. The Netherlands has in the past concentrated strategic intelligence in the Economics Ministry but the resulting remoteness from practice led the Ministry to require SENTER (the innovation agency) to establish an analysis unit.

There are difficult trade-offs to be made in relation to research institutes such as the South African research councils. If the mission of an institute is so important that the state needs to maintain a national capacity in the area, it also needs to ensure that there is an adequate supply of work. New Zealand's experience with making all R&D funding for the Crown Research Institutes (CRIs) contestable was that it eliminated important research capabilities and led to the disappearance of one of the institutes. As a result, the Ministry of Research, Science and Technology has introduced a CRI Capabilities Fund that provides non-contestable core funding. At the same time, giving the institutes too much power in priority setting encourages internal inefficiency and hampers the development of other parts of the research-performing system. It is not necessarily the case (to take just one example) that Mintek is always the best research performer in all matters relating to mining and it is not appropriate that Mintek itself should be in a position to decide this.

Many countries settle on a compromise according to research institutes whose primary customer is the state remain highly funded research-performing agencies of government. These are especially likely to operate in areas like marine or environmental research, where a significant part of the institute's task is to provide the knowledge needed for regulation (*e.g.*

monitoring fish stocks, understanding the relationship between national sources of pollution and climate change). Other institutes, especially industrial ones in the style of CSIR, get less grant funding and are more exposed to research markets. In order to maintain a balance between intramural and external research, Norwegian ministries are required to direct part of their research budgets to the Research Council of Norway, which uses it to fund contestable research in the ministry's area of interest. Ministries therefore have to take responsibility for at least some of the research relevant to their mission and to make an explicit decision about encouraging the development of multiple sources of knowledge in their areas.

Thus, in OECD countries, the degree to which a three-level structure is used depends partly on the sector. In research and innovation policy areas, where the number of potential project performers is large, "agencification" is frequent. However, in areas such as agriculture, where the state acts as proxy customer for end-users of knowledge who have limited absorptive capacity, and in areas like geology where knowledge production is largely intended to support government and regulation, there is less "agencification".

4.3.4. Horizontal co-ordination

Both the Department of Science and Technology and the Department of Education have their own high-level advisory councils. However, there is no high-level body responsible for the direction of the whole of research and innovation policy. There is an independent South African Academy of Sciences, and it is intended to create an Engineering Academy in 2007, but, as already mentioned, these do not appear to have a significant influence on government policy. As a result, there is no Level 1 arena for discussing research and innovation policy and setting cross-departmental priorities. Internationally, there is broad agreement that this function is important and general admiration of the Finnish Science and Technology Policy Council as a model. There are specific cultural reasons why this model works so well in Finland, but the role of the Council in representing a combination of the key stakeholders and ministers under the chairmanship of the Prime Minister, setting broad policy directions and ensuring that lower-level actors comply, appears to have been an important enabling factor for Finland's successful research and innovation policies over the past couple of decades.

South Africa is ahead of the pack, however, in that there is a general process in place for horizontal co-ordination at Level 2. The South African ministries organise a number of policy clusters in order to deal with problems that affect multiple ministry responsibilities.

In addition to the general cluster approach, 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; large-scale, broad-scope new S&T platforms and challenges (such as astronomy, human palaeontology and indigenous knowledge); and system-wide oversight functions, including establishing and maintaining a common governance framework, priority setting, and performance and budgetary monitoring systems. In 2005, DST representatives were appointed to the boards of a number of research councils and the Nuclear Energy Council of South Africa (NECSA).

There appear to be no formal horizontal co-ordination mechanisms in place at Levels 3 or 4.[47] The consequences of limited co-ordination may include an unbalanced mix of instruments, gaps and mismatches in terms of resource availability. It is difficult to obtain definitive figures from the sources available, but if one looks across the DST and DTI system at funding of industry-relevant R&D and innovation at the performer level (Level 4 in Figure 4.7) one sees roughly the following picture of state spending in 2004/05:[48]

- Research and Innovation Support and Advancement (RISA), which is the binary component of university research funding within the NRF, has a budget of about ZAR 300 million, much of it in areas of social relevance (given NRF's priorities), and some of it industry-relevant, at least regarding the generation of human capital.
- THRIP, to which the state contribution was ZAR 131 million.
- The Innovation Fund, which involves commercialisation of university knowledge in partnership with industry, ZAR 210 million.
- CSIR, ZAR 714 million, of which ZAR 366 million in a parliamentary grant via DST and ZAR 348 million in state contracts from DTI and others. (CSIR also sold a further ZAR 326 million to industry).

47. With respect to Level 3, this comment matches similar observations that have been made in several studies (*e.g.* NACI, 2002) in connection with the R&D funding organisations and mechanisms, an issue highlighted by the proposal in the 2002 National Strategy for Research and Development to establish a "Foundation for Technological Innovation" that would "draw together and integrate" various DST and DTI innovation, incubation and diffusion mechanisms and programmes (DST, 2002).

48. It should be noted that whereas DST and DTI are by far the main sources of public funding for industry-relevant R&D and innovation some component of the Department of Education's funding for universities pays for industry-relevant research.

