The State of Science and Technology in South Africa: New Priorities, New Policies

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Development Policy Research Unit
Working Paper 95/06

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INTRODUCTION

South Africa's scientific and technological capacities are considerable, certainly by comparison with other African countries, but even by comparison with many of the newly industrialising countries (NICs). The first part of this paper outlines these capacities, in a comparative perspective detailing the resources committed to S&T, S&T outputs and (very briefly) indicating the human resources dimension. Even at this general descriptive level, it is clear that the S&T "system" is beset with fundamental problems requiring corrective policies. A number of first order policy objectives are therefore derived.

South Africa's considerable S&T capacities are embedded in a diversified and sophisticated institutional, structure. The second part of this paper extends the analysis to the inherited institutional structure and strategies of S&T the present policies, management system for S&T and (especially briefly) a consideration of the principal S&T performers. A number of additional problems besetting the S&T system are evident and further policy objectives are derived.

As with many facets of South African life, S&T has become a highly politicised issue. Organisations outside of government concerned with S&T development have emerged. The new government will therefore seek to realise its policy objectives for S&T within the context of an active civil society. Moreover, the new government has inherited a system which harbours considerable resistance to change and will operate under significant economic constraints. The approach taken by the new government will necessarily reflect these econopolitical factors. The third part of this paper will assess the manner in which the new government is seeking to address the policy objectives outlined here.

This paper is concerned therefore to survey the new government's inheritance with respect to S&T; based on an assessment of that inheritance, define the likely policy objectives of the new government and finally, outline how government will seek to restructure the S&T system to meet these new policy objectives.

South Africa will need to develop an S&T system which simultaneously supports the emergence of an internationally competitive business sector and the enhanced provision of infrastructure, such as housing, clean water and domestic electricity. In particular, in a context of extreme social disparities, enhancing access to infrastructure for the disadvantaged is the heart of the government's commitment to a highly politicised constituency. This requires a fundamental refocusing of existent S&T activities and necessitates that civil society is, in some way, represented and consulted in the identification and definition of S&T priorities.

1. THE STATE OF SCIENCE AND TECHNOLOGY IN SOUTH AFRICA: ESTABLISHING FIRST ORDER POLICY OBJECTIVES.

1.1 INPUTS

South Africa currently devotes R2.8 billion (approx.. $US 0.8 billion) to all types of R&D. This represents fractionally more than 1 percent of GDP[1]. Overall expenditure on R&D and business expenditure on R&D in South Africa as a share of GDP while considerably behind that of South Korea and Taiwan is comparable with a number of the other newly industrialising countries (NICs).

However, over the last decade or so, total expenditure on R&D has shown a pronounced tendency to decline[2]. R&D has declined more rapidly than capital expenditure and R&D personnel as a percentage of the workforce has also declined. This is in sharp contrast with most of the NICs, and is of particular concern to a country which is seeking to increase the relative and absolute importance of manufacturing based exports.

Moreover, by contrast with the Asian NICs, much of South Africa's technology thrust can be described as "mission-oriented" i.e. focused on radical innovations needed to achieve clearly set-out goals of national importance[3]. The goal has been "strategic"– defined as limiting the degree of foreign pressure that could be exerted on the apartheid regime, by establishing capacities in certain key areas. Most important have been technology development in respect of atomic energy and armaments[4]. It is not possible to calculate precisely the importance of R&D expenditure in these areas, but R&D in armaments directly exceeds R290 million (or more than 10 percent of total R&D spend) and 22 percent of the Business sectors' spend on R&D[5]. A recent authoritative report on the defence industry put the total expenditure on all types of defence research and development at R420 million per annum[6]. It is not clear how this figure was derived, but it represents approximately 15 percent of South Africa's total expenditure on R&D. Government has invested heavily in atomic energy culminating in the provision of highly enriched uranium for nuclear weapons and South Africa's nuclear power plant. Over the past 26 years, over R14,600 million has been invested (more than in total R&D). While the R&D component of this expenditure is not known, it is certainly considerable. Atomic energy and armaments together therefore absorb a considerable part of the resources currently invested in R&D. Apart possibly from a few areas related to minerals processing, armaments and atomic energy are currently the areas of greatest national technological capabilities.

TABLE 1:

RESOURCES DEVOTED TO FORMAL R&D

	TOTAL R&D EXPENDITURE (1985 Rand Millions)	BUSINESS R&D EXPENDITURE 1985 Rand Millions)	TOTAL R&D (person Years	BUSINESS R&D (person years)
79/80	641.8	225.3	15,178	N/A
81/ 82	777.8	303.3	14,850	N/A
83/84	955.8	470.3	15,993	8,770
85/88	973.8	373.9	19,510	7,198
87/88	904.7	373.5	20,558	7,257
99/90	924.0	342.2	18,175	5,009

SOURCE: Department of National Education (DNE), (various years), Resources for R&D
Pretoria: Government Printer

1.2 OUTPUTS

Output measures are in principle more significant than input measures in that they indicate the efficiency of the resources committed. But, accurate output measures are particularly difficult to compile and the following should be regarded as 'proxies'.

