Research

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substantial body of natural, human and social scientists helps enormously to build the confidence of that nation state. The creation and development and maintenance of this intellectual culture depends fundamentally on the research culture of its higher education institutions.

This chapter describes the new policy framework for a national research system which was put in place after 1994. It provides a statistical overview of research expenditure and outputs, looks at the new role players, sketches out the emergence of a new research landscape and assesses some of the changes that have occurred since 1994.

South African science before 1994

When compared with the research systems of other nations in Africa and indeed those of other nations in the developing world, South Africa's is a substantial and varied one. It is expected to act as a seed for a new generation system, one which is defined in the context of the social, political, and economic transformations that have characterised the first seven years of post-apartheid South Africa.

South African science[1] has a long and proud tradition. Born in the mid-eighteenth century from the works of amateur natural historians and astronomers who travelled to what was then the Cape Colony to satisfy their intellectual curiosity, it developed into the major science base on the African continent. The initial excursions of amateur scientists soon gave way to more formalised and institutionalised modes of knowledge production in the nineteenth century. With the discovery of gold and diamonds and the subsequent industrialisation of the Witwatersrand, came a new demand for mining engineers and geologists, and for social scientists of various kinds. This was soon followed - because of major

1 This chapter adopts an inclusive definition of science, encompassing the humanities, the social sciences and the natural sciences.

natural disasters (animal epidemics and the proliferation of various plant diseases) - by the establishment of major research centres (most notably Onderstepoort Veterinary Institute) around the turn of the twentieth century.

It was under the ambitious gaze and guidance of former Prime Minister Jan Smuts that South African science came into being as an entity that was recognisable as a system. With its heart in the universities, this became a science system that worked vigorously to make South Africa a global player whilst simultaneously serving South Africa's needs, particularly in the areas of mining and agriculture. It was a system that was to produce the 'nation's' political leadership, provide its creative energy and become the repository for its cultures and traditions.

As was the case elsewhere in the world, the Second World War proved to be a major stimulus for the South African science system - of which the higher education research system was an important element. It gave rise to the establishment of the Council for Scientific and Industrial Research (CSIR), the biggest science laboratory in the country outside of university centres. From its establishment in 1946, the CSIR played a major role in promoting scientific research and through its influence ultimately gave rise to a wider appreciation of the role of research within the country. Directly and indirectly it also gave rise to the establishment of many of the other science councils which were formed between the 1950s and 1970s, including the Human Sciences Research Council (HSRC) which was intended to be the human sciences laboratory of the state.

When the Nationalist Government came to power in 1948, its apartheid policies had major implications for the way in which post-war science in South Africa would develop over the next 40 years. There was a growing emphasis on strategic research within the science councils in order to serve the national security goals of the government. For example, this eventually led to the development of an indigenous nuclear research industry that was able to build atom bombs. Billions of rands were spent

on military and defence R&D. It was during this period that the development of a fragmented higher education system occurred, differentiating between the historically white Afrikaans- and English-medium universities and introducing 'ethnic-based' universities.

At the national level the higher education research system was indeed shaped by the needs of the dominant strata of the society in which these institutions functioned. Major influences on the system can be identified quite easily. For instance, in response to the arms embargo, the atom bomb project and the needs of the military-industrial complex more generally, were built on the base of (and fed into) substantial research capacity in the nuclear and materials sciences. These developments were a major force in shaping the national science agenda, and the research systems within that agenda. It is therefore not surprising that such a substantial and outstanding nuclear sciences enterprise emerged in South African universities. Another example is the academic boycott which affected the social sciences much more than it did the natural sciences. This helped to shape a social science research system that was insular and marginalised in the global context. Similarly, the mining and agriculture industries, also central to the survival of the apartheid regime, were deeply influential.

In 1992 the ANC commissioned a study, sponsored by the International Development Research Centre (IDRC), to review the state of science in South Africa. When the first democratic government came to power in 1994, it took these and other findings of the commission as a point of departure in the unfolding policy development process. As the findings of analytical studies of South Africa's science system in the post-1994 period began to emerge, it became clear that the country's substantial research system was hopelessly disarticulated from the needs of the majority of South Africans. For instance, research capacity and excellence in the areas of infectious diseases or community-based medicine was hopelessly lacking at the very time that Chris Barnard performed the world's first human heart transplantation operation.

A second finding was that the South African national science system - of which the universities are an important part - was deeply fragmented and unco-ordinated. A third finding was that the system was both inefficient and ineffective. It was thus not surprising that the social responsibility of South African science and scientists came under political scrutiny during the early 1990s.

The new policies

• The national science system

In the Green Paper on Science and Technology and the subsequent White Paper (1996), the government committed itself, among other things, to:

- The creation of a new policy framework for public science;
- Conducting a system-wide review of the national system of innovation in order to establish its strengths and weaknesses and future priorities; and
- Creating new structures to develop, implement and monitor the new policy framework.

This policy process vigorously sought to revisit the system in its entirety - the performing science councils, the funding agency science councils, the state corporations such as Eskom, the government laboratories, the higher education system and the private sector laboratories. The major emphasis rested on attempting to understand how to make the science system more responsive to the challenges of South Africa's reconstruction and development needs. As the policy process unfolded, this was captured in the notion of the National System of Innovation (NSI). The core idea was that the NSI would provide a framework within which the different elements of the system could fit to meet this challenge.

The central issues were to overcome fragmentation, promote innovation and to develop a research framework in line with national priorities. The strategy that was adopted to build a coherent system out of the fragmented one depended on three substantial developments, each of which has been partially or fully realised.

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The first outcome was a set of structural developments: the establishment of the National Research Foundation (NRF) and the National Advisory Council on Innovation (NACI). The former brings together the funding agency functions for the human and natural sciences. The legislation that guides its activities requires that it fund university research on the basis of the broad socio-economic and political agendas of the state. The National Advisory Council on Innovation serves to advise cabinet on science and innovation matters as well as issues related to the global competitiveness of South Africa's industry and its ability to meet the needs of the majority of South Africans.