- The Support Programme for Industrial Innovation (SPII) provided some ZAR 81 million in start-up finance to new technology-based firms.
- DTI's spending is hard to understand from available budget information. In addition to schemes like export credit guarantees and paying for the South African Standards Bureau, it spent ZAR 498 million overall on enterprise development, of which ZAR 188 million on the Small Enterprise Development Agency (SEDA), including an estimated ZAR 50 million for SEDA's technology division, which includes the former Godisa Trust and the Tsumishano centres. The DTI transferred ZAR 600 million to the Pebble Bed Modular Reactor company during the year. It is unclear what proportion of this is for R&D but the whole exercise can be regarded as state-sponsored innovation.

4.3.4.1. Implications for policy making and priority setting

South Africa operates a clear and transparent budget-setting process, effectively involving successive stages of planning and negotiation between spending ministries and the National Treasury. At each stage, documents become public once they are agreed, reflecting a high priority on open government. However, in the light of the increasing international consensus on the need for a holistic treatment of research and innovation policy, the fact that the general budget process effectively sets priorities across the whole research and innovation domain may be problematic. There would probably be advantages in establishing a national arena at government level to set broad directions and consider the ways in which research and innovation policies could be joined up, for example by reaching broad agreement on the expected role of large companies in the innovation system or discussing the broad balance between large-scale scientific projects and the need to develop industry's ability to undertake R&D in partnership with the research and higher education sector. Given the urgency of the human resource problem in South Africa, this issue would automatically be taken up in such an arena. Policy contradictions such as that between encouraging research-capable people to work in the South African research and innovation system and the extreme difficulty of getting permission for such people to migrate to South Africa could and should be resolved in such an arena. While Finland has perhaps excessively been the object of policy tourism and imitation in recent years, the model of its National Science and Technology Forum nonetheless has a lot to recommend it.

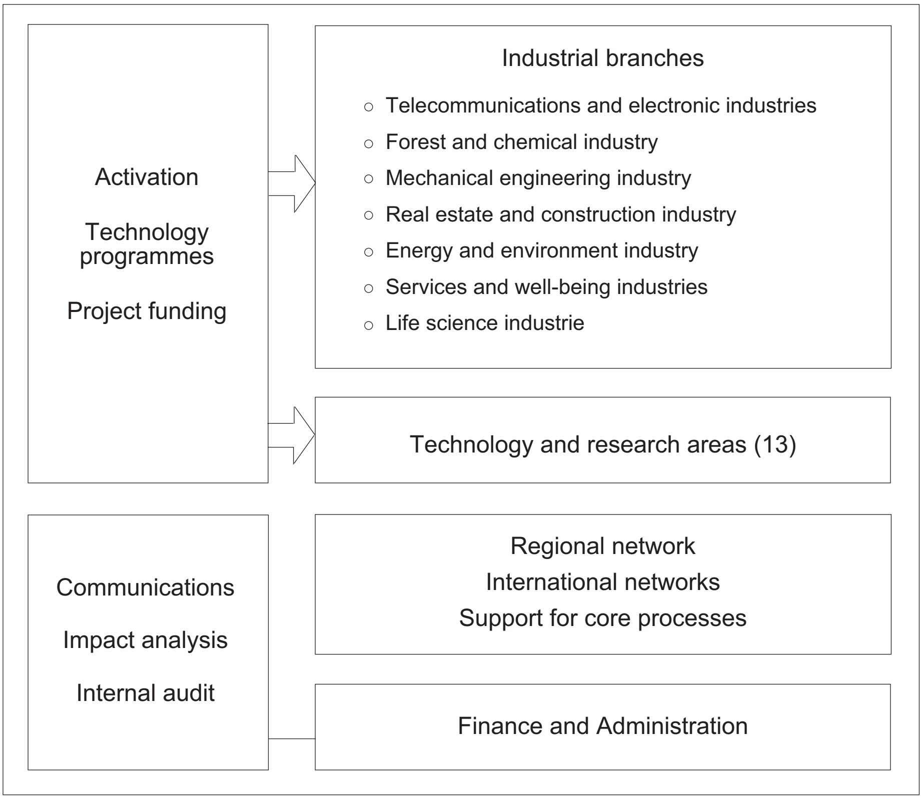
The vertical division of labour should also be examined, especially in relation to the research councils. As indicated, "agencification" of the funding function adds little value to research institutes that deal heavily with government missions. These institutes can be managed using a combination of performance contracts, simple performance indicators and careful qualitative oversight. However, when it is necessary to choose between allocating money and work to themselves or to others, "agencification" has two advantages. First, it makes resource allocation more objective and transparent. Second, it makes possible innovation in funding instruments and shifts in the emphasis of funding among different groups. Understandably enough, research institutes that largely set their own priorities tend to become locked into particular patterns of investment, technologies and partnership rather than changing these over time as needs evolve.

South Africa could usefully establish a Nordic-style innovation agency to bring together strategic research and innovation measures and to develop the capabilities both of the productive sector and of the knowledge infrastructure. Important characteristics of the Nordic agencies include:

- An innovation systems approach, so that they explicitly tackle institutional development – both in industry and in the knowledge infrastructure – not only disciplines or technologies.
- Technically and scientifically qualified staff in project and programme management functions, who can engage directly with at least some of the subject matter being funded.
- Strong internal strategic intelligence and dense networks with industry and the knowledge infrastructure which are very actively used in bottleneck analysis and programme design.
- Correspondingly, a strong *de facto* role in strategy and portfolio development, in partnership with the responsible ministries.