1.2.1 Science Outputs

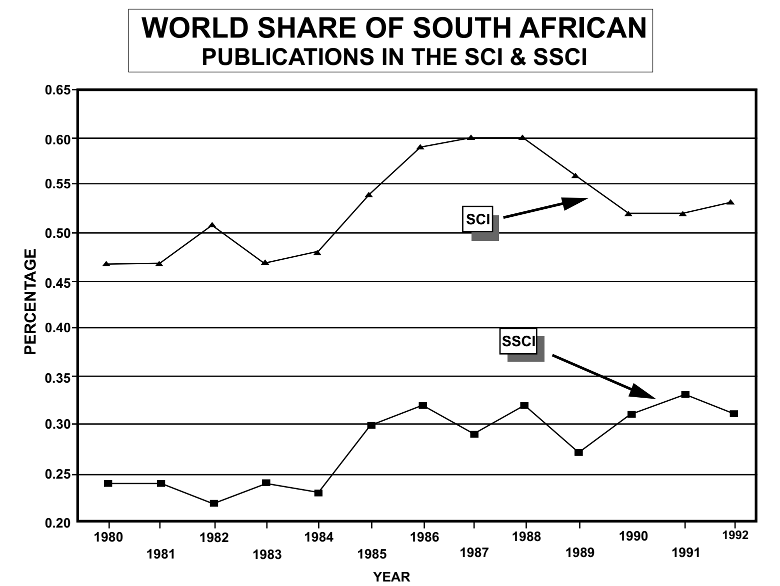
The number of South African publications in the Science Citation Index (SCI) is just under 4,000 per annum. This increased steadily until 1987, but has declined since then. The decline has been most pronounced in respect of publications emanating from the universities whose publications have declined by one-fifth between 1988 and 1991.

South Africa's share of total world SCI is currently a little under 0.5 percent. South Africa's share rose to 0.6 percent in 1986, and remained at this level until 1988, declining thereafter. Citations are currently well below the international average in all fields except agricultural sciences. A recent assessment of the number of South African scientific publications and citations characterised South African science as "anaemic" and dramatically highlighted the extent of its decline in the period 1981-937.

South Africa's share of publications in the SCI is large by comparison with that of other African countries. In 1993, South African publications in the SCI were approximately equivalent to those of Egypt, Nigeria, Kenya and Zimbabwe combined. However, a number of the NICs have been increasing their publications very rapidly and now exceed South Africa. They include India, Taiwan and Brazil.

South Africa's share of world SSCI publications was essentially stable between 1985 and 1992, but rose marginally in 1993 to a little over 0.3 percent[8].

FIGURE 1



Source: FOUNDATION FOR RESEARCH AND DEVELOPMENT (FRD), Directorate for Science and Technology Policy (1993) South African Science and Technology Indicators, 1993: 236 Pretoria: FRD.

1.2.2 Technology Outputs

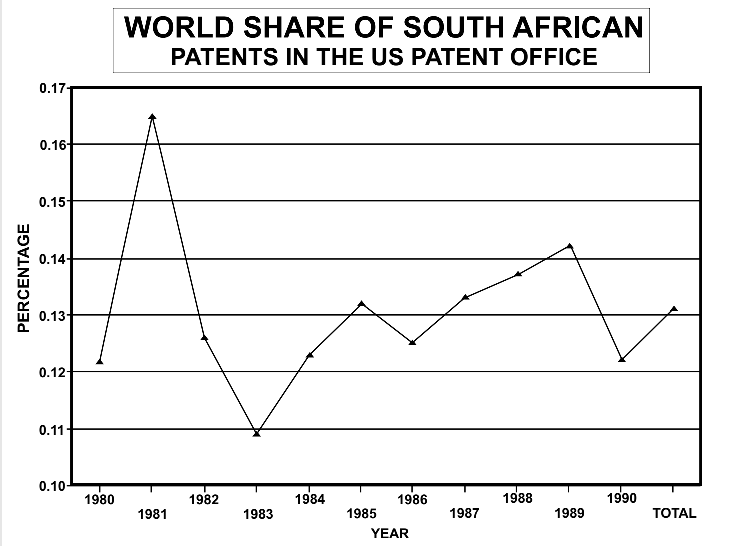
South African origin patents registered in the US have exceeded 100 since 1987. The number of SA patents rose by 63 percent between 1976 and 1989 (total foreign origin patents rose 75 percent), but have declined since then.

In the 1963-75 period, South Africa was the 17th largest country of origin for patents registered in the US and in 1989 South Africa. was the 19th largest country. South Africa is responsible for approximately 16 percent of the patents granted to southern hemisphere countries in the US - second largest but well behind Australia. South Africa certainly dwarfs the international patenting of the rest of Africa.

Domestic patents are a much weaker indicator and, because of national differences in patenting procedures and requirements, cannot be definitively used for comparative purposes.

Nevertheless, South Africa ranks ninth out of thirty major countries in the number of its domestic patent application[9]. However, local patent applications are much less likely to be successful that foreign applications. In 1991, while foreign applications constitute only 46 percent of total patent applications, they constituted 76 percent of all patents granted[10].