The second set of outcomes relates to the establishment of funding drivers for the transformation of the system - the use of significant fractions of the national science vote from parliament to bring about the kinds of changes that are captured in the new policy regime. It may be said that while certain large national strategic projects were identified during the apartheid period - projects (amongst them the atom bomb project) that were funded by the state almost without limit - in the post-apartheid period none have yet been identified. However, the creation of the Innovation Fund, which grew from R30-million in 1999 to R125-million in 2001, provides the means to build the national capacity in sharply defined areas which are likely to be drawn from the national priorities identified by the cabinet.

The third outcome that emerged from this policy process has also been completed viz. the National Research and Technology Audit (NRTA) conducted in 1997/1998, a system-wide review of the science councils and the national facilities undertaken in 1998/1999, and the National

Research and Technology Foresight Exercise (1998/2000) which was to plan for South Africa's long-term research and technology needs and opportunities.

For a short time after the first democratic elections in 1994, the Reconstruction and Development Programme (RDP) provided a substantial and highly textured backdrop for the policy development process. Much of the policy discourse during this period was shaped by the reconstruction agenda which provided a set of priorities to which researchers could respond. The adoption of the Growth, Equity and Redistribution (Gear) macro-economic framework in 1996 altered the nature of this discourse substantially and forced into the centre of the debate the need for a science system that was driven by the competitiveness of South Africa's industrial products and hence its innovation system. An issue for future study would be how the advent of Gear altered the 'balance of forces' between the needs of reconstruction on the one hand and industrial innovation on the other.

By 2001 a very impressive canopy of science policies had been put into place to establish a national science system and, although it may be too early assess their full impact, the following sections will shed some light on some of the effects of these developments.

- Higher education research policies

The higher education research system is very much a part of the national science system. This sector, however, underwent its own policy process and attempts were made to ensure that the different processes articulated with each other - largely through the individuals who were involved in both. The post-1994 higher education policy process, beginning with the National Commission on Higher Education (NCHE), was influenced heavily by the relatively unconstrained discussions that characterised the policy debates that occurred under the aegis of the National Education Policy Investigation (Nepi) and the Union of Democratic University Staff Associations (Udusa). Many of these ideas were carried into the later processes.

The White Paper on higher education transformation (Department of Education, 1997) drew heavily on the Report of the National Commission on Higher Education (1996) and attempted to extend the substance of the proposals for research. The White Paper announced that "The production, advancement and dissemination of knowledge and the development of high level human resources are core functions of the higher education system." It went on to reaffirm that research plays a key role in these two functions and identified the key capacity difficulties: the fragmented national system, the lack of research capacity in the higher education sector, the 'stark race and gender imbalances', and the skewed distribution of the capacity between the historically black institutions and the historically white ones. The White Paper picked up the mode one/mode two knowledge generation debate and made a strong argument for an (Departmenhe e o tw a 90.845 0Tc(pr-0.02ypTc(tw) Tj0 Tc(o (Depart-08 Tw0.043 Tc(a

the part of universities and technikons. There are as yet no mechanisms in place to establish whether the amount that has theoretically been allocated for research, does in fact get allocated for research activities at the higher education institutions. Until such time as such mechanisms are put in place, it will in fact remain a 'blind' allocation. Secondly, most of the increases in research funding within the science system occurred in the areas of directed, strategic funding. Two funds benefited from these increases: the Technology and Human Resources for Industry Project (Thrip) and the National Innovation Fund (NIF). Although the increases were substantial in both cases, both funds are open for application to institutions outside the higher education sector, including, for example, the science councils. Substantial funding from the National Innovation Fund was awarded to the science councils, rather than to universities and technikons.

- The allocation of earmarked funds to build capacity and to develop potential centres of excellence in research and postgraduate training at the historically black universities. Access of black and women students to masters, doctoral and post-doctoral programmes was to be made a priority.

In 1996/7 the National Commission on Higher Education and the White Paper on higher education transformation made scant reference to globalisation. By 2001, however, it was well documented that participating effectively in the global environment depends on the way that four things interact: information technology, knowledge production, human resources and institutions (Castells, 2001). Knowledge and 'informationalism' have become central to globalisation and to development. The sources of productivity and competitiveness are increasingly dependent on knowledge and information being applied to productivity.

The increased generation of knowledge and access to knowledge has led to what is often referred to as the 'knowledge society' (Castells, 1991). It was thus expected that new higher education policies would pay particular attention to these developments. Responding to this expectation, the National Plan for Higher Education identified human

resource development, high-level skill development and the production, acquisition and application of new knowledge as the key challenges facing higher education. It then stated: "These challenges have to be understood in the context of the impact on higher education systems worldwide of the changes associated with the phenomenon of globalisation... Higher education has a critical and central role to play in contributing to the development of an information society in South Africa both in terms of skills development and research." (Department of Education, 2001:5-6)

However, the National Plan for Higher Education made no reference to information technology and its importance to research and teaching, beyond a cursory statement in the introduction. Apart from not mentioning a national approach to or policy for the use of information technology in higher education, the National Plan did not insist that individual institutions should develop their own policies about how to utilise and develop information technology strategies for teaching, learning, and research.

The National Plan put forward two strategies to improve the research endeavour. The first deals with a new approach to funding. Research funding is to be a separate component, based on research outputs and postgraduate students. Earmarked funding will also be made available for research capacity-building and for inter-institutional collaboration. The measurement of research output would be improved, and postgraduate enrolments will receive considerably greater funding. The second strategy deals with improving postgraduate quality and quantity, through the activities of the Higher Education Quality Committee, and by improving postgraduate enrolments through planning, increased funding and the recruitment of foreign students.

The proposed new funding formula released by the Department of Education in 2001 indicated that earmarked research funding would depend on submissions to the Ministry; no criteria were provided at that stage. In terms of encouraging postgraduate enrolments, the formula proposed to increase substantially the subsidy for postgraduate students.

In summary, the new policy regime aimed at the national level to reorganise science and to enable government to make science more responsive to the needs of the majority. The main policy aims of the Department of Education were to expand and strengthen the research base, develop a national research plan and make access to knowledge production more equitable, both at an individual and an institutional level. There were also significant silences in the policy framework, however, such as how to respond competitively to globalisation. As will be shown in subsequent sections, at the time of writing none of the implementation mechanisms necessary to put the polices into operation had as yet been put in place by the Department of Education.