In Finland, TEKES (Figure 4.9) funds national innovation programmes in industry and the knowledge infrastructure. Most commonly, these take the form of technology programmes, which are planned together by industry, academics, institute researchers and other stakeholders and usually comprise two components: a programme of in-company R&D, funded using grant or loan instruments; and a linked programme of more generic research, primarily performed in the knowledge infrastructure but always with the participation of industry in a reference group with early access to the progress and results of the work.

Figure 4.9. The organisation of TEKES, Finland



The bulk of TEKES staff are organised in the eight industrial branch departments that focus on company interactions or in the 13 technology and research areas that are more focused on research and the knowledge infrastructure and cover:

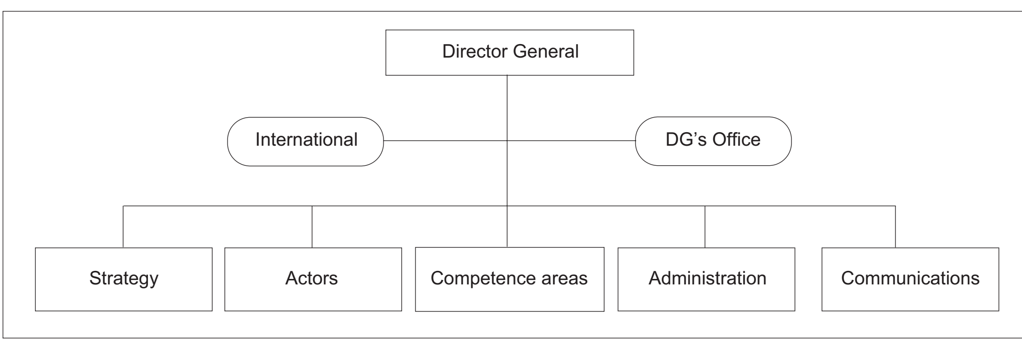
- Software and telecommunications technologies.
- Embedded systems.
- Industrial design and content management.
- Chemical technology.
- Process technology.
- Mechanical engineering and manufacturing technologies.
- Production systems.

- Materials technology.
- Bio- and heath technologies.
- Business competence.
- Built environment, safety and security.
- Service innovation.
- Space technology.

Constructing technology programmes therefore requires internal co-operation among people in the industrial branch and the technology and research area departments. This makes it possible to co-ordinate the work done in industry and the knowledge infrastructure and provides an important focusing device for them.

In Sweden, VINNOVA has a similar style of programme development, but with greater formal analytical inputs from its internal strategy function. Programmes almost always involve the knowledge infrastructure: the kind of direct industrial funding seen in TEKES is largely absent, and this is an important constraint compared with the TEKES model. Figure 4.10 shows the main blocks of VINNOVA's organisation.

Figure 4.10. The organisation of VINNOVA, Sweden



The group of actors focuses on institutional development, while the competence areas group focuses more on areas of knowledge and applications, specifically:

- Working life.
- Biotechnology.
- Information and communication technology.

- Manufacturing and materials.
- Services and IT.
- Transport.

These areas are subdivided into a total of 18 sub-areas, which are described in the VINNOVA strategy.

A key question is whether to do this in the form of a free-standing organisation or to incorporate it with a combined research council and innovation agency, such as the present NRF. In theory, a combined organisation should be a good move, since it allows the agency to devise strategies that cross the traditional boundaries between innovation, applied and fundamental research. However, as the evaluation of the Research Council of Norway (RCN) (Arnold *et al.*, 2001) showed, grasping the opportunities this provides is a considerable organisational task, bringing together two very different cultures and very different principles of funding and quality control.[49]

South Africa has followed a theoretically promising but practically difficult and unusual road. While, in principle, this seems a bold and positive step towards bringing the combined weight of the innovation and science system to bear on development priorities, it would be more encouraging if it were clear that this was a considered and deliberate choice rather than the present drift into a combined role at NRF.

49. In its first eight years, RCN failed completely to address this issue, instead functioning as six rather independent funding organisations with almost no co-ordination. Since the evaluation (in 2001), the Council has merged some of these responsibilities into three divisions, but it is not yet clear whether the integrative potential has yet been realised. The new organisation of RANNIS in Iceland is very recent, and it has chosen to set up separate internal committees for science and technology, so there as yet is no evidence about the success of this organisation but also structural reasons to suspect that RANNIS has simply internalised and reproduced the traditional opposition between researcher-directed and innovation-motivated funding and that this will have no meaningful effect on creating a holistic innovation and research policy.

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.