FIGURE 2

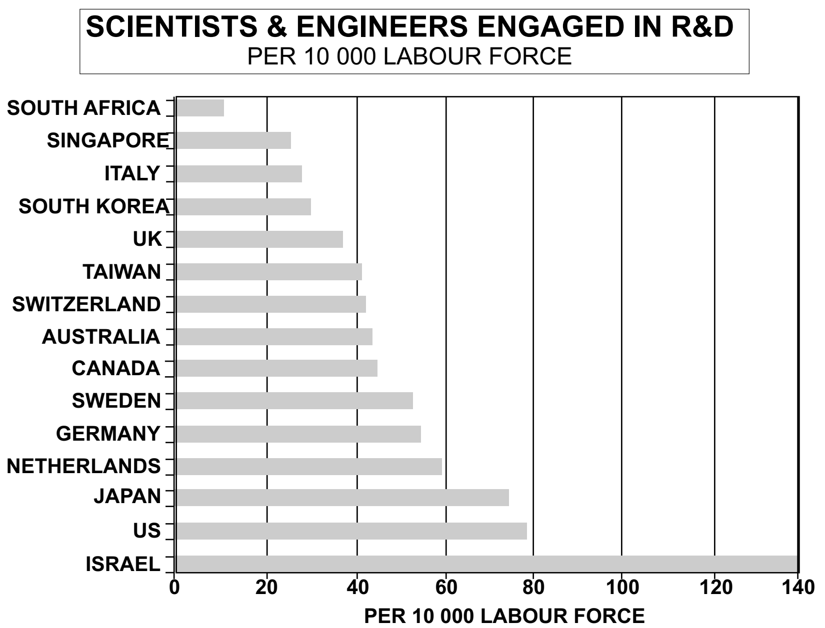


Source: FOUNDATION FOR RESEARCH AND DEVELOPMENT (FRD), Directorate for Science and Technology Policy (1993) South African Science and Technology Indicators, 1993: 246 Pretoria: FRD.

1.2.3 Science and Technology Outputs Compared

With science output proxied by the share of South African publications in the Science Citation Index and technology output by the share of South African patents in the USA, in the 1970-88 period, South Africa contributed 5 times as much in science as in technology. By comparison with a

FIGURE 3



Source: *Financial Times* (London), 18 April 1994: 20 Department of National Education (DNE), Resources for R&D 1991/2 Pretoria: Government Printer.

number of NICs, South Africa has a relatively high science output, but a lower ratio of patents/science output[11].

1.3 HUMAN RESOURCES

All the indicators suggest that, despite a relatively high technological, and more particularly a relatively high scientific output, by comparison with other countries, South Africa has relatively few scientists and engineers actively engaged in R&D.

South Africa's human resources to support R&D are comparatively very poorly developed. This is evident at all levels. To take just one indication of this, in 1988, SA had a total of 100,000 scientists and engineers – a little under 3,000 per million population. This compares with Korea 8,706 1986), Singapore 15,304 (1980) and Brazil 11,475 (1980). Moreover, the gap is widening. Comparisons of graduating engineers per annum, reveals even more sharply, South Africa's poor performance by comparison with the NICs and indeed with a number of African countries.

Moreover, Blacks are severely underrepresented in the ranks of scientists and engineers. To take but one indication of this. Of a total of 3,123 graduates employed by the science councils in South Africa, 2,975 or 95 percent are White[12].

1.4 FIRST ORDER POLICY OBJECTIVES

This description of the South African S&T system suggests the following main features:

- Despite a reasonable commitment of resources to formal technological effort (R&D), the indications are that currently R&D expenditure is declining significantly. Moreover, much of South Africa's R&D is focused in mission oriented projects, especially armaments and atomic energy which are now much less appropriate.
- Scientific output is relatively high, but showing a clear tendency to decline.
- There is strong evidence of 'an imbalance' as between scientific and technological outputs.
- Human resource provision is inadequate and racially skewed.

Within the context of an economic policy which aims for the rapid development of a more value added manufacturing industry and reversing racial imbalances, four first order policy priorities emerge

1. Reverse the decline in the commitment of resources to formal technological effort
2. Re-direct technological capacities established in mission-oriented research programmes to more appropriate areas
3. Ensure that scientific advance is more effectively translated into potential applications
4. Expand the education and training of skilled technical persons (especially of engineers) and redress racial imbalances in provision.

2. THE MANAGEMENT OF S&T, GOVERNMENT POLICY AND THE PRINCIPAL S&T PERFORMERS IN SOUTH AFRICA

This section provides a brief outline of the management and strategies of the current S&T system, government policy and the principal S&T performers. The focus is on the problems that are likely to beset the system and the performers in meeting the multiple objectives outlined above.

2.1 THE MANAGEMENT OF S&T

Under the previous government, management of science and technology was divided - responsibility for science rested with the Department of Education, while technology was the responsibility of the Department of Trade and Industry.

The key mission-oriented research institutions, notably Armscor (for armaments) and the Atomic Energy Corporation (AEC), were separately funded and managed with no reference to broader S&T policies or the impact of these developments for S&T capacities. In addition, a high degree of autonomy was granted to the universities, both in respect of their teaching and research programmes. South Africa's S&T system was therefore highly fragmented. Moreover, there was no organisation with oversight of the entire system. This had a considerable negative impact upon the management and operations of the entire S&T system.

> "*...the absence of any organisation with oversight of the entire national innovation system meant that nobody was responsible for monitoring the ongoing health of the S&T *,stem. In turn this meant that feedback and control measures were lacking so that it became practically impossible even to measure the health of the system*"[13].

The absence of organisational oversight and a clear mechanism for setting national goals, meant that the various S&T performers were denied thematic guidelines for their operations or any criteria against which they could measure their own effectiveness. Lack of representation for S&T at national level had further adverse consequences. At the macro level, policy was made without reference to its impact upon the development of local S&T capacities.

Moreover, there has been no effective "lobby" for S&T at the national level. This has impacted on government funding for S&T, which as a share of the overall government budget, has been declining for more than a decade.