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(Support Programme for Industrial Innovation), both of which encourage closer links between academia and industry.

How has expenditure on R&D been affected by the policy changes? Surprisingly enough, there is no clear answer to this question yet, the reason being that national statistics on R&D are extremely unreliable at this stage. Although major initiatives and positive changes occurred in the National System of Innovation between 1996 and 2001, one area that was seriously neglected was the gathering and storing of reliable data and information on science and technology indicators.

In order to get an impression of the relative size of the research spend that each sector made to the national system of innovation, we begin this section with figure 1. The most recent figures apply to the financial year 1997/98. The total R&D expenditure on public science (excluding the private sector) is estimated at R2.91-billion. This is made up of the following estimated contributions:

- Higher education system: R850-million;[2]
- Science councils: R1.1-billion;[3]
- National facilities: R60-million;
- Government departments: R450-million;[4]
- State corporations such as NECSA (Nuclear Energy Corporation of South Africa Ltd): R350-million.[5]

2 The 1997/8 R&D survey released by DACST in August 2000 put this figure at R496-million which we believe is a huge underestimate. The National Research and Technology Audit (NRTA), which was conducted to record information for the years 1995/1996, estimated the higher education system expenditure on R&D at R670-million which was considered conservative. The figure of R850-million constitutes our best estimate based on the Audit figures as well as a survey conducted with the top five research universities in the country.

3 This figure for the science councils reflects the actual amount of funding received from government in 1997/8. Although one could argue that less than this amount was spent on actual R&D, this sector usually attracts around 20% in contract money which is spent on R&D. The 1996/7 Audit figures produced a similar estimate of R1.1-billion devoted to R&D.

4 This figure is based on a reported amount of R150-million spent by government departments in 1996/7 but which excludes the South African Defence Force. Unverified data on the Defence Force estimate R&D expenditure to have been between R300- and R500-million in 1998. We have taken the more conservative figure as our estimate.

5 This figure excludes the spend on R&D made by Eskom, Telkom, Transnet and various other state corporations that do not receive any direct funding from the national science vote.

Figure 1 shows that, after the science councils, higher education receives the second highest allocation for research from the state

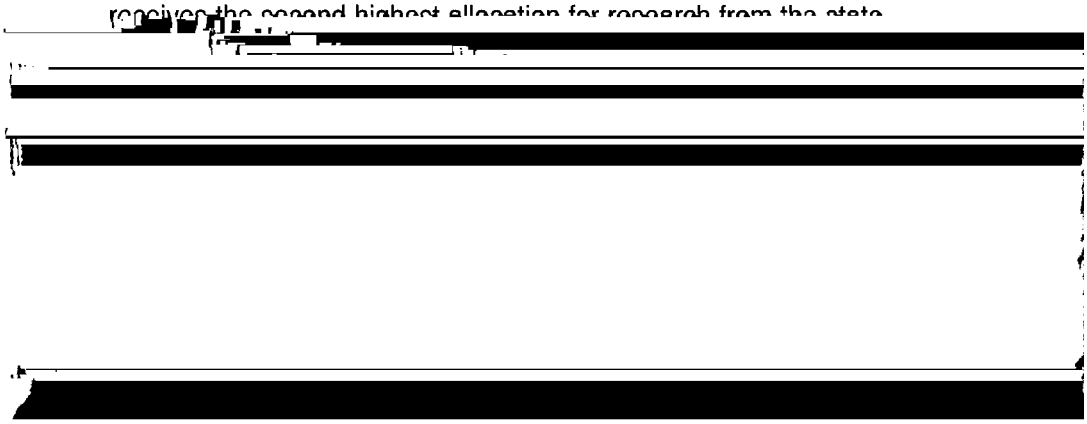


Figure 1 R&D expenditure: 1997/1998

The figures for the period 1983/84 to 91/92 are based on biennial R&D surveys conducted by the former Foundation for Research Development (FRD) and the Centre for Social Development (CSD). The 1993/4 and 1997/8 (DACST) figures are based on surveys conducted by a private consultant for the government and which utilized a very different methodology. The 1995/96 figures refer to the National Research and Technology Audit data. The 1997/98 (estimate) represents the data of Mouton and Boshoff (2000).

One reason why we believe that the latest official data (R496-million) is a serious underestimate of R&D expenditure is because of the results of a survey that one of the authors conducted at the top five universities in the country in 1999. Based on information provided by the universities of Cape Town, Stellenbosch, the Witwatersrand, Natal and Pretoria, it was calculated that the combined R&D expenditure of these five institutions alone amounted to approximately R400-million in 1997/98. Taken together, the previous R&D survey results (and the audit) and the five universities reported on here, account for 60%, on average, of all R&D expenditure. If this calculation is applied here, it means that actual expenditure is in the vicinity of R600-million. This amount does not include the technikons and, even more importantly, also does not reflect labour costs - staff time spent on R&D! If all of these factors are taken into consideration we believe that our estimate of R850-million for 1997/98 is itself a rather conservative estimate.

Two points of caution are necessary:

- The increase in Thrip funding and the National Innovation Fund funding (both of which are categories of strategic research funding) that occurred mainly from 1996/1997 onwards, is not yet reflected in these trends. These two categories of funding represent an estimated boost of about 20% - 25% of additional funding into the higher education sector. This impact will only be evident in a next round of R&D surveying.

- As mentioned above, there is every indication that the top universities and technikons are increasingly successful in obtaining significant contract funding. We also know that in many cases the amounts of contract funding are under-reported.

Figure 2 shows an increase from about R650-million in 1995/6 to at least R850-million in 1998/9, an increase of approximately 30%, which is about 5% higher than the estimated inflation figure over the period. Direct government research funding may not have increased substantially over the period, but it has kept pace with inflation. Once the funding from Thrip, the National Innovation Fund and substantial increases in private contracts are all taken into account, it can be asserted that by 1999 there was considerably more research money in the higher education system than in 1994.