Contacts during the OECD review team's visit to South Africa

Luci Abrahams, Member of Council, NACI

Rob Adam, CEO, Nuclear Energy Corporation of SA (NECSA)

Miriam Altman, Executive Director, Human Sciences Research Council

Coen Bester, Fellow of SAAE and CEO of Brain Works Management Pty. Ltd

Chris Burman, Development Facilitation and Training Institute, University of Limpopo

Belinda Bozzoli, Deputy Vice Chancellor for Research, WITS

Renfrew Christie, Dean of Research, University of the Western Cape

Walter Claassen, Vice Rector, Research, University of Stellenbosch

Neville Comins, CEO, Innovation Hub Management Company Ltd

Robin Crewe, Vice Principal, University of Pretoria, President of the Academy of Science of South Africa

George Djolov, CEO, NCWSTI, University of Limpopo

Peter Franks, Campus Principal, University of Limpopo

Wieland Gevers, Executive Officer, Academy of Science of South Africa

Cronjé Grové, Manager Applied Research, Sasol

Alexandra Hofmaenner, Programme for Science Studies in the South, University of Cape Town

Michael Kahn, Executive Director, Knowledge Systems, Human Sciences Research Council

David Kaplan, Graduate school of Business, University of Cape Town

Jaco Kriek, CEO, PBMR (Pty) Ltd

Bingle Kruger, President, South African Academy of Engineering

Lis Lange, Director of Monitoring and Evaluation, Council on Higher Education

Steve Lennon, Managing Director: Resources and Strategy, Eskom

Eugene Lottering, Executive Director, Innovation Fund, National Research Foundation

Duma Malaza, Chief Executive, Higher Education South Africa

Jan Malherbe, Fellow of South African Academy of Engineering and Emeritus Professor, University of Pretoria

Hendrik Marais, Head, Secretariat of NACI

Gillian Marcelle, Principal Consultant, Technology for Development

Anthony Mbewu, CEO, the Medical Research Council

Philemon Mjwara, Director General, Department of Science and Technology

Shadrack Moephuli, Assistant Director General: Agricultural Production, Department of Agriculture

Mahlo Mokgalong, Vice Chancellor, University of Limpopo

N. M. Mollel, Acting Executive Dean, Faculty of Sciences, Health and Agriculture, University of Limpopo

Prof Mulder, University of Pretoria

Mr Dhesigan Naidoo, Deputy Director General, International Cooperation and Resources, DST

Ignatious Ncube, School of Molecular and Life Sciences, University of Limpopo

Prins Nevuhutalu, Deputy Vice-Chancellor, Tshwane University of Technology

Phuti Ngoepe, Director Material Modelling Centre, University of Limpopo

Blessed Okole, Strategic Partnerships Manager, CSIR Biosciences, CSIR

Adi Paterson, Chief Executive (DDG): Science and Technology Expert Services, DST

Francis Petersen, Head of Strategy, Anglo Platinum Corporation, and Board Member CSIR

Erlank Pienaar, Manager Radar and EW Systems, CSIR Defence, Peace, Safety and Security, CSIR

Calie Pistorius, Vice-Chancellor and Principal, University of Pretoria; Chair, NACI

Thomas E. Pogue, Institute for Economic Research on Innovation, Tshwane University of Technology

Johannes Potgieter, Chief Director, Innovation and Technology, DTI

Marjorie Pyoos, Group Executive, Government Sector Programmes and Co-ordination, DST

Molapo Qhobela, Chief Director, Higher Education Policy, Department of Education

Chris Reinecke, Research Manager, Sasol

C. de la Rey, Deputy Vice Chancellor, University of Cape Town

Simon Roberts, School of Economic and Business Sciences, University of the Witwatersrand

Chris Rust, Manager, science and Technology, Built Environment, CSIR

Johan Slabber, Chief Technology Officer, PBMR (Pty) Ltd

Olive Shisana, CEO, Human Sciences Research Council

Mala Singh, Executive Director, Council on Higher Education

Lourens van Staden, Deputy Vice-Chancellor, Tshwane University of Technology

John Stewart, Member of Council, NACI

A. Suliman, Senior Fund Manager, Support Programme for Industrial Innovation

Petro Terblanche, Executive Director, The Medical Research Council

Nhlanganiso Tshabala, General Manager (Research and Innovation), Eskom

Neil Trollip, Strategic Research Manager, CSIR Materials Science and Manufacturing, CSIR

Errol Tyobeka, Vice Chancellor and Principal, Tshwane University of Technology

David Walwyn, Group Manager, Research and Development, CSIR

Dirk Wessels, Director Research and Development, University of Limpopo

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

References

AfDB-OECD (2006), *African Economic Outlook 2005/2006*, African Development Bank and Development Centre of the OECD, Paris.

Aghion, P., M. Braun and J. Fedderke (2006), "Competition and Productivity in South Africa", CID Working Paper No. 132, Center for International Development, Harvard University.

Aghion, P., N. Bloom, R. Blundell, R. Griffith and P. Howitt (2002), "Competition and Innovation: An Inverted U-Relationship*",* IFS Working Papers, W02/04, Institute for Fiscal Studies.

Altman, M. (2003), "Jobless or Job Creating Growth? Some Preliminary Thoughts", Human Sciences Research Council, paper presented at the TIPS/DPRU Annual Forum, 8-10 September.

Altman, M. (ed.) (2007), *Resource-based Innovation in South Africa: Case Studies in Energy and Mining*, HSRC Press, Cape Town.

Altman, M. and M. Mayer (2003), "Overview of Industrial Policy", in Human Sciences Research Council (2003), *Human Resource Development Review 2003: Education, Employment and Skills in South Africa*, HSRC Press, Cape Town.