In a wide variety of ways, the S&T system was designed to underpin the apartheid regime. One manifestation of this was the racial and gender composition of the system and notably the lack of representation of the disadvantaged communities. This lack of representation had an "internal logic" in the apartheid era since the system was not designed to meet the needs of the disadvantaged. However, it has left an unfortunate legacy of a lack of popular legitimacy and awareness of the importance of S&T.

More importantly, in the post-apartheid dispensation, when government's declared aim is to marshall all the resources at its command to enhance the access of the disadvantaged to social and physical infrastructure, far more popular representation is necessitated[14]. The system lacked the legitimacy, transparency and effectiveness which derives from more broad based representation.

These seriously adverse features have been partially addressed in the new government of national unity by the creation of a new ministry – Arts, Culture, Science and Technology. The Ministry does have the potential to oversee and co-ordinate policy for the entire S&T system. It is committed to ensuring widespread consultation and ensuring transparency on S&T issues. However, the ministry's precise functions, its relation to other "line" ministries and major governmental programmes such as the Reconstruction and Development Programme (RDP) have all still to be determined.

2.2 GOVERNMENT POLICY FOR S & T

There is a defined management system and set of policies governing science15. A Science Vote is determined and allocated to the budgets of the various science councils via the responsible government department, previously National Education and now the Ministry of Arts, Culture, Science and Technology.

The key source of advice to government on science policy was previously the Scientific Advisory Council (SAC). This body was criticised for its lack of transparency, composition of its membership, limited oversight of the system (no oversight of technology but also no oversight of dedicated research facilities which are established within various government departments and which are not funded via the Science Vote) and the SAC's location within the Department of National Education[16]. The determination of priorities for science development and funding was particularly non-transparent.

The IDRC Mission concluded its assessment of the SAC:

> *"The overall impression we gained is that of a body which devotes its energies to matters of detail within the existing system, rather than taking a broad view, and tackling many problems which confront South African S&T. It appears that the SAC, as presently constituted and constrained, is not a useful mechanism for advising on S&T Policy. A new government, committed to participation by all South Africans in debates on public policy, would do well to set up structures appropriate to this kind of political culture - structures which would provide appropriate kinds of advice."*[17]

The SAC was heavily science oriented and it effectively ignored technology policy. The Department of Trade and Industry is primarily responsible for technology but, despite a few programmes to promote technological development, there is currently no comprehensive policy with regard to technology. [18] The lack of a technology policy has reinforced the limited impact that South Africa's science base has had on technological development.

Following the report of the IDRC Mission, a Science and Technology Initiative (STI) was founded. The STI brought together a very wide grouping of persons and organisations concerned with S&T including the S&T performers such as the science councils and universities, but also the professional associations, business and labour. The STI was transformed into the National Science and Technology Forum in March 1995 and will serve as the principal body for the new-Ministry in its consultation with the wider S&T community.[19] A successor to the SAC, the National Advisory Council on Science and Technology (NACOST) will also soon be established as an advisory body to the Minister.

2.3. THE PRINCIPAL S&T PERFORMERS

There are four 'sectors' of S&T performers – government (27%), tertiary education (24.8%), business enterprises (46.6%) and non-profit (1.6%).[20] The non-profit sector is therefore of minor importance and is not described here.

2.3.1. The Government Sector

Government is principally involved in the performance of S&T through its support for the statutory research councils. There are currently eight such councils.[21] The large number of councils contributes significantly to the high degree of fragmentation of the South African S&T system.

Together the councils are funded by government at a cost of over R700 million per annum. In April 1988, government adopted the system of "Framework Autonomy and Base Line Funding" for the management of the science councils. Government subsidy was to be fixed in order that the science councils would have to secure additional funding from 'the market' i.e. clients in the public or private sectors.[22] This has advanced quite rapidly – for example, the CSIR – the largest of the councils with a focus on industry – secures less than 50% of its income from the parliamentary grant, placing it amongst the highest ratio of contract income to state funding of all similar institutions.[23] Monies allocated by the state to the science councils under the base line funding formula, which was designed for their own in-house R&D and for science, manpower and skill development functions, has in fact fallen steadily in real terms. As a result, all of the science councils have become ever more dependent on the market for their funds.

While it is difficult to measure the efficacy of the science councils in promoting and complimenting the research activities of South African industry, a study of firms which had won national design awards strongly indicated that these firms relied upon their own efforts and received very little support, direct or indirect, from any outside organisations. In some sectors however the science councils have been far more effective. For example, the South African Bureau of Standards, is able to provide standard certification and verification for a wide range of manufactured goods which is accepted in the most demanding of export markets. Its services are long established[24] and widely utilised by South African manufacturers, particularly as they expand into new export markets. Linkages between the CSIR and the major chemical companies appear to have been close.[25] Similarly, the council for Mineral Technology MINTEK has reportedly developed close and productive linkages with industry - particularly in the beneficiation field.

Overall, the science councils have established strong linkages with already well-established, well-resourced and generally technologically sophisticated clients. In effect the market orientation of the science councils has allowed those firms and agents which are already powerful in the market, to have the greatest access to state subsidised technology services. South Africa has a number of very powerful conglomerates resulting in a very high level of economic concentration in most product markets.[26] Market orientation, on the part of the science councils, therefore reinforces and complements existing market distortions.

At base, the rationale for this system is misplaced. It has been formulated with a mistaken perception of the optimal role of the market in the development of the pace and direction of local technological capabilities. It particularly ignores the requirements but limited market power of small, medium and micro enterprises (SMMEs). The interests of the latter are supposedly taken account of in 'special divisions' or 'special programs' operated by some of the science councils. But, there is a fair consensus that these are not very effective.