- Research outputs

What do the latest data show about trends in scientific production in South Africa? The most comprehensive bibliometric analyses of South African science have been undertaken by Pouris (1996). Although the most recent of these (Pouris, 1996) only covers trends up to 1994, it does point to a number of interesting patterns.

In his 1996 study of South African scientific output, Pouris identifies a steady decline in comparative output. He shows how the number of publications by South African authors in ISI (Institute for Scientific Information) journals *(Science Citation Index, Social Sciences Citation Index* and the *Arts and Humanities Index)* has been relatively stable (approximately 3 300 a year) between 1987 and 1994. When compared with other countries and calculated as a proportion of world output, however, these figures reveal a steady decline. One indicator of such a decline is the fact that countries that were below or at the same level as South Africa in 1987 have subsequently surpassed her. These countries are Norway, South Korea, Brazil, Taiwan, and the People's Republic of China. Pouris' analyses clearly show how South African scientific output

experienced a gradual growth between 1980 and 1987 (increasing from 2 200 publications in 1980 to 3 400 in 1987). Over that period, South Africa's output as a proportion of world output increased from 0.4% to nearly 0.7%. However, after peaking in 1987, overall output has remained pretty much the same at an average of 3 300 publications per year until 1994. This in effect has meant a drop in proportion of world share from 0.7% in 1987 to 0.4% in 1994. In 1994, South Africa had about 0.5% of the world's scientists.

These studies currently represent the only bibliometric analyses using ISI data. In terms of scientific productivity, South African scientists seem to have peaked around 1987 and subsequently maintained production at an average of 3 300 publications per year. Whether this implies that a type of 'steady state' has been reached, or not, requires further reflection.

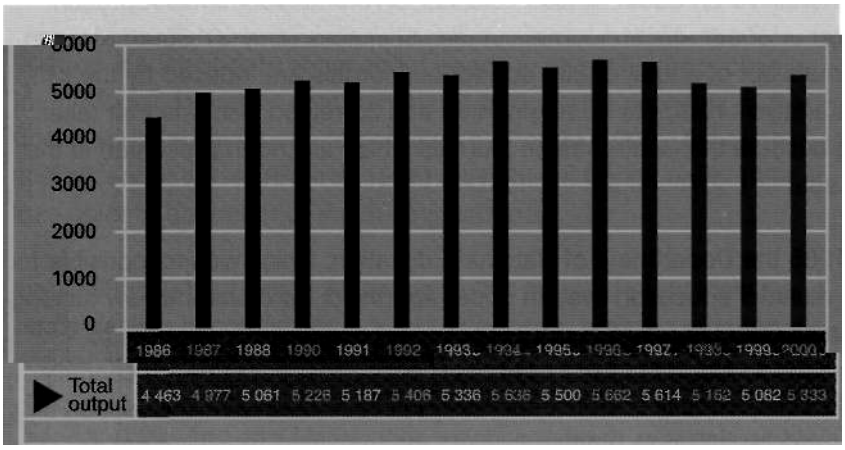
The data on which these analyses are based constitute only a partial perspective on South African science. Given the very small representation of South African journals in the ISI indices (only 31 South African journals out of a total of 205 accredited journals are indexed by the ISI), this analysis needs to be augmented and corrected with one that takes into account the South African journals which are not represented in the ISI set.

In 1985 the

Some black and English-speaking social science and humanities academics refused on principle to publish in SAPSE-accredited journals during the apartheid era. This is one of the constraints which affect the accuracy of the SAPSE data. Other constraints are more technical in nature and would include the time-lag between publication in an unlisted journal and the accreditation of that journal (at least two years). Nevertheless, the SAPSE data does provide a useful additional perspective on scientific production in South Africa.

Figure 3 summarises the main trends in the output of scientific articles and books as represented in the SAPSE database. It shows that, as in the results derived from the ISI data, the system remained fairly stable during the 1990s, but with a worrying downward trend after 1996.

Figure 3 Total output (science articles/books) according to SAPSE figures: 1986-2000[6]



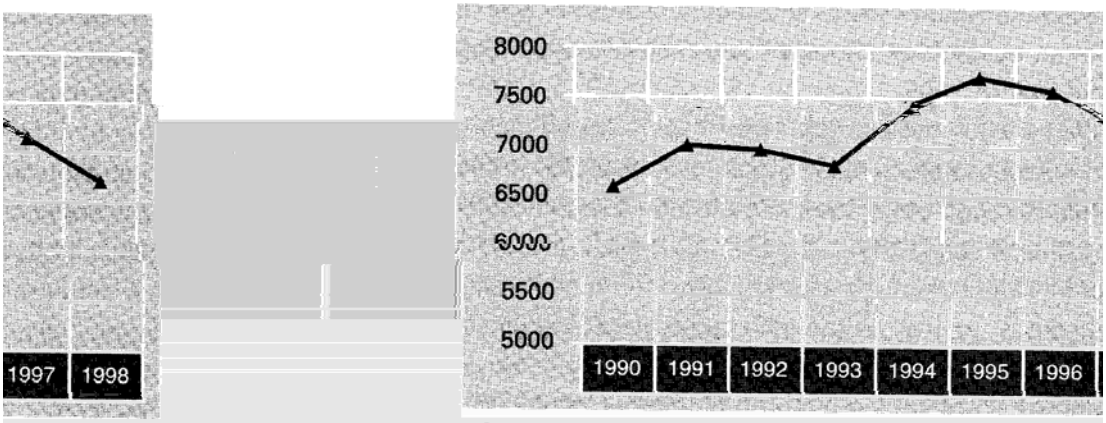
Source: SAPSE database, Department of Education 2000

6 It should be pointed out that the 1999 figure probably does not reflect the late additions which are usually supplied to the Department of Education during a second round. This would make a difference of about 5% in the totals.

Unfortunately the current SAPSE database does not allow any further disaggregation of the data. It is for this and other reasons that the Centre for Interdisciplinary Studies at the University of Stellenbosch in 1997 embarked on a long-term project to build a comprehensive database of South African science. This project is called 'SAKnowledgebase'.