Altman, M., M. Mayer, G. Steyn, S. Roberts, D. Slater, K. Gostner, L. Letlape and R. Daniels (2003), *Promotion of Secondary Industrial Development and Clustering in Mpumalanga stainless steel and chemicals clusters*, Research Report for the Department of Economic Affairs, Gaming and Tourism, Mpumalanga Province, Human Sciences Research Council, Pretoria.

Amsden, A.H. (1989), *Asia's Next Giant: South Korea and Late Industrialization*, Oxford University Press, New York.

Amsden, A. H. (2001), *The Rise of "The Rest": Challenges to the West from Late-Industrializing Economies*, Oxford University Press, Oxford and New York.

Amsden, A.H., and W. Chu (2003), *Beyond Late Development: Taiwan's Upgrading Policies*, The MIT Press, Cambridge, Massachusetts.

Arnold, E. and P. Boekholt (2003), *Research and Innovation Governance in Eight Countries: A Meta-Analysis of Work Funded by EZ*

(Netherlands) and RCN (Norway), Technopolis, Brighton (available at www.technopolis-group.com).

Arnold, A., P. Boekholt and P. Keen (1996), *Good Ideas in Programme Management for Research and Technological Development Programmes*, Project HS-02 Report to the EC VALUE Programme, Technopolis, Brighton.

Arnold, E., N. Brown, A. Eriksson, T. Jansson, A. Muscio, J. Nählinder and R. Zaman (2007), *The Role of Industrial Research Institutes in the National Innovation System*, VINNOVA, Stockholm (forthcoming).

Arnold, E., S. Kuhlmann and B. van der Meulen, (2001) *A Singular Council: Evaluation of the Research Council of Norway*, Royal Norwegian Ministry of Education, Research and Church Affairs, Oslo.

Arora, V. (2006), "Economic Growth in Post-Apartheid South Africa: A Growth-Accounting Analysis", in Nowak, M. and L.A. Ricci, eds. (2006), *Post-Apartheid South Africa. The First Ten Years, International Monetary Fund*, Washington DC, pp. 13-22.

Arora, V., and A. Bhundia (2003), "Potential Output and Total Factor Productivity Growth in Post-Apartheid South Africa", IMF Working Paper WP/03/178.

Arora, V., and L.A. Ricci (2006), "Unemployment and the Labour Market", in Nowak, M. and L.A. Ricci, eds. (2006), *Post-Apartheid South Africa. The First Ten Years, International Monetary Fund*, Washington DC, pp 23-47.

Arvanitis, A. (2006), "Foreign Direct Investment in South Africa: Why Has It Been So Low?", in Nowak, M. and L.A. Ricci, eds. (2006), *Post-Apartheid South Africa. The First Ten Years, International Monetary Fund*, Washington DC, pp. 64-75.

Bhorat, H., M. Leibbrandt, M. Maziya, S. van der Berg and I. Woolard (2001), *Labour Markets and the Challenge of Poverty and Inequality in South Africa*, DPRU/GTZ.

Brandt, N. (2004), "Business Dynamics, Regulation and Performance", STI Working Paper No. 3, OECD, Paris.

Brusoni, S. (2005), "The Limits to Specialization: Problem Solving and Coordination in 'Modular networks'", *Organization Studies*, Vol. 26 (12), pp. 1885-1907.

Brusoni, S., A. Prencipe and K. Pavitt (2001), "Knowledge Specialisation, Organizational Coupling and the Boundaries of the Firm: Why do

Firms Know More Than They Make?”, *Administrative Science Quarterly*, Vol. 46, pp 97-621.

CeSTII (2006), *National Survey of Research and Experimental Development (R&D) – 2004/05 Fiscal Year*, Draft, Centre for Science, Technology and Innovation Indicators, Human Sciences Research Council, Cape Town.

Chandler, A.D., F. Amatori and T. Hikino (1997), *Big Business and the Wealth of Nations*, Cambridge University Press, Cambridge and New York.

CHE (2000a), Size and Shape Task Team: Discussion Document, Council on Higher education, Pretoria.

CHE (2000b), *Towards a New Higher Education Landscape: Meeting the Equity, Quality and Social Imperatives of South Africa in the 21st Century*, report of the Shape and Size of Higher Education Task Team, Council on Higher Education, Pretoria.

CHE (2004), *South African Higher Education in the First Decade of Democracy*, Council on Higher Education, Pretoria.

Cohen, W. and D. Levinthal (1990), “Absorptive Capacity: A New Perspective on Learning and Innovation”, *Administrative Science Quarterly*, No. 35, pp. 128-152.

CSIR (2003), *A National Advanced Manufacturing Technology Strategy for South Africa*, The AMTS Implementation Unit, Council of Scientific and Industrial Research, Pretoria.

CSIR Panel (2003), *Review of the CSIR*, Department of Science and Technology, Pretoria.

DACST (1996), *White Paper on Science and Technology: Preparing for the 21st Century*, Department of Arts, Culture, Science and Technology, Pretoria.

DACST (1999), *Foresight Energy Report*. Department of Arts, Culture, Science and Technology, Pretoria.