The major policy challenge therefore is to "reorient" the science councils so as to ensure that they are more responsive to the needs and requirements of the disadvantaged communities – especially to the needs and requirements of the SMMEs This cannot be achieved simply by the science councils grafting on separate divisions to look aftef the SMMEs but should be inscribed 'in the central dynamic' of these organisations. Ways will need to be found to ensure that SMMEs like larger firms, have the wherewithal to command resources in order to purchase the resources they need for product and process development.[27] Another part of this process will be to ensure that the Boards to which the managements of the councils are, in the first instance responsible, become far

more broadly representative and accountable.[28]
Government involvement in the armament and atomic energy industries is also very substantial. The armament industry is a leading sector both in terms of technological capacities and in relation to actual (and potential) export earnings. With local expenditures on defence likely to rise only in respect of "manpower" (namely incorporating new personnel into the armed forces drawn from the liberation movements' armed wings), increased sales are dependent on exports. The potential sales on export markets are, for obvious reasons, hard to determine. However, there are indications that with the lifting of the UN arms embargo, the potential is considerable. The first major publicised export orders are now in place. Oman has placed an order for $120 million, principally for artillery. Armscor's own assessment is that "...annual sales could be as high as R200 million per annum by 1996."[29] A recent report identifying National Policy for the Defence Industry argues that investment in defence R&D - which is aimed at or near the technological frontier – is largely offset by the considerable potential for export earnings and job creation.[30] The report urges that defence expenditure on R&D not be reduced from its present level:

> *"The current expenditure on all types of defence research and development has reached a critical level. Unless it is maintained at approximately the current level of R420 million per annum , it is Armscor's view that the industry will lose its technological edge and much of its design and development capabilities."*[31]

The report argues further that the defence industry has very considerable technological capacity which, given the right policies, could play a major role in the rebuilding of South Africa's technological base.[32] However, apart from indicating the importance of joint ventures and the role of government in formulating a diversification strategy for the armaments industry, and in playing an enabling and regulatory role to encourage the process, the report formulates no detailed policies.

At this point in time, government has no clear policy either on the optimal degree of support for R&D in armaments nor on what policies are desirable in order to ensure that the existing, undoubtedly considerable, technological capacities in this industry could facilitate the development of local capacities elsewhere.

The atomic energy industry, located near the technological frontier, is also a site of very considerable technological capacity. The Atomic Energy Commission (AEC) currently employs over 3,000 people, the largest single concentration of high-level skills in the country[33] – the vast majority of whom are highly skilled. The AEC is currently engaged in a major commercialisation programme. The objective is
to render itself free of government funding by the year 2000. However, the commercial viability of the AEC is very questionable. Although commercial sales have been rising rapidly, this is from a low base and in 1992/3 commercial sales were less than one-third (R140 million) of state support (R452 million). Moreover, indications are that the AEC cannot produce enriched uranium at prices competitive on the international market. Market demand for enriched uranium is likely to remain stagnant and the former Soviet states, in particular, are very low cost suppliers. Conversion of atomic energy to "civilian/commercial products thus faces considerable barriers". As with armaments, government has, as yet, no clear policy on ensuring conversion of the AEC.

2.3.2 The Tertiary Education Sector

South Africa currently has 21 universities and 15 technical colleges (Technikons). Tertiary level research is well-developed in South Africa, and largely funded by government.[34] The state subsidy to the universities is three and a half times larger than the subsidy to the technikons. The technikons do very little research (collectively only 1.1 percent of total research in the tertiary education sector), while over 70 percent of the research is undertaken in just 6 universities (with the top three universities contributing 40%). The bottom 6 universities contribute under 7%.[35]

Therefore, the research capacities of the tertiary education sector are highly skewed – firstly as between universities and technikons and secondly as between universities. The major research universities have been those who historically have catered primarily to white students.[36]

The universities are primarily responsible for the high levels of scientific output noted earlier. However, there is evidence to the effect that university science rarely finds any commercial applications.[37]

The policy implications are clear. Policies are needed to ensure that tertiary level research does not function in isolation but rather is brought into contact with potential applications. This will require increased business sector involvement in university research and perhaps a greater emphasis on the transfer sciences and more government support for application-oriented research.

2.3.3 The Business Enterprise Sector

There are very few areas where South African firms have achieved leading-edge status. This has occurred in those industries:

(a) where South Africa is a leading international producer and where the particularities of local conditions have necessitated major on-going innovation - principally in some mineral extraction and beneficiation processes (e.g. pyrometallurgy) or

(b) where, for political/'strategic' reasons, South Africa has developed along a different "technological trajectory" from that pursued internationally and has therefore been unable to obtain the technology abroad – principally in oil from coal synfuel production.[38] In these areas, South African firms are significant technology exporters.

Elsewhere however, the importation of foreign technology is critical. South African firms have generally acquired good operational capacities in respect of the technologies that have been imported – even in complex technologies. However, licence agreements entered into by South African firms do not generally lead to the transfer of "know-why" capacities – the capacities necessary not merely to operate the technology but to effectively assimilate, adapt and finally transform the imported technology. Licence agreements frequently contain express provisions which retard the local firms' ability to develop their own technological capacities. This reinforces an existent tendency for local firms to passively rely on technology import rather than developing their own capacities. Imported technology therefore tends to displace rather that complement local capacities.