SAKnowledgebase has as its aim the production of a comprehensive, accurate and effective database on South African scientific production. The database currently contains complete information on 57 226 articles produced by South African authors between 1990 and 1998. These articles were drawn from 11 006 journals, including 205 South African journals. It includes all the SA indices and especially the expanded version of the Science Citation Index. Figure 4 below summarises the trends in output between 1990 and 1998 as compiled by SAKnowledgebase.

Figure 4 Scientific output: 1990-1998



Source: SAKnowledgebase

7 SA Knowledge base is a MS Access database that the centre for interdisciplinary studies (CENIS) has compiled over the past five years

In summary then, the overall annual trend for the period 1990 to 1999 - as is evidenced by all three sets of figures (ISI-only, SAPSE and SAKnowledgebase) - suggests that output has not increased since 1990, and displays a slight downward trend during the latter part of the post-1994 period.

How can the apparent decrease in output be explained? The simplest explanation, offered by some vice-chancellors, is that the Department of Education has not added new journals to the official list since 1998 and that the output statistic is simply a bureaucratic under-count. It would be reassuring if the downward trend could be explained as merely poor counting. Another explanation, also of a bureaucratic nature, is offered by Subotzky at the University of the Western Cape's Education Policy Unit. He comments that during interviews conducted with a number of academics, he was informed that they are not completing the forms to report their publications because the effort is simply not worth the small part of the subsidy that comes back to the researcher. In other words, publications could be under-counted due to a lack of incentive. It is not clear, however, whether academics are now more resistant to completing forms than they were before 1995.

the many and substantial policy initiatives that were introduced were not accompanied by coherent implementation strategies to facilitate the orderly roll-out of transformatory actions

A second, and more serious, set of explanations could relate to the loss of top academics, both through emigration and through academics taking up positions in government during the mid-1990s. The decline could also be due to a range of other factors such as staff cuts and rationalisation at universities.and technikons, as well as the time taken up with institutional restructuring undertaken by all of the research institutions, activities which have been hugely disruptive. Yet another factor may be that the many and substantial policy initiatives that were introduced were not accompanied by coherent implementation strategies to facilitate the orderly roll-out of transformatory actions. One example of this is the inordinate time commitment demanded of many academics in the chaos that resulted from the establishment of the South African Qualifications Authority. There are other examples. What seems clear is that the human capital base for research may

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In summary, the higher education sector remains a major player in public knowledge production in the country. Its expenditure on R&D represents approximately 35% of total public R&D expenditure in the country. But in terms of assessing output according to peer-reviewed publications, the research output has not increased since 1994.

- Shifts in types of research

There is little dispute that R&D expenditure and sources of R&D funding have shifted very noticeably over the past five years: the movement has been away from basic and fundamental research towards the support of strategic, applied and product-related research. Compared with earlier R&D surveys, the National Research and Technology Audit of 1995/96 found a significant increase in applied and strategic research being undertaken. The audit classified half of all research in the higher education sector as basic research. This constitutes a substantial decline when compared with 1991 figures where 75% of higher education sector research was classified as basic research.[8]

How substantial this shift has been is also apparent in that half of the research classified as 'basic' is further categorised by scholars to be strategic research and the remaining half as fundamental research in the 1995/6 Audit. According to the classification used during that audit,

8 The following are the official Frascati definitions: Basic research: Original investigation with the primary aim of developing more complete knowledge or understanding of the subject(s) under study; Fundamental research: Basic research carried out without working for long-term economic or social benefits other than the advancement of knowledge, and no positive efforts being made to apply the results to practical problems or to transfer the results to sectors responsible for their application. Strategic research: Basic research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognised current or future practical problems. Applied research: Original investigation undertaken in order to acquire new knowledge, and directed primarily towards specific practical aims or objectives such as determining possible uses for findings of basic research or solving already recognised problems. Source: OECD (1992) Proposed standard practice for surveys of research and experimental development. 5th Edition. Paris: Organisation for Economic Co-operation and Development.

applied research now makes up 37% and product-related work 13% of all research in universities and technikons. The audit classifies only 23% of all research done in higher education as fundamental or curiosity-driven research. We would suggest that this is one of a number of indicators that signify a clear trend towards more 'application-driven research' (to use Gibbons et al's 1994 term) at South African universities and technikons. This research categorisation is difficult to define, is inconsistent over different studies and at this stage these movements should be regarded as trends, rather than definitive indices.

The establishment of the National Innovation Fund and Thrip and the shifts in the way that the National Research Foundation distributes its resources, are clear indications that there is a redistribution of research resources towards the applied and product-related end of the spectrum. This reflects the drive towards responding to local needs and to global changes in knowledge systems, but it is still too early to assess the effectiveness of this shift. It could provide the basis for the theoretical foundations underpinning the philosophical changes in the funding and structures of the national research system.

Directors of research who were contacted at the top research institutions in South Africa all agreed that there has been dramatic increases in contract income over the previous three to five years. Figure 5 reflects the significant increase in this income stream at four institutions between 1995 and 2000.

Figure 5 Trends in contract income at four institutions (rands millions): 1995-2000

Institution	1995/6	1998	2000	% increase from '95 to 2000
Pretoria	27	61	92	480%
Stellenbosch	46	78	119	258%
Natal	46	83	138	300%
Cape Town	102	139	190	186%

Source: Research directors of the institutions contacted

Adjusted for inflation, the increase shown in figure 5 is still more than 100% over the five-year period. The highest proportional increase occurred at the University of Pretoria, but the University of Cape Town still raises the most money. Currently very few institutions can provide systematic information as to how much of the contract research gets published in reports or in accredited journals, and how much is consultancy rather than research. With such huge increases in contract research it appears that South African academics are working harder, but it is not clear how much of this is counted as published output.

The analysis above shows two 'pulls' towards the strategic/applied end of the research continuum. The one is through a shift in government funds and the other is the significant increase in private research funds becoming available on a contract basis in the 'new democracy' period. In this sense the state and the market are in tandem, pulling academics towards mode two-type knowledge production, and the impact is reflected in academics reporting a decrease in basic research. The question raised in another research project by Mouton (2001) called "Between Adversaries and Allies" is whether the self-reporting is accurate or whether it is biased towards what academics think the government, the market or their peers want to hear.