DBSA (2006), *Infrastructure Barometer 2006*, Development Bank of Southern Africa, Johannesburg.

Department of Education (2005), Student Enrolment Planning in Public Higher Education, Pretoria, March.

Dowrick, S. and J.B. DeLong, (2003), “Globalisation and Convergence”, in M. Bordo *et al.*, eds., *Globalization in Historical Perspective*, University of Chicago Press, Chicago.

DST (2002), *South Africa's National Research and Development Strategy*, Department of Science and Technology, Pretoria.

DST (2006), *System-wide review of the Science Councils of South Africa*, Department of Science and Technology, Pretoria.

DTI (2003), *Annual Review of Small Business in South Africa – 2003*, Department of Trade and Industry, Pretoria.

DTI (2004), *Small Business in South Africa – 2004, A Statistical Review*, Department of Trade and Industry, Pretoria.

DTI (2005), *Metals Sector Development Strategy*; Trade and Investment South Africa (Customised Sector Programmes), Department of Trade and Industry, Pretoria.

Du Plessis, S. and B. Smit (2006), "Economic Growth in South Africa since 1994", *Stellenbosch Economic Working Paper* 1/2006.

Edwards, L. (2003), "A Firm-level Analysis of Trade, Technology and Employment in South Africa", Discussion Paper 5, Globalisation and Poverty Programme, Department of Economics, University of Cape Town, Cape Town.

Edwards, L. and R. Lawrence (2006), "South African Trade Policy Matters: Trade Performance and Trade Policy", National Bureau of Economic Research Working Paper No. 12760.

Enos, J.L. and W.H. Park (1988), *The Adoption and Diffusion of Imported Technology: The case of Korea*, Croom Helm, Beckenham.

Fedderke, J. (2002), "The Structure of Economic Growth in the South African Economy: Factor Accumulation and Total Factor Productivity Growth", *South African Journal of Economics*, 70(4), pp. 612-646.

Fedderke, J. (2004), *From Chimera to Prospect: Toward an Understanding of South African Growth Absence*, School of Economics, University of Cape Town.

Feinstein, C.H. (2005), *An Economic History of South Africa: Conquest, Discrimination and Development*, Cambridge University Press, Cambridge.

Fine, B. and Z. Rustomjee (1996), *The Political Economy of South Africa: From Mineral-Energy Complex to Industrialisation*, Hurst, London.

Gelb, S. (2003), *Inequality in South Africa: Nature, Causes and Responses*, Report for DfID Project on Inequality in Middle-Income Countries: EDGE Institute, Johannesburg.

Global Entrepreneurship Monitor (2005), *South African Report 2005*, www.gemconsortium.org.

Godfrey, S. (2006), "Partnerships and Networks in New Materials Development", in G. Kruss, ed., *Creating Knowledge Networks*, Human Sciences Research Council, HSRC Press, Cape Town.

Goldstein, A. (2004), *Regional Integration, FDI and Competitiveness in Southern Africa*, OECD Development Centre Studies, Paris.

Granstrand, O., P. Patel and K. Pavitt (1997), "Multi-Technology Corporations: Why they have 'Distributed' rather than 'Distinctive Core' Competences", *California Management Review*, Vol. 39, No. 4, pp. 8-25.

Hausmann, R. and B. Klinger (2006), "South Africa's Export Predicament", *CID Working Paper* No. 129, Center for International Development, Harvard University.

Hoogeveen, J. and B. Özler (2004), "Not Separate, not Equal? Poverty and Inequality in Post-apartheid South Africa". World Bank Working Paper, Washington DC.

HSRC (2003), *Human Resource Development Review 2003: Education, Employment and Skills in South Africa*, Human Sciences Research Council, HSRC Press, Cape Town.

Human Science Research Council (2003), Nelson Mandela/HSRC Study of HIV/AIDS: South African National HIV Prevalence, Behavioural Risks and Mass Media, Human Sciences Research Council, Pretoria.

Hviding, K. (2006), "Liberalizing Trade and Capital Transactions: An Overview", in Nowak, M. and L.A. Ricci, eds., *Post-Apartheid South Africa. The First Ten Years, International Monetary Fund*, Washington DC, pp. 133-141.

International Monetary Fund (2006), *World Economic Outlook 2006*, Washington, DC.

Kahn, M. (2005), *Overview of HRD and R&D Policy: Recent Research and Indicators*, Human Resources for Knowledge Management Conference, Cape Town, 23-4 June.

Kahn, M. J. (2006), *Going Global: Working with South Africa's Universities*, Keynote Address to the University of Kwazulu-Natal Conference on Internationalization of Higher Education, 25 August, Durban.

Kahn, M.J., W. Blankley, R. Maharajh, T.E. Pogue, V. Reddy, G. Cele and M. de Toit (2004), *Flight of the Flamingoes: A Study on the Mobility of R&D Workers*, HSRC Press, Cape Town.

Kaplan, D. (2004), "South Africa's National Research and Development Strategy: A Review", *Science, Technology and Society*, Vol. 9 (2), pp. 273-294.

Kim, L. (1997), *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, Harvard Business School Press, Boston, Massachusetts.