By way of example, the Table below relates to the consumer durables division of one of South Africa's largest industrial companies. The Table indicates the character and prevalence of restrictive clauses. In addition, the limited company spend on own R&D, the absence of training and the tendency to continually renew agreements, all indicate a passive reliance on overseas licensors on the part of the local firm.

One major reason why local firms are not aggressive in developing their own technological capacities is that they are oriented to the local market. Moreover the local market is characterised by a limited degree of competitive pressure. In a more open trading environment consequent upon South Africa entering into an agreement of phased liberalisation with the GATT, in order to compete more effectively with imports, and more especially to enter into export markets with differentiated and high quality goods, South African manufacturing firms will have to deepen their capacities in product design and development.

TABLE 2:
SOME FEATURES OF LICENCE AGREEMENTS ENTERED INTO BY ONE OF SOUTH AFRICA'S LARGEST MANUFACTURING COMPANIES IN RESPECT OF CONSUMER DURABLE PRODUCTS

No. of Agreements	8
Export Restrictions	5 (2 others unclear)
Express Tied Purchasing Clause	1
Length of Agreement – 10 years or longer	6 (2 others unclear)
Royalty on Sales – Average	3.125
Additional Front End Charges	2 (2 others unclear)
R&D Expenditure as % of Turnover (for the group)	0.32
No. of Licence Agreements entailing Training	0

Source: Department of Trade and Industry, Register of Licence Agreements.

The absence of a policy for technology development has already been noted.[39] Creating the incentives and the wherewithal so as to encourage local firms to enhance their technological capacities is however a wider and more complex task. In very important part, this will be dependent on broader macro policies – and most specifically policies with respect to industrial development. Technology policy can only be effective when integrated and sequenced with other policies – i.e. when it is conceived of and implemented as an integral part of a far more over-arching industrial strategy. The success of technology policy in the East Asian NICs exemplifies this:

> *"In large measure, the success of Taiwan's science and technology development program can be attributed to the fact that it was formulated within the context of a well-defined industrial strategy. Taiwan's S&T development program was effective because it was closely linked with, and occurred within, the general context of a national economic plan."*[40]

In brief, there is a critical need to develop a coherent set of policies to enhance technological development in South Africa – most notably at the level of the enterprise – and to locate such policies within the context of a broader strategy for the development of South African manufacturing industry.

3. S&T MANAGEMENT AND POLICY UNDER THE GOVERNMENT OF NATIONAL UNITY

The examination of the current system. of management for S&T and the principal S&T performers suggests a number of further policy objectives:

1. Establish a management system for S&T which has the capacity to oversee and coordinate the entire system for both S&T. This should be able to inter alia identify national S&T priorities and define thematic goals for S&T performers.

2. Develop a comprehensive technology policy within the context of broader macro, and particularly industrial policies.

3. Ensure that the science councils become far more responsive to the needs of those who currently command few resources in the market, especially SMMEs.

4. Develop a clear industrial strategy with respect to the armaments and atomic energy industries ensuring that technological capacities already developed here are effectively transferred to other areas of the economy.

5. Address the skewness of research activities within the tertiary education sector and, at the same time, ensure that more of this research finds expression in technological and commercial activities

6. Enhance the incentives (and pressures) for firms to innovate, inter alia by advancing a more competitive environment and encouraging local firms to rely more on developing their own capacities as opposed to passive reliance on imported technologies.

The creation of a new Ministry – for the first time, South Africa has a Ministry of Science and Technology (albeit combined with Arts and Culture) – provides the focus for developing a new vision for S&T. In his recent Budget speech, the Minister provided some indications as to the future directions for S&T. He pointed to the unacceptably low and declining levels of expenditure on R&D and stated that the Ministry will recommend to Cabinet "...to target between 1.5 and 2 percent of our GDP towards R&D effort. This request is not to fund science for science's sake : it is a signal of intent to link R&D with the satisfaction of basic human needs and economic growth".[41] It will be particularly important to enhance R&D spending on the part of the private sector and the Ministry will be examining various incentives in this regard.

Three activities will be critical in determining the direction of future policy. Firstly, there is to be an audit of the roles and performance of the science councils. Secondly, with the support of the British government, there will, be a major Technology Foresight Study – "...the overall purpose of which is to identify critical and strategic technologies that can secure the nation's future well-being". [42] Finally, the Ministry will formulate a Green and then a White Paper on S&T policy which will be wide-ranging in their brief.

The ending of apartheid and acceptability in the community of nations has produced many new opportunities for South African S&T. One indication of this is the new S&T cooperation agreements that have been signed with the UK, the USA and the Russian Federation. Agreements with the European Union, Germany and India are pending. But, despite new opportunities and despite significant capacities, S&T in South Africa is clearly beset with problems. With demands on government to redress the wrongs of the past and to direct itself to meeting the immediate needs of its poorer constituents, government support for S&T is being questioned. The system is necessarily facing a fundamental restructuring. The S&T community and the Ministry will have to demonstrate the capacity of S&T to make a significant and immediate contribution to meeting broader social priorities. Future decisions with regard to S&T will reflect 'the play of socio-political forces' as much as the working out of different rational perceptions as to what is desirable.

END NOTES

1 DNE, 1993.
South African data, on R&D are comprehensive and since they are based on the Frascati Manual, internationally comparable.

2 The R&D census data show a very substantial increase of approximately 20% in R&D expenditures in 1991/2 as compared to 1989/90. However, most observers believe that this is a statistical artifact and that R&D expenditures have continued to decline. The R&D census says of the unexpected increase: " *The rise can be partly explained by the more complete coverage of the private sector.* "
DNE (1993): 9

3 Ergas (1987): 192

4 Oil from coal and, to a lesser extent, telecommunications equipment have also seen extensive technology development driven by the state on the grounds of their strategic importance.