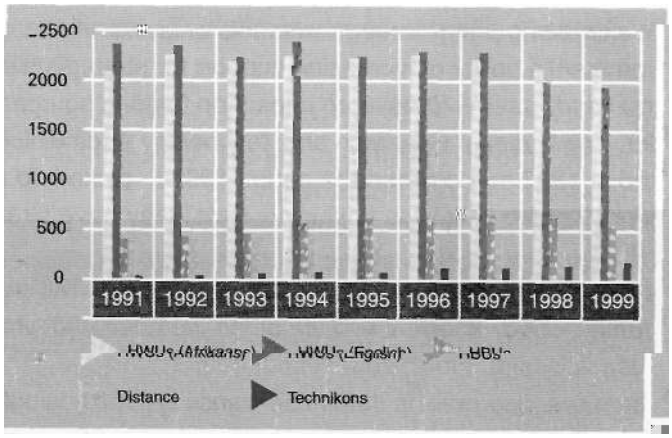
Despite the lack of reliable and comprehensive data in the system, a number of interesting points emerge from this analysis:

- The government's policy of increasing support for strategic and relevant research already seems to have an impact on funding sources within the sector. The National Research and Technology Audit which was conducted in 1997 and covered the period 1995/6 picked up this shift, while recent funding initiatives (including Thrip) may have strengthened this trend;
- There is undoubtedly an increase in contract research. The problem is that currently nobody knows the scale of the increase and whether this is seriously affecting published research output;
- The bottom line, however, is that these trends are increasingly putting basic and fundamental research within higher education under severe strain and could seriously constrain the growth of the knowledge base in the sector.

- Equity in the research sector

The Department of Education and the Department of Arts, Culture, Science and Technology White Papers promoted greater access to knowledge production at the institutional level and among individuals. The general output trends reveal some interesting dynamics within the higher education sector. Figure 6 presents the SAPSE output figures disaggregated by 'institutional groupings'. So, for example, it shows that the relative contribution of historically white Afrikaans-medium universities to published research has increased moderately from 37.2% in 1986 to 41.5% in 1999. The proportion of outputs from the historically white English-medium universities declined substantially from 53.5% in 1986 to 37.9% in 1999. Although the contribution of the historically black universities to the overall output is still low, these institutions have more than doubled their contribution from a base of 5.1% in 1986 to 10.7% in 1999. The output from the technikon sector has increased quite substantially from 23.52 units in 1991 (0.4% of the total) to 174 units in 1999 (3.1%). This percentage increase represents more than a seven-fold improvement and suggests that attempts by the sector to raise both awareness of research and research output have been successful.

Figure 6 SAPSE output by sector: 1991-1999



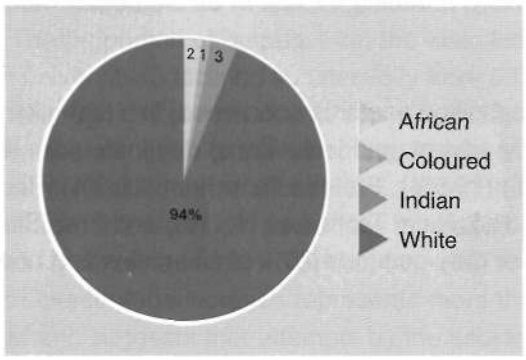
Source: Department of Education 2000

9 Distance = Unisa and TSA; Technikon data is only available as from 1991.

Although an analysis by these institutional categories is useful, it still masks huge inequalities among the institutions. Within the university sector, five universities continue to dominate scientific production: the University of Cape Town, University of Natal, University of Stellenbosch, University of

authors produced 3.2% of the total output. And finally, African authors produced 2.1% and so-called coloured authors produced 1% of the total output. However, the data also show that the output by African authors increased from 20 units (1%) in 1990 to 59 units (2%) in 1994 and 63 units (3%) in 1998. For Indian South Africans the number of units decreased from 93 in 1994 to 71 in 1998.

Figure 7 South African scientific product by race (1990-1998)



Source: SAKnowledgebase

Output by gender

In terms of gender distribution, male authors produced 83% of total scientific output during the period 1990 to 1998, and women authors produced 17%. Between 1990 and 1998 this output division has been very steady. The more detailed breakdown by year shows that although the number of SAPSE units overall declined from 490 in 1994 to 335 in 1998, women maintained their overall proportion of output at 17%.

In an attempt to deal with the race and gender imbalances referred to above, a significant effort was made to deal with institutional redress and capacity building. The Department of Education, according to the Minister, established a redress fund for capacity development, while the

national science councils spearheaded redress in the research activities of the historically disadvantaged institutions - to the tune of R79-million in 2001 (see NPHE). A senior representative from the National Research Foundation says, however, that not all of this is for institutional redress or capacity development. R18-million of this came from the National Research Foundation in 2001 for research and for capacity building in the historically black universities while another R12-million went to all the technikons and R49-million went to bursaries for white and black students at all higher education institutions.

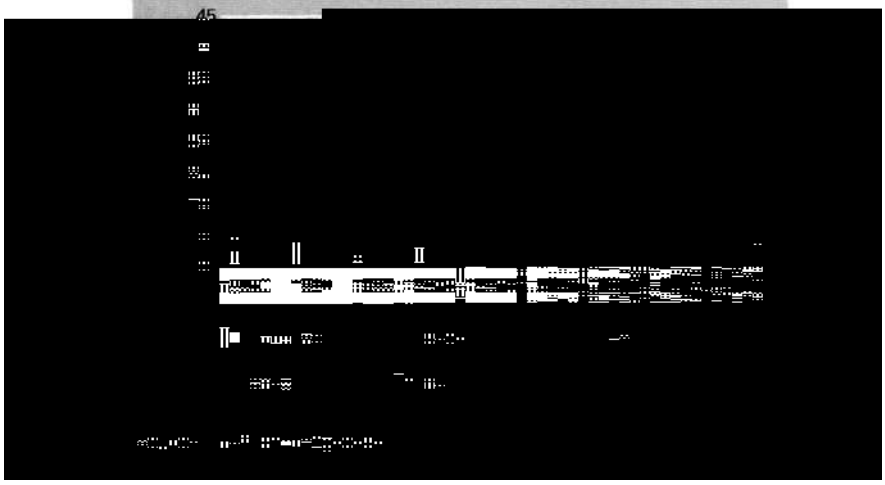
The question of institutional redress remains a central challenge. Various policy initiatives pushed very hard to address the race and gender imbalances that characterise the scientific terrain in South Africa. The data indicates that these represent themselves both at the level of individuals and at the level of institutions. These haveh Development and the National Research

Foundation. These programmes began with the University Development Programme (UDP) in 1989. As the data in the earlier section indicates, however, these processes have not been successful.