Kingdon, G. Gandhi and J. Night (2004), "Unemployment in South Africa: The Nature of the Beast", *World Development*, Vol. 32, March, pp. 391-348.

Knutsen, R. D. (undated), "Towards Understanding the Role of New Materials in South African Society", report for the HSRC, Centre for Materials Engineering, University of Cape Town.

Koyama, T. and St. Golub (2006), "OECD's FDI Regulatory Restrictiveness Index: Revision and Extension to More Economies", *Economics Department Working Paper* No. 525, OECD, Paris.

Kruss, G., ed. (2006), *Creating knowledge networks: Working Partnerships in HigherEducation, Industry and Innovation*, HSRC Press, Cape Town.

Lawless, A. (2005), *Numbers and Needs: Addressing Imbalances in theCivil Engineering Profession*, The South African Institution of Civil Engineering, Johannesburg.

Lewis, J. D. (2001), "Policies to Promote Growth and Employment in South Africa", *Discussion Paper* 16, World Bank, Washington, DC.

Lord Rothschild (1971), The Organisation and Management of Government R&D, HMSO, London.

Lorentzen, J., ed. (2006a), *Innovation in Resource-based Technology Clusters: Investigating the Lateral Migration Thesis*, Human Sciences Research Council, Cape Town.

Lorentzen, J. (2006b), "DaimlerChrysler South Africa, Human Capital Upgrading and Regional Economic Development", Education, Science and Skills Development Programme, Occasional Paper 2, Human Sciences Research Council, Cape Town.

Machaka, J., and S. Roberts (2006), "Addressing the Apartheid Industrial Legacy: Local Economic Development and Industrial Policy in South

Africa – the Case of Ekurhuleni", in S. Roberts, ed., *Sustainable Manufacturing? The Case of South Africa and Ekurhuleni*, Juta Press, Cape Town.

Maharaj, R., J.A. Heraud, F. Hugo, F. Gault and N.C. Manganyi (2003), *Evaluation of the Implementation of the South African Innovation Policy*, National Advisory Council on Innovation, Pretoria.

Mashelkar, R., E.K.M. Leppävuori, L. A. Abrahams, D. Kaplan and J. Stewart (2003), "Review of the CSIR" (mimeo).

Mendonca, S. (2006), "The Revolution within: ICT and the Shifting Knowledge Base of the World's Largest Companies", *The Economics of Innovation and New Technologies*, Vol, 15 (8), pp. 777-799.

Morris, M., G. Robbins and J. Barnes (2006), "The Role of Government in Fostering Clusters: The South African Automotive Sector", in V. Padayachee, ed., *The Development Decade? Economic and Social Change in South Africa, 1994-2004*; HSRC Press, Cape Town.

MRC (2006), *SETI Review 2006*, Medical Research Council.

Mytelka, L.K. and L.A. Barclay (2004), "Using Foreign Investment Strategically for Innovation," *The European Journal of Development Research*, Vol. 16, No. 3, pp. 531-560.

NACI (2002), *Evaluation of the Implementation of the South African Innovation Policy,* National Advisory Council on Innovation, Pretoria.

NACI (2003), The Potential Impact of Skills Shortages on the Innovative Capacity of Major Capital Engineering projects, National Advisory Council on Innovation, Pretoria.

NACI (2006), *The South African National System of Innovation: Structures, Policies and Performance - Background Report to the OECD Country Review of South Africa's National System of Innovation*, National Advisory Council on Innovation, Pretoria.

Nelson, R. R., ed. (1993), *National Innovation Systems: A Comparative Analysis*, Oxford University Press, Oxford and New York.

NESTA (2006), *The Innovation Gap: Why Policy Needs to Reflect the Reality of Innovation in the UK*, National Endowment for Science Technology and the Arts, London.

OECD, (2005), *Governance of Innovation Systems, Synthesis Report – Volume 1*, OECD, Paris.

OECD (2006a), *OECD Review of Agricultural Policy: South Africa,* OECD, Paris.

OECD (2006b), *Main Science and Technology Indicators: 2006 (1),* OECD, Paris.

Oerlemans, L.A.G., M.W. Pretorius, A.J. Buys and G. Rooks (2003), *Industrial Innovation in South Africa: Report on the South African Innovation Survey for the Period 1998-2000*, University of Pretoria.

Ozawa, T. (1974), *Japan's Technological Challenge to the West, 1950-74*, MIT Press, Cambridge, Massachusetts.

Patel, P., and K. Pavitt, (1997), "The Technological Competencies of the World's Largest Firms: Complex and Path Dependent, but not Much Variety", *Research Policy*, Vol 26, pp. 141-56.

Paterson, A., (2006), "Information and Communication Technology Networks: Leading or Following the Economic Sector?" in G. Kruss, ed. (2006), *Creating Knowledge Networks: Working Partnerships in Higher Education, Industry and Innovation*, HSRC Press, Cape Town.

Paterson, A., E. Nesamvuni and A. Canca, eds. (2005), "Synthesis Paper, Human Resources for Knowledge Production in South Africa", 23-24 June, Cape Town.

Pouris, A. (forthcoming), "The international performance of the South African Academic institutions: a citation assessment", University of Pretoria.