5 In 1991/2, the Defence Department contributed R97 million to R&D directly; a further R51 million was allocated by the different branches of the armed forces to "technology retention projects" and R&D to the amount of R100 million was supported by capital projects. A further R30 million was contributed directly by the Armaments Corporation (Armscor) itself and R13 million by Denel. This excludes student bursaries and other forms of support on the part of Armscor and, most critically, defence related R&D in the private sector which is not directly supported by Armscor. The data in this paragraph were obtained from Garbers (1993).

6 TEC, Subcouncil on Defence (1994): Executive Summary Point 7.

7 Mitton (1995): 1

8 FRD, Directorate for Science and Technology Policy (1 993): Figure 3.1

9 Gerntholtz (1990): 11.

10 FRD, Directorate for Science and Technology Policy (1993): 82. Data given here conflict with the data in an earlier publication, which show "...patents for local inventions represented 50 percent of all patents granted in South Africa.. ."
FRD, Scientometric Advisory Center (1990): 82.

11 Pouris (1991): 28.

12 LHA Management Consultants (I 994): 3.

13 Kaplan and de Wet (1994: 11).

14 Such representation is not merely "good politics". Representation in order to gain diversity of insight and expertise is good system engineering practice. Kaplan and de Wet (1994: 43).

[15] This is outlined in DNE (1988).

[16] IDRC (1993: 25). Kaplan and de Wet (1994: 11-12).

[17] IDRC (1993: 26).

[18] Garbers (1993: Al).

[19] Ngubane (1995: 3).

[20] These figures are for 1991/2. DNE (1993).

[21] The eight councils and their principal areas of research are as follows:

Agricultural Research Council – grain crops; vegetable and ornamental plants; tropical and sub-tropical crops; plant protection, tobacco and cotton, viticulture and oenology; fruit technology, soil, climate and water, grasslands; agrimetrics; animal production and veterinary science.

Council for Mineral Technology – the needs of the mining and metallurgical industries including hydrometallurgy, minerals engineering, physical metallurgy, process chemistry, mineralogy, pyrometallurgy and measurement and control.

CSIR (Formerly Council for Scientific and Industrial Research) – acquisition, development and implementation of technology for industry. Aeronautics; building; earth, marine and atmospheric science; energy, food science; forest science; information; materials science; micro-electronics and communications; production technology; roads and transport; textiles; water and mining.

Foundation for Research Development – principally a funding agency for tertiary education in order to foster human resource development in science, engineering and technology. It operates a national research network, has a directorate for science and technology policy and represents the country on the International Council of Scientific Unions. It also manages three national facilities viz. a separated sector cyclotron; the South African Astronomical Observatory and a Radio Astronomy Observatory.

Geo-sciences Research Council – recently established to undertake wide ranging research in this area with reference to South Africa and the wider region. Also operates the Geological Survey.

Human Sciences Research Council – promotes and itself undertakes research in the social and human sciences. In regard to the latter it undertakes research in human resource development, education; social dynamics; information dynamics and science development.

Medical Research Council – promotes and itself undertakes research in the broad area of health. Conducts biomedical research (laboratory research on the biology of disease and clinical research in the diagnosis and treatment of disease) and community health research (prevalence, incidence and causes of disease and the evaluation of intervention). The MRC also supports research in these areas in the tertiary education sector.

South African Bureau of Standards -promotes quality, standardisation and certification for industry, commerce and consumers, for both the domestic and the international market.

[22] The system was expressly designed to increase the linkages between the councils and industry. "Base line funding of scientific councils has the specific objective of encouraging or even obliging

councils to generate their own funds by means of contract research. In this way the free market system is applied as a prioritization mechanism and problems are identified for which the solution has a price in the market" Garbers (1992: 5).

[23] "...our ratio of state funding to contract income places us second amongst the top contract income earners (just behind TNO, the Dutch national research organisation)." Garrett and Clark, (1992: 15).
These figures are to be treated with some caution since a part of the income earned outside of the parliamentary grant is from the investment of capital. Lutjeharms and Thomson (1993: 11).

[24] Standards, and "specs" eg. for public sector procurement, from roads to telecommunications have historically been set very high in South Africa, by comparison with other countries at similar stages of development It is likely that the setting of "European standards", is traceable to a political economy dominated by White "European" settlers.

[25] For example, in catalyst design. Crompton (1993: 39-44).

[26] Joffe et al in Baker et al. (eds) (1993: 101-4).

[27] SMME development, including technological support, has been a major area for governmental activity under the direction of a newly established directorate for SMME development within the Department of Trade and Industry. Inter alia, new technology support institutions for SMMEs are soon to be piloted.

[28] Major recommendation have been made in this regard by Badat and Prozesky (1994).

[29] TEC, Subcouncil on Defence (1994: para 2.29).

[30] Transitional Executive Council, Subcouncil on Defence (1994): Executive Summary, point 5.

[31] TEC, Subcouncil on Defence (1994): Executive Summary, point 7.

[32] "South Africa has allowed its research and development (R&D) skills and technology base to decline almost everywhere outside the defence industry .... Only in the defence industry has there been continuous, substantial investment in R&D technology, Plant and skills. Because of the low R&D expenditure elsewhere, this industry contains much of the R&D skills available in South Africa ..Ibis resource represents a huge investment of public funds and it must therefore be made available to assist the rebuilding of South Africa's technology base and its industry..." TEC, Subcouncil on Defence (1994): para 2.50.