Output by age

The production of research papers as a function of the age of the researchers in the system is an extremely important and sensitive diagnostic of the overall state of the research system since it is a first measure of the system's medium- to long-term sustainability. The overall position for the nine-year period is summarised in figure 8 below. The results show that more than 40% of all articles produced were generated by authors in the 40-49 age bracket. Approximately a quarter of the output was produced by each of the 30-39 and 50-59 age cohorts. This characteristic of the system would have to be benchmarked against other national systems to assess whether or not it is out of line with trends in other countries.

Figure 8 Trends in research output by age intervals: 1990-1998



Our overall conclusion with regard to redress is that the production of knowledge within South African higher education continues to be dominated by white male scientists at five historically advantaged institutions. Although there are small shifts towards more gender and race representation in the higher education research sector, these remain insignificant. With the exception of the University of the Western Cape and the University of Durban-Westville, the outputs for the historically black universities have hardly changed during the period under review. The fact that more than 70% of all articles published are by academics over 40 years of age, and the limited increase in the production of PhDs (see Chapter Five on Students) indicates that a serious problem has arisen with reproducing a next generation of academics.

A new research landscape

The analysis undertaken above shows that a new landscape is developing in the research sector - both at the national level and within institutions.

• The national landscape

As the National System of Innovation and the higher education sector within it head towards the end of the first ten-year period after the miracle of 1994, the key questions that must be asked is whether the restructuring processes are meeting the national policy aims identified for the reorganisation of science. The analysis performed in the post-1994 period indicated that in addition to the lack of a coherent strategic direction, the deep fragmentation of the system was a hindrance to reducing the disarticulation which had occurred during apartheid.

The establishment of the Department of Arts, Culture, Science and Technology, the National Research Foundation and the National Advisory Council on Innovation are examples of the structural changes, which, in theory, help to address this fragmentation. Whether the system has the imagination and the political will to achieve what it has set out to achieve, is not fully clear at this point.

An important issue that has yet to be assessed is the effectiveness of the Department of Education in developing policy implementation strategies. Even though we must think of the policy development process as being holistic in nature and influencing various government departments, the policies that have the most potential to impact on the higher education research system are those that were instituted through the Department of Arts, Culture, Science and Technology. The nominal location of the higher education research system within the National System of

Innovation presents both advantages and challenges. However, these have not been properly understood and hence there have not been any creative attempts at the development of suitable implementation strategies. The interrogation of these advantages and challenges is crucial since, without this, the higher education research system will simply be drawn into the overall National System of Innovation on the basis of a very economistic approach to the role of science in society. Neither the Department of Education nor the higher education sector has made any attempt to unpack these issues and this is deeply problematic.

The first two sets of institutional three-year plans (1998/99) requested by the Department of Education, stressed student numbers and programme mixes, and perhaps inadvertently gave the impression that research was not a priority - an impression strengthened by the fact that the National Research Plan which had been promised in the White Paper (1997) has not yet materialised. In addition, no mechanisms have yet been put in place to give effect to the operational aspects of the White Paper in respect of research; these include steering subsidy funds to build capacity at specific institutions and allocating special funds to identified high-need areas. In the 2001 National Plan for Higher Education the promise of earmarked funding was repeated, but the Minister also said that earmarked funding would be 'onerous' to administer, thus raising questions as to whether the policy intention would be implemented at all.

it seems that departments such as the Department of Arts, Culture, Science and Technology and the Department of Trade and Industry are becoming increasingly influential in steering research

Currently there is little evidence of greater articulation between the Department of Education and the science councils, the National Research Forum and the other departments such as the Department of Arts, Culture, Science and Technology and the Department of Trade and Industry. Instead, it seems that departments such as the Department of Arts, Culture, Science and Technology and the Department of Trade and Industry are becoming increasingly influential in steering research. The increasing involvement of multiple government departments in shaping research in higher education seems to be a worldwide phenomenon. On the one hand this can perhaps be seen as another indicator of the importance of research in the knowledge society. On the other hand, it signals the decreasing influence of the Department of Education.

There is also evidence of changes taking place in terms of the role of the national research agencies. During the policy discussions of the early 1990s there were heated debates as to whether some of the national research councils such as the Human Sciences Research Council (HSRC) should survive in the new South Africa. While they have all survived, albeit having been scaled down in personnel by up to two-thirds, it seems that these councils are developing divergent roles. The Council for Scientific and Industrial Research (CSIR), for example, entered into an unprecedented partnership with one university, the University of Pretoria. In more recent times the CSIR has also developed partnerships with other universities; for example, with the University of Natal it has developed, amongst others, a Centre for Forestry and Forestry Products Research. The Medical Research Council seems to be continuing to strengthen its symbiotic relationship with medical schools and science laboratories at a number of universities.

The HSRC, on the other hand, seems to be moving back into a situation (similar to that of the late 1980s and early 1990s) where it is competing directly with universities and non-governmental organisations for state tenders and staff. It could be argued that the 'new' HSRC is in exactly the same relationship to the new government as the old HSRC of the 1970s and early 1980s was in relation to the apartheid government! While acknowledging the handmaiden relationship between the 'old' HSRC and the apartheid government, Cloete and Muller (1991) question whether the HSRC actually was useful to the government that sponsored it. The same question can be raised about the 'new' HSRC.

The major response of the new system has been the establishment of funding drivers to develop the desired shift in the system. It would seem that the scale of the drivers - the Innovation Fund, the National Advisory Council on Innovation mechanism for the distribution of the science vote, various changes in the research funding paradigm of the National Research Foundation, the Thrip fund and others - have begun to influence the nature of the research enterprise. However, it is too early to determine whether these are contributing positively to building coherence and whether they are working towards the development of a higher level of articulation with societal needs.