Roberts, S. (2004), "RBTC Case Study: Dense Medium Cyclone for Materials Separation: Multiotec Process Equipment", Mimeo report, School of Economic and Business Sciences, University of the Witwatersrand, Johannesburg.

Roberts, S. (forthcoming) "Industrial Development and Industrial Policy in South Africa – A Ten Year Review", *Journal of African Economies*.

Rodrik, D. (2006), "Understanding South Africa's Economic Puzzles", National Bureau of Economic Research Working Paper No. 12565.

Rosenberg, N. (1976), *Perspectives on Technology*, Harvard University Press, Cambridge, Massachusetts.

Rush, H., M. Hobday, J. Bessant, E. Arnold and R. Murray (1996), *Technology Institutes: Strategies for Best Practice*, International Thomson Business Press, London.

Segal, N., and S. Malherbe (2000), *A Perspective on the South African Mining Industry in the 21st Century*, report by the Graduate School of Business of the University of Cape Town, Chamber of Mines of South Africa, Johannesburg.

Sercovitch, F. C. (1980), *State Owned Enterprises and Dynamic Comparative Advantages in the World Petrochemical Industry: The Case of Commodity Olefins in Brazil*, Harvard Institute for International Development, Cambridge, Massachusetts.

South African Reserve Bank (2006), *Annual Economic Report 2006*, Pretoria.

Statistics South Africa (2005a), *Labour Force Survey*, September 2005, Statistics South Africa, Pretoria.

Statistics South Africa, (2005b), *Gross Domestic Product: Annual Estimates 1993-2004,* Statistical Release P0441, Pretoria.

Steyn, G. and R. C. Daniels (2003), "Engineers and Technicians", in Human Sciences Research Council, *Human Resource Development Review 2003: Education, Employment and Skills in South Africa*, HSRC Press, Cape Town.

Steyn, G., A. Hofmaenner, S. Roberts and M. Altman, (2004) "Innovation in Resource-based Technology Clusters: project overview and synthesis of findings", mimeo, Human Sciences Research Council, Pretoria.

UNCTAD (2005), *World Investment Report 2005: Transnational Corporations and the Internationalisation of R&D*, United Nations Conference on Trade and Development, New York and Geneva.

UNDP (2003), *South Africa Human Development Report: The Challenge of Sustainable Development: Unlocking People's Creativity*, United Nations Development Programme, Pretoria.

UNDP (2006), *.Human Development Report 2006*, New York.

UNIDO (2002), *Industrial Development Report 2002/03: Competing through Innovation and Learning*, United Nations Industrial Development Organization, Vienna.

Van den Heever, R.J., R. Brighton, D. I. Gihwala, K. Pather and D. Pillay (2001), *Evaluation of the Technology and Human Resources for Industry Programme (THRIP)*, Department of Science and Technology, Pretoria.

Van Rooyen, J. (2000), "Regional Food Security and Agricultural Policy in Southern Africa: A Challenge of Policy Conversion in Diverse Settings", Development Southern Africa, 17 March.

Walker, M., and P. Jourdan (2003), “Resource-based Sustainable Development: An Alternative Approach to Industrialisation in South Africa”, *Minerals and Energy*, Vol. 18 (3), pp. 25-43.

Walwyn, D. 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.

Woolard, I. (2002), “An Overview of Poverty and Inequality in South Africa”, working paper prepared for DfID South Africa.

World Bank (2003), *Millennium Development Goals. South Africa Country Profile*.

World Bank (2006), *Africa Development Indicators 2006*, Washington, DC.

World Bank (2006), *Enhancing Agricultural Innovation: How to Go Beyond Strengthening Agricultural Research Systems*, Economic Sector Work Report, The World Bank, Washington, DC.

World Bank (2007), *Global Economic Prospects 2007*, The World Bank, Washington, DC.

OECD PUBLICATIONS, 2, rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(92 2007 09 1 P) ISBN 978-92-64-03823-3 – No. 55827 2007

OECD Reviews of Innovation Policy

SOUTH AFRICA

What are a country's achievements in innovation, and how does this relate to economic performance? What are the major features, strengths and weaknesses, of its innovation system? How can government foster innovation?

The *OECD Reviews of Innovation Policy* offer a comprehensive assessment of the innovation system of individual OECD member and non-member countries, focusing on the role of government. They provide concrete recommendations on how to improve policies which impact on innovation performance, including R&D policies. Each review identifies good practices from which other countries can learn.

Post-apartheid South Africa has succeeded in swiftly opening its economy to international trade and capital flows, and in stabilising the economy while achieving reasonably good growth performance, mainly driven by productivity gains. However, important socio-economic problems persist, especially unemployment, poverty and the exclusion of a large fraction of the population from the formal economy. The country is now in the middle of two more specifically economic transitions: *i)* responding to globalisation and *ii)* transforming the structure of the economy away from its former heavy dependence on primary resource production and associated commodity-based industries. In this context, enhancing innovation capabilities is key to a sustained improvement of living standards based on productivity-driven growth. This review assesses the national innovation system of South Africa from this perspective, identifying areas and means for improvement with an emphasis on the role of public research organisations and policies.

OECD*publishing*
www.oecd.org/publishing

ISBN 978-92-64-03823-3
92 2007 09 1 P