[33] This may be compared with a total of 22,223 man(sic!) years devoted to total R&D in South Africa

[34] In 1989/90 only 10% of funding for tertiary level research was Provided by the business sector. DNE (1991: 54).

[35] DNE (1993: 54).

[36] This has been changing rapidly. At the University of Cape Town, for example, the leading research university, more than 60% of the first year intake in science, and 56% of the first year intake in engineering is black.

[37] A survey of the characteristics and sources of over 200 significant South African innovations

concluded: "There was strong evidence of a failure to commercialise significant university-led inventive abilities." Phillips (1992: 32).

[38] Crompton (1993: 83).

[39] The government did publish two discussion papers on the subject, DTI (1991) and DTI (1992). However, as yet, there is no policy document.

[40] Dahlman and Sananikone (1990: 213).
Japan similarly had a very high level of coordination between technology and other policies.
"In building up its industrial might, Japan relied heavily on coordinated technology, industrial and trade policies to promote key industries." US, Office of Technology Assessment (1990: 21).

[41] Ngubane (1995: 2).

[42] Ngubane (1995: 5).

Bibliography

Badat, S. and Prozesky, W. (1994) Science Councils: Towards the Democratisation of Governance, Mimeo. Pretoria: Report for the Science and Technology Initiative.

Crompton, R. (1993) Report on the Chemicals Industry, Mimeo. Cape Town: Industrial Strategy Project, University of Cape Town.

Dahlman, C. J. and Sananikone, O. (1990) Technology Strategy in the Economy of Taiwan: Exploiting Foreign Linkages and Investing in Local Capacity', Mimeo. Washington: World Bank.

Department of National Education (DNE) (various years) Resources for R&D. Pretoria: Government Printer.

Department of National Education (DNE) (1988) The Science Policy and System of the Republic of South Africa. Pretoria: Government Printer.

Department of Trade and Industry (DTI) (1991) Report on Technology Policy and Strategy, Draft II. Pretoria: Government Printer.

Department of Trade and Industry (DTI) (1992) Innovating Growth. Pretoria: Government Printer.

Ergas, H. (1987) 'Does technology policy matter?' in B. Guile and H. Brooks (eds.) Technology and Global Industry. Washington DC: National Academy Press.

Foundation for Research Development (FRD), Directorate for Science and Technology Policy (1993) South African Science and Technology Indicators, 1993. Pretoria: FRD.

Foundation for Research Development (FRD), Scientometric Advisory Centre (1990) South African Science and Technology Indicators, 1990. Pretoria: FRD.

Garbers, C.F.(1993) The South African Science and Technology System: Structure and Policy, Mimeo. Pretoria: Science and Technology Initiative.

Garbers, J. G. (1992) 'Opportunities and constraints in science policy in South Africa', in Center for Science Development Symposium on Science Policy and Research Management: Vol. 1(1).

Garrett, G. G. and Clark, J. B. (1992) ''Science and Technology in Transformation in South Africa' Transformation. vol. 18-19.

Gerntholtz, R(1990) A Basic Guide to the Law of Patents. Cape Town: Allegretto.

International Development Research Center (IDRC) (Canada) (1993) Towards a Science and Technology Policy for a Democratic South Africa, Mission Report. Ottawa: IDRC.

Joffe, A., Kaplan, D., Kaplinsky R., and Lewis, D. (1993) 'Meeting the Global Challenge: A Framework for Industrial Revival in South Africa', in Baker, P., Boraine, A. and Krafchik, W. (eds.) South Africa in the World Economy in the 1990s. Cape Town: David Philip.

Kaplan, D. and de Wet, G.(1994) Proposals for a Future National Science and Technology Management System in South Africa, Mimeo. Pretoria: Science and Technology Initiative.

LHA Management Consultants (1994) Human Resources Composition and Development in the Science and Technology Area, Mimeo. Pretoria: Science and Technology Initiative, Working Group 5.

Lutjeharms, J.R.E. and Thomson, J.A. (1993) 'Commercialising the CSIR and the death of science,' South African Journal of Science. vol. 89.

Mitton, Simon (1995) 'South African Science Anemic: Serious Action Surely Advisable', Science Watch. vol. 6, No. 3.

Motala, E. (1994) The Employment Composition and Affirmative Action Programmes of the Science Councils in South Africa, Mimeo. Pretoria: Science and Technology Initiative.

Department of National Education (DNE), (1988) 'The Science Policy and System of the Republic of South Africa.' Pretoria: Government Printer.

Ngubane, B. S. (1995) 'Speech by the Minister of Arts, Culture, Science and Technology, DR B S Ngubane, in the Debate on his Budget Vote', Mimeo. Cape Town: Department of Arts, Culture, Science and Technology.

Phillips, B. (1990) 'Innovations in South Africa: a basis for technological policy guidelines,' Science and Public Policy. vol. 17 No. 1.

Pouris, A. (1991) 'Identifying Areas of Strength in South African Technology,' Scientometrics, 21.

Transitional Executive Council (TEC), Subcouncil on Defence (1994) National Policy for the Defence Industry, Mimeo. Pretoria: Defence Industry Working Group.

United States of America, Office of Technology Assessment (1990) Making Things Better. Competing in Manufacturing. Washington: Office of Technology Assessment.

United States of America, Patent Office (1990) All Technologies Report, 1990. Washington: US Department of Commerce.