The available indicators show there is a marked increase in strategic and applied research. However, two caveats need to be made: first, the full impact of the funding regime of the state has yet to manifest itself; and second, the indicators from the National Research and Technology Audit are both dated and inadequate. We have no recent information on the substance and content of research programmes, nor on their utilisation by society. Thus it is extremely difficult to assess whether the higher education research system has become more responsive to the challenges of reconstruction and development and, in particular, whether it is responsive to the needs of the majority of South Africans. In a sense this is a question that cannot be answered since the issue of what, precisely, is regarded as the 'needs of the majority' is a contested matter - even within the tripartite alliance between the ANC, Cosatu and the South African Communist Party. This is compounded by the fact that even at the time of the policy development, a thorough study of the nature of the required responsiveness had not been made - except for broad brush strokes based on a very instrumentalist approach to research and development activities.

South African universities are not immune to the vast changes that are occurring in the global higher education system. Perhaps the most important of these is the commercialisation of research since this is a direct challenge to the very essence of 'the university'. Perhaps it is the scale of the activities that is critical to understand here rather than the fact that such activities actually take place. Several institutions are able to raise substantial sums of money for research activities from the various international foundations and from the private sector. Very often this kind of research activity results in research outputs which are measured more acutely for their social or economic impact than by the usual norms for academic research output. Very often they are linked to industrial innovation and this raises a critical question that relates to the public subsidisation of research activities which are profit-driven. In the absence of a national policy in this regard - such as the Bayh-Dole legislation in the United States of America - the institutions are caught by a national policy imperative to enhance partnerships with the private sector

and at the same time reconcile themselves to a genuine subsidisation of private sector research by the state. The impact of the commodification of knowledge on higher education is an international phenomenon and it presents the most exciting prospects for the fundamental reconceptual-isation of 'the university'. In South Africa, however, because of the small scale of the research system, this may take a form that will have important lasting consequences - consequences that may well be unexpected and severely damaging to the sustainability of the system.

• A new institutional research landscape?

In one sense the marked differentiation of the past remains among the higher education institutions: the same five historically advantaged universities continue to dominate, producing 60% of the output, and six technikons (five of them historically advantaged) produce 70% of accredited articles in that sector. However, certain shifts are beginning to take place. The technikon sector is slowly, and only in certain institutions, beginning to produce more research, while two of the historically black institutions (the University of Durban-Westville and the University of the Western Cape) have increased their output to a level comparable with some of the historically advantaged institutions. The average annual output for the University of the Western Cape for the period 1986 to 1999 is 97 publication units and for the University of Durban-Westville it is 100. This compares favourably with a young historically advantaged institution such as the University of Port Elizabeth, with an average of 98 publication units, and even with established historically advantaged institutions such as Rhodes University, with an average of 169 units per year, and Potchefstroom University, with an average of 189.

Without further study, it is difficult to explain the increase in the research output of the historically white Afrikaans-medium institutions, compared with the four historically white English-medium institutions. It may be that the incentives provided to individual researchers at the Afrikaans institutions are greater. It is more likely that some of the historically white

Afrikaans-medium universities did not prioritise research in the 1960s and 1970s because many of them saw themselves as *'volksuniversiteite'* that served the cause of Afrikaner nationalism. The advent of the Foundation for Research Development provided them with a framework within which to measure and improve their output - even though they initially resisted the foundation, according to Rein Arndt, its first president. The introduction of the SAPSE research subsidy system gave further impetus to increasing research output. On the other hand, the historically white English-medium universities that had a more fully developed research culture and were already publishing optimally, continued to operate at that level. However, there was indeed a decline in real terms in the publication output of the universities of the Witwatersrand and Cape Town.

Since 1994 there has been a further weakening of the research base at the historically disadvantaged institutions (except for the University of Durban-Westville and the University of the Western Cape) and many of these institutions have suffered substantial administrative difficulties, financial mismanagement, and student and staff strife. There has been an exodus of good academics from these institutions to historically white universities and several of the historically black universities may be financially and academically unsustainable.

This analysis shows that in the case of research it has been more difficult to break down the apartheid legacy than it was in other spheres of higher education (such as student access). Whilst a reshuffling seems to be occurring amongst the high producing institutions, it seems unlikely that any of the previously disadvantaged institutions will join the elite group. Instead, there is evidence that the gap between the 'haves' and the 'have-nots' in knowledge production is widening, not narrowing.

Conclusion

All in all, the policy development process was an invigorating intellectual enterprise, having drawn in higher education experts, science and technology practitioners, policy experts, government representatives and representatives of the private sector and community-based organisations. It brought into focus the major challenges that face the science and technology system and raised the profile of the tensions that arise in the transformation processes. It also produced interesting approaches to facilitate the management of these tensions. And while significant progress was made in producing policies, which in turn resulted in the promulgation of various key pieces of legislation, what was sadly lacking were coherent and managed implementation strategies. The impact of policy changes on the higher education system are of such enormous significance - whether positive or negative - that a substantial and well-managed implementation strategy should have been a priority. This did not happen and the result was an almost anarchic approach to the implementation of the various policy initiatives, with each institution adopting its own approach to understanding and implementing these policy changes. Where there was some level of national co-ordination this was often inept and variable. Consequently, the impact on higher education, and especially on its research system, was profound. It caused serious erosion of confidence in the system and a sense of despair amongst academics as institutions attempted to understand what was required of them in the new policy context.

The higher education research system needs to be defended and supported on the basis of its contribution to the nurturing and growth of a national intellectual culture. From this flow its numerous contributions to more instrumentalist imaginations that have become the engine for transformation in recent years. As has been argued earlier, the deepening of the nation's democratic ethos and its ability to contribute to the generation of a South African knowledge system, which can be a

viable contributing component of the international knowledge system, depends on the enlarged programme of high-level human resource development and the creation of a tradition which sees the production of new knowledge as a national endeavour that must be measured in terms of this nation's vision of itself as a beacon for Africa in the knowledge era.

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